Influence of Strength Training Background on Postactivation Potentiation Response

Mauro A.B. Batista, Hamilton Roschel, Renato Barroso, Carlos Ugrinowitsch, and Valmor Tricoli

Laboratory of Neuromuscular Adaptations to Strength Training, Department of Sport, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil

Abstract

Batista, MAB, Roschel, H, Barroso, R, Ugrinowitsch, C, and Tricoli, V. Influence of strength training background on postactivation potentiation response. J Strength Cond Res 25(9): 2496–2502, 2011—The aim of this study was to evaluate the influence of the subjects’ level of maximal dynamic strength and training background on postactivation potentiation (PAP). A group of 23 subjects, composed of power track-and-field athletes (PT = 8), bodybuilders (BB = 7), and physically active subjects (PA = 8), participated in the study. Maximal dynamic strength (1 repetition maximum test) was assessed in the leg press exercise for subjects’ characterization. Their countermovement vertical jump (CMJ) performance was assessed before and after 2 different conditioning activity (CA) protocols (1 or 3 maximum voluntary isometric contractions [MVICs] of 5-second duration in the leg press exercise) or after control (no CA), performed on separate days. No significant differences among groups were found for CMJ height or take-off velocity after any of the CA protocols (p ≤ 0.05). However, individual analysis showed that some subjects increased performance in response to the CA, despite their previous training history. We concluded that subjects’ level of maximal dynamic strength and training background have no influence on PAP manifestation. Our data suggest that coaches should individually identify the athletes that are PAP responders before introducing MVICs as part of their warm-up routines.

Key Words: warm-up, vertical jump, MVIC, conditioning activity

Introduction

It has been previously suggested that the inclusion of high-intensity resistance exercise during warm-up routines before strength and power competitive events may induce short-term improvements in motor performance (12,16,17). This phenomenon is known as postactivation potentiation (PAP). Such a strategy may also provide an advantage that can be used during specific training regimens. For instance, complex training is a combination of high-intensity resistance exercise preceding low-intensity high-velocity exercise (12).

It is generally accepted that PAP is the net effect between the performance-enhancing physiological adjustments and the deleterious effects of fatigue. It has been demonstrated that both submaximal dynamic (1,8,10,22,25,37) and maximal voluntary isometric contractions (MVICs) (2,16,18,31) may be successfully used as conditioning activity (CA) to trigger PAP. However, despite the general notion that high-intensity short-duration CA is the best approach in inducing PAP (1,26,30,37), additional factors other than CA characteristics may influence performance improvement (15,20,21,33).

Subjects’ training status and strength level may represent important variables in PAP (9) because they might also affect the level of fatigue induced by the CA. Some studies have demonstrated PAP only in previously strength training experienced subjects. Chiu et al. (9) compared PAP-induced changes in performance between athletes and physically active subjects and observed jump squat peak power potentiation only in the athletes. Similarly, Rixon et al. (31) found greater improvements on vertical jump performance in weightlifters compared to in resistance-untrained subjects. Further, Duthie et al. (11), Gourgoulis et al. (17), and Young et al. (38) showed jump-height improvements after CA only among the stronger cluster of subjects. These results indicate that subjects’ resistance training background may affect PAP occurrence. Additionally, in the light of previous results, it seems reasonable to suggest that PAP is induced basically in stronger subjects. However, no study has investigated the specific effect of different strength training backgrounds (i.e., power-oriented training vs. hypertrophy-oriented training) on PAP. Thus, it is not clear as to which athletes may benefit from this phenomenon. If PAP depends primarily on muscle strength, then subjects with similar muscle strength but different training background should experience the same effect of PAP on performance.

Therefore, the aim of this study was to evaluate the effect of muscle strength and training background on PAP response.
METHODS

Experimental Approach to the Problem
High-intensity short-duration resistance exercise may induce PAP (1,26,30,37). However, PAP effects seem to be dependent on training background and muscle strength. Therefore, we chose to test 3 different groups: international level power track-and-field athletes (PT), recreational bodybuilders (BB), and physically active individuals (PA). The proposed design allowed us to compare subjects with similar muscle strength but different training background (i.e., PT vs. BB) and subjects with similar muscle power but different muscle strength levels (i.e., BB vs. PA).

Initially, the subjects had their maximal dynamic strength (1-repetition maximum [1RM]) on the leg press exercise assessed. One week after the 1RM test, all of the subjects were randomly submitted to 3 different experimental sessions (at least 96 hours apart). All subjects had to perform either a low or moderate volume CA (i.e., 1 or 3 sets of MVICs on the leg press) in 2 experimental sessions. The third session served as control. During the experimental sessions, countermovement vertical jump (CMJ) height and take-off velocity were evaluated before and 4 minutes after the completion of the CA (16,18,25,26,37). These dependent variables were chosen to represent subjects’ performance and provide an insight into the PAP effect.

The leg press exercise was chosen because it has been shown to activate the same muscle groups as squat and vertical jump (13). Additionally, previous data have indicated a link between leg press training-induced strength gains and jumping performance (10,14) and a positive correlation between leg press 1RM values and vertical jump height for power-trained athletes and bodybuilders ($r = 0.93$ and $r = 0.89$, $p < 0.05$, respectively) (36). Further, we chose to assess 1RM in the leg press because it poses as a less complex motor task compared to squat, which could impair strength measurements (especially in the PA group). The CMJ was chosen because it is a common task in many sports (37) and a reliable measurement of lower limbs power performance (16,18,25,26,37).

Subjects
Twenty-three healthy male subjects volunteered to participate in the study. Participants were divided into 3 groups according to their training background: PT group ($n = 8$; age 22.0 ± 4.5 years; 82.6 ± 14.2 kg; 177.7 ± 22.8 cm) consisted of international level athletes currently competing in international power track-and-field events (long jump, high jump, and triple jump) and involved in daily power and strength training routines (e.g., complex training, jumping, and weightlifting); BB group ($n = 7$; 24.1 ± 2.5 years; 84.7 ± 14.5 kg; 177.0 ± 9.5 cm) consisted of subjects with >3 years of experience in lower limb hypertrophy-oriented strength training (e.g., high-volume and high-intensity resistance training); and PA group ($n = 8$; 23.7 ± 3.7 years; 79.2 ± 10.2 kg; 180.9 ± 9.1 cm) consisted of physically active subjects engaged in health-oriented physical activities twice a week for at least 1 year and with no previous experience in strength training. A preliminary statistical analysis showed no significant differences in anthropometric variables ($p > 0.05$). All of the subjects were free from any musculoskeletal injuries. Subjects were asked to refrain from strenuous activities and caffeine consumption 24 hours before the evaluations. All 3 experimental sessions were conducted at the same time of the day, and subjects were asked to maintain similar diet consumption before each session. Before participating in the study, subjects were informed of the potential risks and benefits and provided written informed consent to participate in accordance with the policies and procedures of the institution’s Research Ethics Committee for use of human subjects in research.

Procedures
Familiarization. All of the subjects visited the laboratory before the first experimental session to have their body mass and height measured. Subjects also underwent a familiarization session to the CMJ test, CA procedures, and 1RM test in the leg press machine. The CMJ test familiarization consisted of the performance of 10 jumps (15-second interval between jumps) following the same pattern as described later. After CMJ familiarization, subjects were positioned on the leg press machine to determine body positioning (see 1RM test section). A familiarization testing session was conducted, and values were registered for future use during the 1RM leg press test. In addition, subjects performed a familiarization to the CA consisting of 5 MVICs on the leg press with 3-minute intervals between contractions.

Maximum Dynamic Strength Test (1 Repetition Maximum). The 1RM leg press test was conducted on a standard inclined (45°) leg press machine (Nakagym model NK5070, SP, São Paulo, Brazil). Body positioning was reproduced throughout the study according to the familiarization records. In short, the leg press footplate was divided into 100 cm² (10 × 10 cm) squares with adhesive tape, and foot positioning was recorded on a paper sheet containing a template of the leg press plate. The range of motion was determined with the use of a manual goniometer. Participants performed an unloaded repetition, starting at full extension (~180°) and stopping at knee and hip angles of 80–90° and 55–65° ranges, respectively. A plastic “stopper” was attached perpendicularly to the lateral column of the leg press to determine the end of the eccentric phase (i.e., when the leg press platform touched the plastic stopper). A measuring tape was also glued onto the lateral column of the leg press to guarantee the reproducibility of the stopper. The test was performed between 4 and 7 days after the first laboratory visit and followed the American Society of Exercise Physiologists (ASEP) recommendations (7). Subjects ran for 5 minutes on a treadmill at 9 km·h⁻¹ followed by lower limb light stretching exercises. Then, the subjects performed 5 repetitions with 50% of the estimated 1RM in the first set,
followed by a set of 3 repetitions with 70% of the estimated 1RM. A 3-minute interval was allowed between sets. After the second warm-up set, subjects rested for 3 minutes. Then, they had up to 5 trials to achieve the 1RM load (e.g., maximum weight that could be lifted once with proper technique), with a 3-minute interval between attempts.

Conditioning activity. Considering that the PAP effect on performance may be masked by fatigue, 2 CA protocols were used. Either 1 or 3 5-second MVICs were performed on the same standard inclined (45°) leg press machine used for IRM assessment. During the 3 5-second MVICs session, a 3-minute interval was allowed between repetitions. The sliding platform was locked to avoid any movement when force was applied. The platform locking position was individually adjusted, so that the knee and hip angles were kept at the 80–90° and 55–65° range, respectively. These positions were previously established in the familiarization session and reproduced throughout the experimental sessions. During CA, subjects were instructed to push the leg press platform with both legs as fast and as hard as possible. Verbal encouragement was provided during MVICs.

Countermovement Jump Assessment. The CMJ performance assessment protocol consisted of 5 jumps with 15-second intervals between jumps. Subjects were instructed to keep their hands on their waist and encouraged to jump as high as possible. Countermovement jumps were initiated from a standing position, and upon command, subjects squatted to an individual optimal depth, then immediately jumped vertically for maximal height. The best jump result was registered for further analyses.

A force plate (AMTI model OR6-WP, Watertown, MA, USA) was used to measure jumping performance. Data referring to the vertical ground reaction force component (Fz) were collected at a 1,000-Hz frequency. A Butterworth low pass (200-Hz cutoff frequency, AMTI Watertown, MA, USA) on-line filtering was also performed. Jumping height was determined by the concentric impulse. Take-off velocity was

<table>
<thead>
<tr>
<th>Condition</th>
<th>PT</th>
<th>BB</th>
<th>PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>41.7 ± 5.7</td>
<td>33.2 ± 4.7</td>
<td>31.2 ± 5.4</td>
</tr>
<tr>
<td>1 MVIC</td>
<td>41.4 ± 5.3</td>
<td>32.2 ± 5.6</td>
<td>31.7 ± 6.3</td>
</tr>
<tr>
<td>3 MVICs</td>
<td>41.8 ± 6.1</td>
<td>32.4 ± 4.4</td>
<td>31.4 ± 4.9</td>
</tr>
</tbody>
</table>

*PT = power-trained group; BB = hypertrophy trained group; PA = physically active group.
†Significant main effect between groups (p < 0.05).

TABLE 1. Countermovement jump height (cm) for each group pre and postconditioning activity (mean ± SD),

Figure 1. Experimental procedures.

Figure 2. Maximum dynamic strength (1 repetition maximum) values for each group (mean ± SD). PT = power-trained group; BB = hypertrophy trained group; PA = physically active group. *Denotes significant difference between groups (p < 0.05).
calculated from the impulse momentum theorem. Jumping height was then estimated using a projectile equation.

**Experimental Sessions.** All the experimental sessions were preceded by a warm-up consisting of treadmill running at 9.0 km h\(^{-1}\) for 5 minutes followed by 3 minutes of light stretching exercises and 2 submaximal isometric contractions (1-minute rest interval between contractions) on the inclined (45°) leg press machine (5,6). Subjects rested for 2 minutes between the end of the warm-up and the pre-CMJ assessment. A 4-minute rest period was taken between pre-CMJ measurement and the beginning of the CA. Post-CA CMJ assessments were performed after 4 minutes of the completion of the CA protocol (Figure 1). During the control session, an 8-minute rest period was allowed between the pre- and post-CMJ measurement.

**Statistical Analyses**

All of the data are presented as mean ± SD. Vertical jump height and take-off velocity data were analyzed by Mixed Model (35). Groups (PT, BB and PA), treatment (1-MVIC, 3-MVICs, and Control), and time (Pre and Post) were considered fixed factors, whereas subjects were considered random factors. Between-group comparisons for age, body mass, height, and maximum dynamic strength (1RM) were assessed by 1-way analysis of variance. When significant F values were found, a post hoc comparison (adjusted by

**Table 3.** Effect sizes for countermovement jump height.\(^*\)

<table>
<thead>
<tr>
<th>Condition</th>
<th>PT</th>
<th>BB</th>
<th>PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>−0.05</td>
<td>−0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>1 MVIC</td>
<td>−0.09</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>3 MVICs</td>
<td>−0.2</td>
<td>0.05</td>
<td>−0.1</td>
</tr>
</tbody>
</table>

\*PT = power-trained group; BB = hypertrophy trained group; PA = physically active group; MVIC = maximal voluntary isometric contraction.
Strength Training Background and PAP

Tukey–Kramer) was used. Significance level was determined at \( p \leq 0.05 \).

**RESULTS**

There was no significant difference in leg press 1RM values between PT and BB, showing that these groups had similar strength levels. However, both groups were significantly stronger than PA (Figure 2).

Countermovement jump height and take-off velocity were found to be reliable (intraclass correlation coefficient [ICC] = 0.92–0.99). Countermovement jump height (Table 1) and take-off velocity (Table 2) were significantly higher for the PT group when compared to BB and PA. No significant differences in the CMJ height (Table 1) or take-off velocity (Table 2) were observed after either CA protocol (1 or 3 MVICs) or control. Figure 3 shows individual responses for CMJ height. Effect sizes for countermovement jump height are presented in Table 3.

**DISCUSSION**

The purpose of this study was to investigate whether different strength training backgrounds would affect the PAP response. We recruited subjects from 3 populations with significantly different strength training backgrounds: power track-and-field athletes (training for power), bodybuilders (training for hypertrophy), and physically active (no strength training experience) subjects. We aimed to induce PAP by having participants perform either 1 or 3 5-second MVICs on an inclined leg press machine on different occasions. Our main finding was that PAP is not affected by the strength training background, considering that none of the CA protocol induced PAP in any of the groups, despite the significantly different levels of strength and power between groups.

It has been previously suggested that subject’s strength level is related to PAP manifestation. Stronger subjects within a sample showed greater increase in jump-height performance after 1 set of 5RM squat exercise (38). Similarly, stronger subjects showed greater peak force values in a loaded (30% 1RM) jump test after a 3RM squat exercise, whereas the weaker group of subjects showed a trend of diminished peak force production after the same protocol (11). In the same way, some studies have shown PAP in athletes experienced in strength and power training when compared to in untrained subjects (11,18). Accordingly, we expected to find CMJ potentiation in both the PA and BB groups because they had higher muscle strength levels than the PA group did. In contrast, the lack of potentiation in our study cannot be explained by the subjects’ strength training background.

Conditioning activity protocol is considered to play an important role in PAP. A high-intensity and high-volume CA may induce high levels of fatigue, which would overcome the physiological mechanisms underlying PAP (30). To avoid fatigue, we used short-duration and high-intensity isometric exercise to induce PAP on CMJ performance. In addition, we tested 2 different volumes of the proposed CA, because this protocol has been previously reported to increase performance on lower limb tasks (2,3,16,18,19). Regardless of this, no improvement in CMJ performance was observed in any group in our study. On the other hand, Güllich and Schmidtbleicher (18) reported a mean 3.3% increase in CMJ height after subjects had performed 3 sets of 5-second MVICs in the leg press, and a 4.7% increase after 5 sets. Thus, it seems reasonable to suggest that performing only 1 5-second MVIC may not have been sufficient to induce any physiological events related to PAP. Additionally, it is quite unlikely that the 3 5-second MVICs set protocol induced enough fatigue to mask PAP effects. If this was the case, then we probably should have found a significant reduction in CMJ performance in the PA group, as they were more sensitive to fatigue because they were not involved in any kind of strength training.

Another hypothesis commonly used to explain the lack of potentiation regards insufficient muscle activation by the CA. Because we did not assess the force produced against the leg press platform, or conducted any electromyographical register during the CA, we cannot assure that the subjects elicited high levels of muscle activation during the task. However, all of the subjects were strongly and continuously encouraged to push the leg press platform as hard as possible during all experimental conditions. In addition, a few studies showed CMJ jump potentiation even when performing submaximal resistance exercise as CA (29,38). Therefore, we believe it is unlikely that the lack of CMJ improvement in our study is related to insufficient muscle activation during CA.

One could suggest the time interval (4 minutes) between the end of the CA and the CMJ performance assessment, as a possible explanation for the lack of CMJ potentiation in our study (30). However, even though some authors have used such an argument to explain the absence of performance improvements in their studies (4,22), others have shown PAP after shorter rest intervals (29), whereas some have failed in demonstrating improvements even after longer rest intervals (4,23,33). In addition, if we consider the increased alpha motoneuron excitability as an underlying mechanism for PAP, this argument could not be sustained. In fact Trimble and Harp (34) demonstrated H-reflex depression during the first seconds (10–60 seconds) after CA (8 sets of 10 maximal ankle flexions). However, after this brief initial depression, H-reflex was in fact potentiated above resting levels for 6–10 minutes. Accordingly, Paasuke et al. (27) demonstrated a significant twitch peak torque potentiation 5 minutes after a 10-second MVIC CA. Therefore, we do not believe that the lack of acute improvements on CMJ in our study is related to the moment of the postintervention assessment.

It is generally accepted that increased alpha motoneuron excitability is responsible for PAP. Further, significant increases in H-reflex amplitude have been found within a few minutes after both isometric (15) and dynamic (34) CA protocols. Because H-reflex is considered a measure of alpha...
motoneurons excitability when activated through Ia discharge (28), it suggests that increased excitability should only be available in the alpha motoneurons previously activated by the CA. From this point of view, the CA chosen to induce PAP should be the closest to the actual performance task as possible so that the neural drive would travel through the same pathways during both conditioning and performance evaluating activities. In support of this hypothesis, a number of studies have found CMJ performance potentiation after subjects performing dynamic or isometric squat exercises such as CA (9,17,37). Therefore, one may speculate that the lack of CMJ performance potentiation in our study is related to the biomechanical differences between the leg press exercise performed as a CA and the CMJ. However, Scott and Docherty (32) and Radcliffe and Radcliffe (29) also failed to find CMJ height potentiation despite using the back squat exercise as CA. In addition, Güllich and Schmitzbücher (18) found an average of 3.9% increase in jump height after subjects had performed MVICs in the leg press, suggesting the effectiveness of the CA selected in this study.

Nevertheless, despite the fact that no significant within- or between-group differences in CMJ performance were observed, individual analysis shows a marked intersubject variability in response to both 1 and 3 MVICs (Figure 3). These findings contrast with previous studies that observed a more uniform response pattern (i.e., an increase in performance after a CA) among the stronger and more experienced athletes (9,11,17,38). On the other hand, our data are in accordance with previous findings from Mangus et al. (24). These authors did not find a significant correlation between strength and jumping performance before and after the CA in strength-trained individuals, refuting the hypothesis that PAP is dependent on the subject’s strength level. However, individual analysis showed that 5 out of the 10-subject sample did increase their vertical jumps after CA, suggesting that PAP may be subject dependent.

In conclusion, our data suggest that the incorporation of high-intensity resistance exercise into warm-up routines should not be decided based only on the athlete’s previous training experience. Instead, coaches should previously identify the individuals that are PAP responders.

Practical Applications

Based on the main findings of this study, we cannot suggest the use of high-intensity resistance exercise, as part of the warm-up or training routine (i.e., complex training), to induce acute improvements in subsequent motor tasks. However, our data showed a marked intersubject variability regarding the effects of PAP on CMJ performance, which indicates that even though not all athletes may benefit from PAP, some athletes may improve performance from such strategy.

Therefore, we recommend coaches to carefully identify among their athletes those who have performance improvements in response to 1 or 3 5-second MVICs. In addition, because many athletes have reported subjective feelings of improved performance after performing a few sets of intense resistance exercise, coaches could also incorporate such strategy during warm-up routines to exploit this psychological benefit in those athletes identified as not responders, without any concerns regarding performance hampering.

Acknowledgments

Mauro Batista was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior process number 133153/2002-9. Hamilton Roschel is supported by Fundação de Amparo a Pesquisa do Estado de São Paulo - FAPESP (2010/51428-2).

References


