

POSTACTIVATION POTENTIATION: EFFECT OF VARIOUS RECOVERY INTERVALS ON BENCH PRESS POWER PERFORMANCE

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ABSTRACT

Ferreira, SLA, Panissa, VLG, Miarka, B, and Franchini, E. Postactivation potentiation: effect of various recovery intervals on bench press power performance. *J Strength Cond Res* 26(3): 739–744, 2012—Postactivation potentiation (PAP) is a strategy used to improve performance in power activities. The aim of this study was to determine if power during bench press exercise was increased when preceded by 1 repetition maximum (1RM) in the same exercise and to determine which time interval could optimize PAP response. For this, 11 healthy male subjects (age, 25 ± 4 years; height, 178 ± 6 cm; body mass, 74 ± 8 kg; bench press 1RM, 76 ± 19 kg) underwent 6 sessions. Two control sessions were conducted to determine both bench press 1RM and power (6 repetitions at 50% 1RM). The 4 experimental sessions were composed of a 1RM exercise followed by power sets with different recovery intervals (1, 3, 5, and 7 minutes), performed on different days, and determined randomly. Power values were measured via Peak Power equipment (Cefise, Nova Odessa, São Paulo, Brazil). The conditions were compared using an analysis of variance with repeated measures, followed by a Tukey test. The significance level was set at $p < 0.05$. There was a significant increase in PAP in concentric contractions after 7 minutes of recovery compared with the control and 1-minute recovery conditions ($p < 0.05$). Our results indicated that 7 minutes of recovery has generated an increase in PAP in bench press and that such a strategy could be applied as an interesting alternative to enhance the performance in tasks aimed at increasing upper-body power performance.

KEY WORDS upper-body maximal power, repetition maximum, complex training, concentric contraction, eccentric contraction

INTRODUCTION

Several studies have demonstrated a high degree of lower and upper-body power after postactivation potentiation (PAP) strategies in animals and humans. The PAP appears in response to acute short-term (AST) effects, and there appears to be a close relationship between stimuli orientation and the ability of subjects to benefit from activation exercises with dynamic overload (1,12,20). After AST, both fatigue and PAP can occur. Therefore, rest is one of the main variables influencing PAP. Consequently, subsequent muscle performance depends on the balance between AST and rest (4,15).

Two mechanisms are proposed to explain PAP. The first is related to the phosphorylation of myosin regulatory light chains, which increases Ca^{2+} sensitivity of myofilaments. The consequence is an improvement in the level of myosin crossbridge activity in response to submaximal concentrations of myoplasmic Ca^{2+} (16). In this way, an important characteristic pointed out by Sale (20) is that PAP has no effect on high-frequency tetanic isometric contractions. This is because, during such contractions, a “saturating” concentration of Ca^{2+} is attained, making any increase in Ca^{2+} sensitivity insignificant. Although there have been few studies examining the connection between repetition frequency and PAP, it has also been shown that PAP increases the force of concentric contractions and that the highest frequency at which PAP is effective is greater for rapid concentric contractions than for isometric contractions (1). Mechanical responses and energy requirements differ between concentric and eccentric actions. Although the force produced in eccentric contractions in animals always exceeds that recorded in isometric contractions, the results in humans have been variable (17). The second mechanism to account for PAP is related to the excitation of the central nervous system, which produces an increase in contractile function after heavy conditioning stimuli (19). The methodological strategy used to explore PAP generally involves the execution of maximum or submaximum dynamic or static strength exercises before the main task.

Few studies have verified AST in upper-body exercises, with some studies reporting positive effects of PAP (3,4) and

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others not observing changes (5,8,14). According to some authors, the coexistence of fatigue and PAP is relative, and plausible reasons for unclear results may be the differences in the training status of subjects, the optimal interval between the AST and the task, and in the intensity of the conditioning activity (5,11,18,20). Although increases in recruiting of muscle units, potentiation, and exhaustion have opposing effects, some studies have explained that the interaction between these factors influences manifestations of strength in different ways without altering performance (8,14). There is no agreement regarding the optimal recovery required between the AST stimulus and subsequent explosive movement performance (3,4). The issue of this optimal time has received additional attention, but there is no general agreement, especially with respect to upper-body exercise. There are indications that the best PAP effect for the upper-body occurs between 8 minutes (4) and 12 minutes (15). Importantly, in studies conducted to test the best recovery interval to maximize PAP effects, attempts were made on the same day (4,10,15), which could result in interference among subsequent sets.

Consequently, the first purpose of this research was to verify that the performance of explosive bench press exercise was improved when it was preceded by a 1 repetition maximum (1RM) that incorporated upper-body dynamic resistance training. The secondary purpose was to determine the optimal rest period between the PAP exercise and the power bench press exercise.

METHODS

Experimental Approach to the Problem

An intervention study was implemented to investigate if the mean and peak power output in concentric and eccentric actions generated during a bench press exercise could be potentiated by a maximum strength action (1RM) of the same exercise after different recovery intervals (1, 3, 5, and 7 minutes) in 11 healthy male subjects. The bench press exercise was selected because it is commonly used to assess power performance. Moreover, this movement is widely used during training sessions in many sports and physical conditioning workouts. In the first session, the participants were subjected to the 1RM test, and they then performed a control test of the power output (1 set of 6 repetitions using 50% of the 1RM load) to compare later with the performance of the same exercise preceded by a 1RM by different time intervals. Experimental sessions were performed on different days.

The values for mean and peak power output in the bench press were the dependent variables, whereas the recovery interval was the independent variable.

Subjects

The research design included a group of 11 healthy, adult, physically active men with experience in strength training. These subjects practiced resistance exercises 3–5 d·wk⁻¹ for >1 year.

Additionally, they were engaged in high-intensity intermittent exercise sessions (3 times per week), typically conducted in team and combat sports. However, these subjects were not competitive athletes. The participants' characteristics (mean $\pm$ SD) were as follows: age 25 ± 4 years, height 178 ± 6 cm, body mass 74 ± 8 kg, maximum dynamic bench press strength (1RM) 76 ± 19 kg. All the study participants took part voluntarily after being informed of the risks and benefits of the procedures involved and signed an informed consent form. This study was approved by the Local Ethics Committee, according to Federal Law 196/96.

Procedures

The study participants completed 6 test sessions over a period of 2 weeks. The study was randomized such that the subjects participated in 2 control sessions and 4 experimental sessions. The first control sessions were performed to establish bench press maximum dynamic strength (1RM). A different session was used to determine the power performance (control condition) for the same exercise. This session was determined randomly as were the PAP sessions. The subjects completed sessions composed of a 1RM exercise followed by a power bench press exercise after 4 different rest intervals (1, 3, 5, and 7 minutes) on different days. These experimental sessions and baseline performance were determined randomly.

Tests were conducted at an average room temperature of 27°C. A minimum of 48 hours rest was observed between tests to avoid interference between different interventions. All the participants had previous experience with power training typically used in team and combat sports training (e.g., plyometric and medicine ball exercises and sports-specific actions, such as short sprints, kicks, throws, and punches) and the procedures used in this study. Testing took place at the same time of the day for each subject. The subjects were instructed to abstain from any strenuous exercise at least 48 hours before each testing session and were encouraged to maintain their nutritional and hydration routines. To ensure that these recommendations were followed, the subjects were questioned regarding their diet and hydration immediately before each experimental session. All the subjects declared that they followed these instructions.

Measurements

Repetition Maximum Protocol. Maximum dynamic strength (1RM) for the traditional bench press exercise was assessed using a barbell and free weights. The bench press test was performed according to standard procedures (6). The participants were made to lie supine on a bench with their head, shoulder blades, and buttocks touching the bench in all the test conditions. Both feet were placed on the floor, and their knees were bent at approximately 90°. The bar was first lowered to approximately 5 cm above the chest, parallel to the nipple line, and then pushed upward until the elbows were fully extended. The positioning of the subject's body and the bar was recorded. The 1RM bench press test was also performed according to standard procedures (6,18). Briefly,

the subjects ran for 5 minutes on a treadmill at $9 \text{ km} \cdot \text{h}^{-1}$, followed by lower limb stretching exercises and 2 bench press warm-up sets. In the first set, the individuals performed 5 repetitions of 50% of the estimated 1RM, and for the second set, they performed 3 repetitions of 70% of the estimated 1RM, with 3-minute intervals between each set. After the second warm-up set, the subjects rested for 3 minutes and then had up to 5 trials to achieve the 1RM load (i.e., maximum weight that could be lifted once with proper technique), with a 3- to 5-minute interval between trials.

Power Output Measures. The power output for the bench press exercise was measured in the same position used during the 1RM protocol test. The mean power during each repetition was measured using the Encoder Linear Peak Power 4.0 (CEFISE, Campinas, Brazil). This equipment works using a cable positioned in the bar through which displacement is registered electronically, converted digitally, and transferred to the computer. The displacement is recorded in millimeters, and a chronometer registers the time in microseconds (1×10^{-6} seconds). The software analyzes load, time, and displacement information and calculates velocity, acceleration, and power. These calculations are done in both concentric and eccentric phases. Before the measurements, the equipment is calibrated using a known distance (1 m), which is used as a reference for all other displacements. In high-speed resistance exercise, this equipment has a reliability of 0.95 using the intraclass coefficient correlation.

Furthermore, measures of average power output were conducted after each participant performed the 1RM bench press. During the power output measurement, the subjects performed 1 set of 6 repetitions using 50% of the 1RM load after a resting period. This load was selected because it resulted in the highest power output for this group. The recovery protocol changed during each session between 1, 3, 5, and 7 minutes.

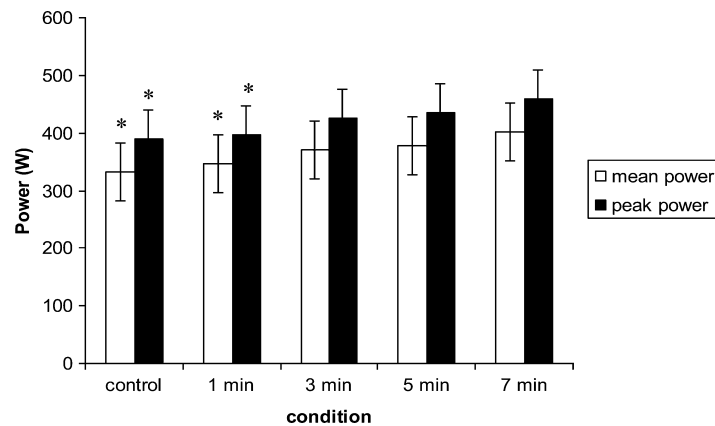


Figure 1. Mean power and peak power (watt) during the concentric phase of bench press exercise (6 rep at 50% 1 repetition maximum). Data are expressed as mean and SD. *Different from the 7-minute condition ($p < 0.05$).

Statistical Analyses

Measures of centrality and dispersion were calculated and presented as mean $\pm$ SD. A repeated measurement analysis of variance was performed to compare the differences in interventions. When differences were detected, the Tukey test was used as a post hoc test to identify specific differences between the intervention protocols. The significance level was set at $p \leq 0.05$. All analyses were conducted using SPSS 15.0 for Windows.

RESULTS

Figure 1 presents the main results of mean and peak power during the concentric phase for each rest condition.

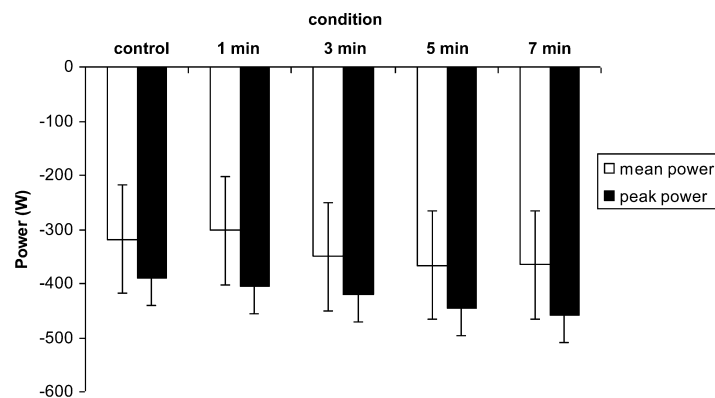


Figure 2. Mean power and peak power (watt) during the eccentric phase of bench press exercise (6 rep at 50% 1 repetition maximum).

A significant difference was found in mean power ($F_{[4,40]} = 4.88$; $p = 0.003$). The post hoc test indicated lower concentric phase mean power between the control and 1-minute recovery conditions compared with the 7-minute recovery condition ($p = 0.003$ and $p = 0.021$, respectively).

Figure 2 presents the main results of mean power and peak power during the eccentric phase for each rest condition.

In the eccentric phase, no significant differences were found in either peak or mean power ($F_{[4,40]} = 2.22$; $p = 0.084$).

DISCUSSION

Important factors affect PAP in both short-term and acute performances. In this study, the execution of 1RM in the bench press before a set of 6 repetitions at the maximum speed (50% of the 1RM) increased performance. In this case, it was noticed that among the 5 intervals studied (1, 3, 5, and 7 minutes), lower values in both mean and peak power during concentric contractions were found between control and 1-minute interval conditions when compared with the 7-minute condition. These results, therefore, suggest that, when 1RM is used as the conditioning activity before bench press exercise, the state of potentiation is reached at an interval of 7 minutes.

There are many studies evaluating the effects of PAP using lower limb exercises, whereas there are only few studies evaluating the effects of PAP using upper limb exercises (3–5,8,14). Of the studies examining upper limb exercises, some found no change in performance (5,8,14), others reported potentiation (3,4), and 1 study found a decrease in performance (4). These divergent findings are mainly because of the different training protocols; the wide variety of exercises examined; variation in the intensity, volume, and time interval between the activities; and the use of subjects with different training statuses.

This research assumed that PAP occurs during an optimal time in concentric contraction, when the muscle has recovered from the fatigue induced during the AST. Active stretching of sarcomeres induces eccentric muscular contractions, but this study did not observe PAP in the eccentric phase. We did not find other research studies that assessed PAP in different types of contraction using upper-body exercises. Babault et al. (2) described different PAP responses in concentric and eccentric contractions of the quadriceps femoris. This group studied 9 healthy men performing a conditioning activity composed of 3-second isometric maximal voluntary contractions (MVC). Maximal twitches evoked on the knee extensor muscles were observed before and 5 seconds after the conditioning activity. The PAP was determined at a constant joint angle under isometric conditions during and immediately after passive shortening and lengthening. The results demonstrated that peak twitch torque was dependent on the type of contraction. This conclusion was made because PAP was greater during the shortening condition when compared with the lengthening condition, without modifications in

the M-wave. These findings suggest that the differences between the PAP observed for different types of contractions can be attributed to the inherent nature of muscular contractions, although the authors also speculated that potential changes in myofilament arrangement, Ca^{2+} sensitivity, and muscle stiffness differences may be responsible.

Ebben et al. (8) analyzed power performance in a task consisting of throwing a ball with a weight equivalent to 30% of 1RM while lying on a bench after conducting an activity in the bench press exercise (3–5RM) and found no effect of PAP. Hrysomallis and Kidgell (14) also found no effect of power on push-ups (3 repetitions as fast as possible) after a bench press exercise (5RM). Another study (5) also failed to find enhancement in performance during bench press (8 reps at 40% 1RM) using various intensities (5 repetitions at 100% of 5RM, 75% of 5RM, and 50% of 5RM).

Some points should be highlighted as potentially being responsible for the fact that no changes in performance were observed in the aforementioned studies: (a) the use of conditioning and conditioned activities with very different patterns of movement (8); (b) control conditions performed on the same day, only a few minutes before the conditioning activity (5,14); and (c) insufficient recovery intervals, given that these studies used rest intervals of 5 minutes (8), 3 minutes (14), and 4 minutes (5), which would not induce a state of potentiation. This latter point is in contrast to that of this study, in which a PAP effect was observed only with longer recovery intervals.

Confirming the present results, Bevan et al. (4) examined the effect of different interval times (15 seconds, 2, 4, 8, 16, 20, and 24 minutes) on peak power during bench press (40% 1RM) preceded by an activity also performed using the bench press exercise (3 sets of 3 repetitions at 87% 1RM) in 26 professional rugby players. This study found a performance drop in the 15-second interval condition. The benefit of PAP occurred only when an 8-minute interval was used (879 ± 100 vs. 916 ± 116 W). Therefore, it is possible that studies demonstrating no PAP effect used too short an interval, as this study showed that performing a 1RM activity was able to improve performance of both mean and peak powers in the concentric phase of the bench press exercise when the interval was 7 minutes. Unfortunately, this study did not test intervals >7 minutes to determine if the PAP effects could still be observed with the protocol used.

Kilduff et al. (15) found a PAP effect for upper-body exercise (ballistic bench throws) with 8-minute (880 ± 130 W), 12-minute (903 ± 145 W), and 16-minute intervals (863 ± 126 W) compared with baseline (856 ± 121 W), with the best score observed using 12-minute intervals. An interesting component of this study was that the protocol was the same as that of Bevan (4), except that the conditioning activity intensity was 3RM, slightly more intense than the one used by Bevan et al. (4). This difference

could explain why Bevan found the best PAP effect with an 8-minute interval and Kilduff et al. (15) with a 12-minute interval, that is, higher loads would need longer intervals.

In contrast, Esformes et al. (9) used a similar protocol as that of Kilduff et al. (15) and found differing results. Ten male competitive rugby players performed 4 types of conditioning exercises on separate days: isometric (7-second isometric barbell bench press), concentric, eccentric, and dynamic, (1 set of 3RM) to examine PAP effects in a ballistic bench press throw at 40% of predicted 1RM. The subjects completed the ballistic bench press throw (baseline) followed by a 10-minute rest, performed the bench press conditioning contractions, and after 12 minutes performed another ballistic bench press throw. The isometric conditioning activity alone produced significantly higher peak power (587 ± 166 and 605 ± 126 W for pre and post, respectively), whereas the dynamic conditioning activity did not produce PAP effects. The authors speculated that the load used in Kilduff et al. (15) might have been appropriate for their subjects' preseason (August–September) training but not appropriate for the competitive phase of the annual training cycle. The main issue with the studies from Bevan et al. (4) and Kilduff et al. (15), however, is that all the experimental sessions performed using different time intervals were conducted on the same day. This is in contrast to the study from Esformes et al. (9), which used a unique time interval.

Of the studies that used shorter time intervals (<6 minutes) (5,8,14), Baker's (3) was the only one to find an increase in power (4.5%) during the bench press (5 reps with 50 kg). This study used a 3-minute recovery interval after a submaximal load (6 repetitions at 65% 1RM) in 16 rugby players experienced in power and complex training. It is important to note that the load used as the conditioning activity (50 kg) represented approximately 34% of the 1RM (143.7 kg). Thus, this load is much lighter than the load used in this study and in other studies reporting PAP effects with upper-body exercise (4,15). Additionally, this load was also lower than those used in studies that found no PAP effect, although the time interval was similar (5,8,14). Although Baker (3) found the effect of PAP with 3-minute intervals, the use of only 1 absolute load must be interpreted with caution.

With respect to the use of 1RM as AST in the concentric phase, the present results confirm the findings of Gullich and Schmidtbleicher (13), who used maximum contractions and reported an improvement in upper-limb muscle performance. In contrast, Farup and Sorensen (10) used a conditioning activity with a maximal load (5 reps at 1RM) in the bench press. Preintervention and postintervention (first to the 21st minute) tests were performed (isometric MVC or a bench throw) on different days to evaluate isometric rate of force development and maximum power. No significant difference was found in maximum power between preintervention and postintervention, and there was a reduction in the rate of force development, indicating that no potentiation was present. Additionally, some subjects did not complete

the conditioning activity and needed spotter assistance, suggesting that perhaps the conditioning activity was too intense to generate performance improvement. A separate issue may have interference among tests, as interventions were performed every minute. Thus, these results may have been different had the attempts with different time intervals been conducted on different days.

According to Sale (20), a high-intensity or prolonged activity can not only activate PAP but can also produce fatigue. Alternatively, long recovery periods between activities can contribute to recovery from fatigue and may also decrease the magnitude of PAP. To properly induce PAP, it is therefore important to find the optimal relationship between fatigue and PAP, because this relationship will determine whether the main activity will be impaired, unchanged, or enhanced.

With respect to the relationship between fatigue and PAP, Tillin and Bishop (21) reported that the contrasting results in the literature are obtained because this relationship can be influenced by many variables related to the conditioning activity (e.g., intensity, number of sets and repetitions, recovery interval between activities, and dynamic or isometric contractions), subject characteristics, and by the type of conditioned activity, suggesting that both effects are multifaceted. Other studies (4,7,22) have assigned the contrasting results to individual differences. For example, in the study by Bevan (4), individual variation was observed in the recovery time for which the best performance was observed; 15 subjects showed the best performance with 8 minutes of recovery, 7 subjects with 12 minutes, 3 subjects with 16 minutes, and 1 subject with 4 minutes. Therefore, there appears to be a wide variation in the PAP response between individuals, and an individual determination of an optimum interval may be necessary (4,7).

PRACTICAL APPLICATIONS

Postactivation potentiation has gained popularity because of its benefits in power performance. The current findings indicate that the performance of 1RM activity was able to improve the performance of both mean and peak power in the concentric phase of the bench press exercise when the intervening interval was 7 minutes. Such a strategy could be applied as an interesting alternative to enhance the performance during competition or for tasks aimed at increasing upper-body power in training conditions. However, it will be important to study the same effect after longer intervals, with the aim of observing if performance can be further improved.

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