INFLUENCE OF RECOVERY DURATION AFTER A POTENTIATING STIMULUS ON MUSCULAR POWER IN RECREATIONALLY TRAINED INDIVIDUALS

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ABSTRACT

Jo, E, Judelson, DA, Brown, LE, Coburn, JW, and Dabb, NC. Influence of recovery duration after a potentiating stimulus on muscular power in recreationally trained individuals. J Strength Cond Res 24(2): 343–347, 2010—Research examining postactivation potentiation (PAP) in recreationally trained individuals (RTI) shows mixed results. Because the balance of PAP and fatigue after heavy-load exercise influences performance outcomes, recovery duration after the stimulus might explain inconsistent results noted in RTI. The purpose of this study was to investigate the effect of recovery duration after a potentiating stimulus on muscular power in RTI. Twelve healthy RTI males (age = 23 ± 1 yr, height = 174.6 ± 2.5 cm, mass = 86.3 ± 6.6 kg, 1 repetition maximum [1RM]:mass = 1.4 ± 0.1, body fat = 15.1 ± 2.5 %) minimally possessing 1 year of back squat experience participated. A control session assessed baseline measures on a 30-second Wingate Test. During experimental sessions, subjects performed a back squat exercise (1 set of 5 repetitions at 85% 1RM), rested for 5, 10, 15, or 20 minutes, and performed the Wingate Test. No significant differences existed among control and experimental conditions in all outcome variables; however, maximal values (regardless of rest duration) for absolute peak power (APpwr) (+7.1%), relative peak power (RPpwr) (+7.1%), and fatigue index (FI) (+8.9%) significantly differed from respective control values. The rest duration eliciting maximal PAP significantly correlated (r = −0.771) with relative 1RM. Although recovery duration failed to influence performance after a heavy-load exercise in RTI, discrepancies in individual strength might have influenced the time subjects potentiated. These results suggest stronger subjects might potentiate with less rest after a stimulus (5–10 min), whereas weaker subjects require longer rest durations (15–20 min).

KEY WORDS performance, postactivation potentiation, rest, strength, Wingate

INTRODUCTION

Postactivation potentiation (PAP) refers to the enhanced contractile ability of muscle in response to a conditioning stimulus such as a heavy resistance exercise (36). Therefore, PAP serves to improve muscular performance, potentially enhancing exercise performance. The potentiating stimulus is usually high intensity in nature and muscle specific (i.e. a heavy-load exercise will produce potentiating effects in the muscle groups involved in the exercise) (28,32,40,41). A heavy-load exercise can also trigger fatigue (8) and mask the effects of PAP. Thus, the balance between PAP and fatigue after a heavy-load exercise influences ensuing contractile ability (7).

Recovery duration after the stimulus might influence this balance because the degree of potentiation might vary at different time intervals after a heavy-load exercise. Enhanced muscular force induced by PAP dissipates after approximately 30 minutes, and fatigue overcomes PAP 1 minute after the stimulus (19,35). Despite limited supporting scientific evidence, most previous PAP studies commonly used a 5 to 10 minute rest duration postconditioning exercise. Moreover, the few studies examining recovery duration yielded conflicting results: previous literature confusingly suggests shorter (5 min) (38), moderate (8–12 min) (26), and longer (18.5 min) (8) recovery durations each optimize the response to a high-intensity stimulus. These conflicting results clearly indicate that recovery duration influences PAP responses and warrant further research to clarify these discrepancies.

An investigation examining various rest durations might also explain mixed outcomes in previous research studying PAP in recreationally trained individuals (RTI). Several studies displayed potentiation in RTI (17,38), whereas, in other research, RTI failed to potentiate (25,28). These studies used various rest durations, which might explain the mixed responses. Given that individuals can benefit from PAP during short-term competition or as a component of training,
the purpose of this study was to investigate the influence of recovery duration after a potentiating stimulus on muscular power in RTI.

**Methods**

**Experimental Approach to the Problem**

This randomized, cross-over, repeated measures study investigated the effects of 4 poststimulus rest periods on Wingate performance. Investigators administered the Wingate Anaerobic Test after 5, 10, 15, and 20 minutes of rest after heavy-load back squats (PAP stimulus). Subjects had each rest duration during separate trials, which occurred on separate days. Peak power, mean power, and FI were used to measure Wingate performance. The study included 1 orientation session, 1 control session, and 4 PAP experimental sessions.

**Subjects**

Twelve healthy recreationally resistance trained males (age = 23 ± 1 yr, height = 174.6 ± 2.5 cm, mass = 86.3 ± 6.6 kg, back squat 1 repetition maximum [1RM] mass = 1.4 ± 0.1, body fat = 15.1 ± 2.5%) volunteered for this study. The subjects participated with informed consent. Inclusion criteria included at least 1 year of resistance training experience, at least 1 year of back squat experience, and the ability to properly parallel back squat body mass.

**Procedures**

**Experimental Controls.** Forty-eight to 72 hours separated each session, providing subjects with adequate recovery. During the entire study, investigators instructed subjects to control for diet, hydration, sleep, physical activity, and testing schedule. Subjects recorded their dietary intake in detail for 24 hours preceding each testing session for adequate rest. To control for circadian rhythm, all testing occurred during the same time of day ± 1 hour.

**Baseline Testing and Familiarization.** Session 1 consisted of anthropometric measurements, 1RM back squat assessment, and Wingate orientation. Anthropometrics included height, body mass, and body composition. A stadiometer (SECA, Ontario, CA, USA) measured height, and a digital scale (Ohaus, ES200L, Pine Brook, NJ, USA) measured body mass.

To assess body composition, investigators used a 3-site skinfold caliper test (Harpenden, England) and the Jackson and Pollack formula specific for ethnicities (22).

Session 1 also included 1RM assessment of the parallel back squat (i.e., the maximum load properly lifted exactly once) (27). Subjects began testing with 10 minutes of self-selected cycling and an activity-specific warm-up of 5 to 10 repetitions at 40% to 60% of estimated 1RM. After resting 1 minute, subjects completed 3 to 5 repetitions at 60% to 80% of estimated 1RM. Subjects rested 1 minute and then attempted 90% of estimated 1RM as their first trial. If successful, investigators increased the load based on subject perception of the previous attempt; if unsuccessful, the last successful load defined the subject’s 1RM. Investigators determined 1RM in 3 to 5 trials, between which subjects rested 3 to 5 minutes.

Investigators also familiarized subjects with the Monark Cycle Ergometer (Monark 894E, Sweden) and the Wingate Anaerobic Test protocol (5,6). The protocol consisted of 3 different stages of cycling: (1) 5 seconds at 60 rpm against no resistance, (2) 30 seconds at maximum intensity against 7.5% of body mass (6,13,23) immediately after the first stage, and (3) 5 to 10 minutes at low intensity for cool down. Computerized software (31) measured power parameters at 1 second intervals throughout the 30-second test, and peak power occurred at 6 ± 1 seconds. Although many strength athletes and coaches might not typically use the Wingate

<table>
<thead>
<tr>
<th>Absolute peak power (W)</th>
<th>Absolute average power (W)</th>
<th>Relative peak power (W kg⁻¹)</th>
<th>Relative average power (W kg⁻¹)</th>
<th>Fatigue index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1,054.79 ± 184.81</td>
<td>696.62 ± 128.12</td>
<td>12.56 ± 1.89</td>
<td>56.02 ± 6.34</td>
</tr>
<tr>
<td>5 min</td>
<td>1,094.12 ± 169.19</td>
<td>708.80 ± 127.67</td>
<td>13.06 ± 1.95</td>
<td>59.55 ± 5.01</td>
</tr>
<tr>
<td>10 min</td>
<td>1,081.42 ± 179.07</td>
<td>701.74 ± 129.91</td>
<td>12.93 ± 2.10</td>
<td>58.19 ± 4.68</td>
</tr>
<tr>
<td>15 min</td>
<td>1,103.65 ± 177.72</td>
<td>707.67 ± 150.15</td>
<td>13.11 ± 1.63</td>
<td>57.84 ± 6.64</td>
</tr>
<tr>
<td>20 min</td>
<td>1,086.42 ± 176.81</td>
<td>709.24 ± 134.51</td>
<td>12.94 ± 1.81</td>
<td>56.68 ± 5.19</td>
</tr>
</tbody>
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*Values are means ± SD. No significant differences existed among control and experimental conditions.
Anaerobic Test, the scientific community accepts the Wingate as a valid assessment of power, and our results possess special applicability to cyclists and possibly sprinters (39). We specifically chose to examine the PAP and Wingate performance because (1) cycling performance for RTI requires less technical demands than running or jumping, (2) the Wingate Test allowed us to research the influence of PAP on more prolonged, near-maximal power events without sacrificing the measurement of peak power, and (3) several previous PAP studies evaluated cycling tests (32,39).

For session 2 (control), subjects warmed up by cycling at self-selected intensity for 10 minutes. After resting 2 minutes, subjects back squatted 5 repetitions at 50% of 1RM. Subjects rested for 2 minutes then began the Wingate Test.

Experimental Trials. For sessions 3 to 6 (experimental trials), each experimental session evaluated 1 rest period post-PAP stimulus (5, 10, 15, or 20 min), assigned in randomized order for each subject. Subjects replicated the warm-up in session 2 (low-intensity cycling and back squatting) then immediately back squatted 5 repetitions at 85% of 1RM. This load successfully stimulated PAP in previous literature (29,42). Subjects then passively rested for the prescribed duration and immediately began the Wingate Test.

Statistical Analyses
Descriptive statistics (means, SD, SEM) were calculated for all variables. Five 1 × 5 repeated measures analysis of variance were used to assess statistical differences among the control, 5-, 10-, 15-, and 20-minute sessions for APpwr, absolute average power (AAPwr), RPpwr, relative average power (RAPwr), and FI. In the event of a significant F ratio, Tukey’s post hoc was used to analyze pair-wise comparisons. For each power measure, a dependent t-test assessed statistical differences between the subjects’ best performance among all experimental conditions and the relevant control values; this “maximal” performance occurred after different recovery durations for each subject (i.e., subject 1’s maximal performance occurred after 5 min of recovery, whereas subject 2’s maximal performance occurred after 15 min of recovery). Investigators correlated the rest duration eliciting each subject’s maximal performance with descriptive and control variables. The alpha level was set at 0.05.

RESULTS
Comparisons Among Control and Experimental Trials
Table 1 displays the results obtained during all 5 trials. No significant differences existed among control and experimental conditions in APpwr, AAPwr, RPpwr, RAPwr, and FI.

Comparisons Among Control Trial and Maximal Performances
Maximal APpwr (+7.1%), RPpwr (+7.1%), and FI (+8.9%) significantly differed from their respective control values. Maximal AAPwr (+4.6%) and RAPwr (+4.3%) failed to significantly differ from their respective control values.

Figure 1 shows the relationship (r = -0.771, p < 0.05) between the rest duration eliciting maximal APpwr and relative 1RM for each subject. No other anthropometric or control variables significantly correlated with time eliciting maximal APpwr. Because subjects achieved maximal RPpwr during identical trials as maximal APpwr, the same relationship (r = -0.771, p = 0.003) existed between the rest duration eliciting maximal RPpwr and relative 1RM. No anthropometric or control variables significantly correlated with time eliciting maximal FI.

DISCUSSION
The primary findings of this investigation were that no significant differences existed in performance variables among control and experimental trials, suggesting heavy-load squats fail to induce PAP in RTI. These results imply that rest duration might not explain previous inconsistencies in PAP studies examining RTI. However, maximal APpwr, RPpwr, and FI significantly exceeded respective control values. In total, these results provide 2 divergent interpretations: heavy-load squats fail to induce PAP in RTI or heavy-load squats...
induce PAP in RTI, but the influence of an additional variable masked statistically significant differences across rest intervals.

Similar performances among control and experimental trials indicate that heavy-load squats known to stimulate PAP in competitive athletes (8,29,30,33,41,42) failed to induce PAP in RTI. This suggests differences in rest duration cannot explain discrepancies in previous literature describing RTI. Because previous research demonstrates that competitive athletes respond more favorably to PAP than less-trained individuals (8), RTI might display these inconsistencies because "recreational training" encompasses a wide spectrum of training intensities (i.e., better-trained RTI might demonstrate PAP similar to athletes, whereas less-advanced RTI fail to experience similar benefits). In the present study, we operationally defined RTI as subjects who back squatted at least their body weight and possessed at least 1 year of back squat experience; however, subjects displayed a spectrum of relative 1RM because this definition lacked an upper threshold. Previous research supports the contention that this variability in our subjects influenced the results. Duthie et al. (9) found that although stronger subjects (predicted 1RM of 139 ± 6 kg) improved peak power after heavy-load half squats, weaker subjects (predicted 1RM of 116 ± 10 kg) peak power decreased. Young et al. (42) correspondingly found stronger subjects demonstrated greater jump height increases after heavy squats than weaker subjects as based on subject 5RM. Potentially, stronger subjects in this study exhibited PAP, whereas weaker subjects failed to potentiate. This variability in PAP responses possibly disguised statistically significant differences among rest durations.

Although previous research indicates stronger individuals respond to heavy-load stimulus more favorably than weaker individuals, several studies (8,42) suggest weaker subjects still possess the capability to potentiate. Because all individuals might potentiate, an alternative hypothesis also explains the current results: all subjects potentiated but in a way that masked statistical differences across rest intervals.

To assess this hypothesis, we compared each subject’s maximal performance (greatest value for each variable among all experimental conditions) with the relevant control measures. Maximal APpwr (+7.1%), RPpwr (+7.1%), and FI (+8.9%) significantly exceeded their respective control values, suggesting subjects demonstrated PAP but inconsistently across rest durations (Figure 1). To explain these discrepancies, we correlated rest duration eliciting each subject’s maximal APpwr to descriptive variables. Only subject relative 1RM significantly correlated (r = −0.771) with the rest duration inducing maximal APpwr. Stronger subjects (relative 1RM ≥ 1.5 × body mass) potentiated maximally at 5- and 10-minute rest periods, whereas weaker subjects (relative 1RM < 1.5 × body mass) maximally potentiated at 15- and 20-minute rest periods.

The data of Rassier and Macintos (34) might explain these findings because these investigators indicated that fatigue and PAP could coexist after heavy resistance exercise and that performance improves only when PAP exceeds fatigue. Our results suggest that the relationship between these variables changes with relative strength. In assuming that training status differentiates weaker from stronger subjects, 3 possible mechanisms explain the transition from “weak” to “strong”:

- Training alters PAP, fatigue, or both. Previous research supports each possibility. Trained individuals display elevated regulatory myosin light chain phosphorylation and also develop larger and stronger type II fibers (which exhibit greatest neural excitation after heavy resistance exercise), suggesting training increases potentiation capability (20,32,37,40). Advanced weightlifters also develop fatigue resistance to heavier loads as a training adaptation (8,32,40), thus allowing PAP to predominate immediately after resistance exercise (20). Because increases in fatigue resistance and PAP are not mutually exclusive, training-induced improvements in both mechanisms might explain the transition from “weak” to “strong.”

Similar to the vast majority of other PAP studies, the current design limits our ability to extrapolate these findings to entire workouts or training programs. Although the present study solely examined acute effects, previous work demonstrates that manipulating PAP (by way of complex training) might produce beneficial chronic adaptations (11). On the basis of the current study, the lifter must consider the time effect of PAP (i.e., using a rest duration that allows optimal PAP effects).

In conclusion, the pooled data suggest that rest duration failed to influence performance after heavy-load exercise in RTI, but relative strength discrepancies might influence when subjects potentiated. These results imply stronger subjects might potentiate with less rest after the stimulus (5–10 min), whereas weaker subjects require longer rest durations (15–20 min). Although tempting to do so, attributing the discrepancies in optimal PAP rest duration to individual relative strength will require further research to more explicitly examine the effects of relative strength on recovery duration.

**Practical Applications**

These findings indicate RTI exhibit PAP; to improve power performance (e.g., sprinting or jumping) people should consider using heavy-load exercise 5 to 20 minutes preceding explosive activities. Although this study implies stronger individuals experience PAP earlier than weaker individuals after heavy resistance exercise, we suggest testing individuals multiple times to identify the optimal rest duration.

**Acknowledgments**

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