Original Research

Acute Post-Activation Potentiation Effects in NCAA Division II Female Athletes

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ABSTRACT

International Journal of Exercise Science 7(3): 212-219, 2014. Post-activation potentiation (PAP) is a phenomenon in which the power output of a muscle is immediately enhanced after heavy resistance exercise. Whereas the majority of PAP research has examined males, minimal research exists as to how female athletes respond. Therefore, the purpose of this study was to investigate the acute PAP response of back squats on static squat jump (SSJ) performance among NCAA Division II female athletes. Female athletes (n=29) who were current roster members from basketball, softball, and volleyball, performed 3 SSJ prior to 3 repetitions of the back squat exercise at 90% 1RM. After a 5-min rest, athletes once again performed 3 SSJ for maximal height, with peak power calculated using the Sayers equation. There was a significant interaction effect observed between time and team, p=0.022; post-hoc tests indicated that the volleyball team had a significant decrease in power, p=0.008. The main effect for time was not significant, p=0.279, indicating for the group as a whole, there was no evidence of a PAP response. The main effect for team was also nonsignificant, p=0.173, indicating no difference in power outputs by team. Strength and conditioning coaches who work with female athletes should be aware that the successful implementation of PAP complexes within this population appears to be highly individualized. Therefore, the use of PAP complexes in female athletes should consider both the absolute and relative strength of each athlete in conjunction with the length of the rest period when attempting to optimize the PAP response.

KEY WORDS: Complex training, peak power, static squat jump, muscle activation

INTRODUCTION

Post-activation potentiation (PAP) is a neuromuscular phenomenon in which the force and power output of a muscle is immediately enhanced after heavy resistance exercise (9). The underlying principle of the ability of PAP to increase force and power output of muscle is theorized to be a result of phosphorylation of myosin regulatory light chains (21). It has been hypothesized that the phosphorylation of myosin regulatory light chains cause the interaction between actin and myosin to become more sensitive to Ca^{2+} released from the sarcoplasmic reticulum, resulting in an increased level of myosin cross bridge activity in response to submaximal resistance exercise (20, 21).

The majority of PAP research has investigated a practice referred to as complex training, in which a heavy resistance training exercise is executed prior to performing an explosive bodyweight movement with similar biomechanical characteristics (12). The heavy resistance exercise is hypothesized to induce PAP, thus increasing the acute performance of the bodyweight exercise, with the prospect of superior chronic neuromuscular adaptations (9,12). This increase in central nervous system stimulation causes greater motor unit recruitment and force production that may last from 5 to 30 minutes (18).

To date, PAP research has shown a few general trends. First, trained individuals appear to respond more favorably to eliciting the PAP response than do untrained subjects (15,18). Second, moderate to heavy intensity of resistance exercise elicits the most favorable PAP response (4,16,18). Third, there appears to be a critical window of time for power output due to PAP, as an initial decrease in power is observed immediately after heavy resistance exercise, followed by an optimal time of PAP where peak power can be harnessed (11,16,24), followed by gradual diminishing power output (3,4,6,7,11). Collectively, a recent meta-analysis by Wilson et al. (25) suggested the optimization of the PAP effect would utilize a combination of multiple sets, moderate intensity (60-84% 1RM), and moderate rest periods (7-10 minutes).

Whereas the majority of previous PAP research has examined male subjects within athletic or recreationally trained populations, minimal research exists as to how females respond to PAP, with even fewer studies in regards to female athletes (8). Previous studies on females have found evidence of a PAP response, albeit with small effect sizes (ES=.20) (13,14,25), yet the PAP response in female athletes is largely unknown. Common limitations in previous PAP studies that have examined female responses are small sample sizes leading to underpowered studies, and often no differentiation between male and female responses in statistical analysis (5,13,14,18).

According to National Collegiate Athletic Association (NCAA) data, nearly 204,000 females participated in college and university sponsored athletics in 2012-2013 (17). The paucity of research concerning female athletes should be a top priority for sport scientists to address, providing strength and conditioning coaches who work with female athletes evidence-based recommendations on best practices. Therefore, the purpose of this study was to investigate the acute PAP response of back squats on static squat jump performance among NCAA Division II female athletes.

METHODS

Participants

NCAA Division II female collegiate athletes from a Midwestern University were recruited for this study. Inclusion criteria sought healthy female athletes in the off-season of their respective training macrocycle. Subjects with any musculoskeletal injuries or other health problems that would inhibit the ability to jump and/or squat were excluded from the study. Female athletes who volunteered for this study (n=29, age 19.9 ± 1.0 years) were current roster members from the University's basketball (n=11), softball (n=10), and volleyball (n=8) teams. All subjects signed informed consent documents and completed a Physical Activity Readiness-Questionnaire (PAR-Q) before participation. This study was approved by the University's Institutional Review Board, and all participants completed the study with no injuries reported. Additionally, all testing of athletes was coordinated with the strength and conditioning staff of each team to minimize any potential disruption in off-season workouts.

Protocol

Upon reporting for testing, subjects prepared for 1RM testing by performing a light 3-minute bicycle warm-up at a self selected pace. Next, subjects performed a 3-minute dynamic warm-up consisting of a series of dynamic stretches spanning 15 meters. Following the warm-up, back squat 1RM was determined based on NSCA testing protocol (1). Subjects were instructed to descend to a depth in which the femur was parallel to the ground. A Certified Strength and Conditioning Specialist (CSCS) and experienced spotters were present at all times to ensure safety of subjects and appropriate exercise technique execution. In addition, the spotters visually inspected and confirmed the depth of the squat and provided verbal feedback when needed.

Upon determination of 1RM, subjects were familiarized with the squat jump technique. A static squat jump (SSJ) was used to increase consistency and minimize variability of jumping form (22). In accordance with proper SSJ technique identified by Sayers et al. (22), subjects assumed a squat position, feet shoulder width apart, knees bent at approximately a 90-degree angle, with arms back and ready to be swung upward (Figure 1). Once in the desired position, the subject was verbally prompted to jump.

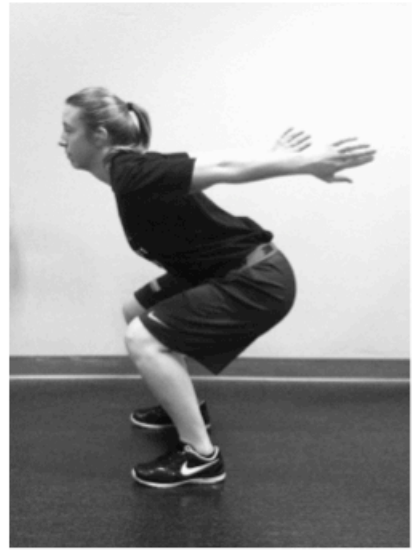

Figure 1. Starting position, static squat jump.

Subjects returned for PAP testing at least 96 hours after 1RM testing was performed. Subjects were instructed to refrain from performing any cardiovascular or strength training 24 hours prior to PAP testing. Subjects prepared for PAP testing by performing the same bike and dynamic stretching warm-ups as performed on day 1 in which 1RM was tested. After the 6-minute warm-up, subjects performed 3 SSJ's for maximal height, as measured by a Vertec (Sports Imports, Hilliard, OH). Each subject performed 3 jumps in which the highest jump height was recorded, with 30 seconds of rest separating each jump attempt. The pre-PAP jumps served as a control for examining the influence of the resistive loads on jump performance.

After the pre-PAP vertical jumps, the subjects rested for 3-minutes before performing the following 4-stage squat warm-up: 1) 5 repetitions at 50% 1RM, 2) 5 reps at 60% 1RM, 3) 3 repetitions at 75% 1RM, and 4) a final PAP inducing set of 3 repetitions at 90% 1RM. Subjects rested 3-minutes between each successive stage.

Table 1. Anthropometric and physical characteristics of subjects (n=29).

Sport	Height (cm)	Body Mass (kg)	1RM (kg)	PAP load (kg)	1RM/Body Mass
Basketball	175.0±6.0	70.4±7.7	77.6±9.3	70.2±8.5	1.1±0.9
Softball	169.3±4.4	70±6.9	103.5±18.1	93.5±16.3	1.5±0.2
Volleyball	178.9±6.1	76.7±11.1	96.8±11.9	87.4±10.8	1.2±0.1
Total	174.1±6.6	72.0±8.7	91.8±17.5	83.0±15.8	1.3±0.2

Values are given as mean ± SD.

After the final PAP set at 90% 1RM, each subject rested for 5 minutes while height and body mass were recorded. Height was measured to the nearest 0.1 cm using a stadiometer (Seca 213, Chino, CA) and body mass was measured to the nearest 0.1 kg using a calibrated scale (Befour, Saukville, WI). Once the 5-minute rest period was complete, the subject performed 3 SSJ's utilizing the same procedure as the pre-PAP jumps. All 3-jump heights were recorded with the highest number being used for subsequent data analysis. Anthropometric and physical characteristics of the female athletes are presented in Table 1.

Maximal jump height was determined by calculating the difference between the highest jump and the subject's reach height. This calculation was used for both pre-PAP jump height and post-PAP jump height. Peak power of each subject's pre-PAP highest jump and post-PAP highest jump were calculated using the Sayers Equation in which Peak Power (W) = 60.7 x (jump height [cm]) + 45.3 x (body mass [kg]) – 2055 (22).

Statistical Analysis

All data were analyzed using IBM SPSS Statistics (version 21). A mixed between-within repeated measures ANOVA was performed to determine main effects for time (pre vs. post power) and team (volleyball vs. basketball vs. softball), as well the interaction effect (time x team). In the presence of significant interaction effects, follow-up contrasts were used to evaluate the simple-effects of time within levels of team. To maintain global $\alpha = 0.05$, the level of significance was set at $p < 0.0167$ for each of the 3 simple effects contrasts (pre vs. post for each team).

RESULTS

Post-activation potentiation results by athletic team are presented in Table 2 with all data as mean ± SD. There was a significant interaction effect observed between time and team, $F(2,26)=4.5$, $p=.022$. Post-hoc tests indicated that the volleyball team had a significant decrease in power output from pre to post, -96.4±54.5 W, $p=.008$. The main effect for time (pre vs.

Table 2. Post-activation potentiation results by athletic team.

Sport	Pre SSJ (cm)	Post SSJ (cm)	Pre Power (W)	Post Power (W)	Δ (W) (Post-Pre)	p-value
Basketball	49.8±6.4	49.9±6.5	4156.7±525.1	4163.7±512.7	7.0±94.1	.807
Softball	52.2±6.2	52.7±7.2	4283.5±484.5	4313.3±495.3	30.8±116.1	.310
Volleyball	53.5±4.3	51.9±4.1	4665.8±538.9	4569.4±538.3	-96.4±54.5	.008*

Values are given as mean ± SD. SSJ, static squat jump; W, watts. *Statistically significant from Post-Pre.

post power) was not significant, $F(1,26)=1.2$, $p=.279$, indicating for the group as a whole, there was no evidence of a PAP effect. The main effect for team was also non-significant, $F(2,26)=1.8$, $p=.173$, indicating no difference in power outputs by team. Individual PAP responses by percent power change are displayed in Figure 2.

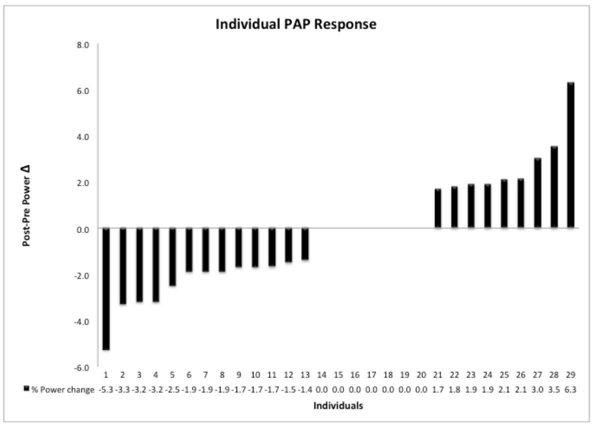

Figure 2. Individual PAP responses and percent power change.

DISCUSSION

The purpose of this study was to determine the acute effect of back squats on static squat jump performance in NCAA Division II female athletes. The results of this study found that a PAP set of 3 reps at 90% of 1RM followed by a 5-minute rest period did not potentiate subsequent jump height in this cohort of female athletes. Whereas a small subset of athletes did successfully potentiate, these differences were not observed for the cohort as a whole, or when examined by each of the three athletic teams. Additionally, this study provided descriptive data on absolute strength (1RM ~ 92 kg) and relative strength (1RM/Body Mass ~1.3) back squat levels in female athletes, which are noticeably lacking within the strength and conditioning literature.

Previous studies have found the PAP response to be highly individualized (5,10,14) thus the results of our study clearly mirror this trend. The challenge to consistently elicit the PAP response stems from a careful balance of the training status of the athlete, the level of strength attained by the athlete, the intensity of the conditioning activity, and the period of time following the potentiating activity (20,23,25). Whereas our study consisted of trained female athletes, the absolute and relative strength levels of our subjects may provide clues as to why the majority failed to potentiate. Within our study, of the athletes above the 80th percentile for 1RM/Body Mass (>1.44, n=5), 4 of the 5 did successfully potentiate. Previous research provides evidence that stronger athletes have a greater potential to potentiate (2,26), which is hypothesized to be due to an ability to become more fatigue resistant as strength levels increase (25). Additionally, emerging research suggests that individuals who have the strength to squat twice their body mass are able to display both earlier and greater PAP responses than weaker individuals (19,23). Given that our subjects average 1RM/Body Mass ratio was 1.3, it is thus very plausible that the combination of low levels of absolute and relative strength, in conjunction with 90% 1RM PAP load, and 5-minute rest period, was too fatiguing to successfully potentiate with a protocol commonly used within several previous PAP research studies within an athletic population (5,23).

As previously stated, minimal research exists on female athletes as a whole (8), let alone the PAP response, therefore comparisons and potential conclusions are somewhat limited. Nonetheless, our results are similar to those of Jensen and Ebben, in which NCAA Division I anaerobic female athletes utilized a PAP protocol consisting of 5RM back squats followed by countermovement vertical jumps at 10 sec, 1 min, 2 min, 3 min, and 4 min post-squat jumps, respectively, which resulted in no significant effect on subsequent jump heights or ground reaction forces (13). However, our results contrast those of McCann and Flanagan, who in a study of NCAA Division I female volleyball athletes, found that a PAP protocol of 5RM back squats followed by 4 min rest, resulted in significant increases in vertical jump height (14). Likewise, in a study of national and international hockey and softball female athletes, Duthie et al. found a PAP protocol of 3RM half squats followed by 5 min rest, resulted in significant increases in both peak power and maximal force for athletes with a 1RM > 139 kg (10). The 1RM strength levels of the female athletes from Duthie et al. are in stark contrast to the female athletes in our study (91.8 kg), providing additional evidence on the impact of maximum strength on the ability to successfully potentiate. Additionally, when comparing NCAA Division II, NCAA Division I, and International caliber female athletes, the inherent difference in athleticism, genetic potential, and skill at each level of competition, does warrant serious consideration when contrasting previous findings.

This study has a few notable limitations. First, the subjects in this study were from a select population of healthy, exercise ready, off-season NCAA Division II female athletes. Thus, care should be taken if attempting to extrapolate our findings to other populations of athletes. Therefore, the results of this study are best generalized to female athletes with a similar strength profile as observed in our subjects. Second, this study used a single PAP protocol of 90% 1RM followed by a 5 min rest period. In order to create minimum disruption to the athlete's training cycle, the above protocol was deemed acceptable by the University's strength staff when consulting with our research team as per how and when to best gain access to the athletes limited availability. Additional manipulation of PAP load, rest period, or combination of each, could have certainly resulted in a different temporal pattern of PAP responses among our subjects, and is duly noted as a limitation. However, we feel the inclusion of trained female athletes, albeit with limited access, provides a much more valuable understanding to the PAP response than had we utilized recreationally trained females. Finally, whereas jump height was objectively measured via the use of a Vertec, peak power measurements were determined by utilizing the Sayers equation, and are thus noted as estimates. When the use of a force plate is impractical, the Sayers equation has been cross-validated to be an accurate estimate of peak power for both R^2 and SEE (22).

In conclusion, the results of this study found that a PAP set consisting of 90% 1RM followed by 5 min rest, failed to potentiate static squat jump performance in a cohort of NCAA Division II female athletes. Strength and conditioning coaches who work with female athletes should be aware that the successful implementation of PAP complexes within this population appears to be highly individualized. Therefore, the use of PAP complexes in female athletes should consider both the relative strength of each athlete and the length of the rest period when attempting to optimize the PAP response. Based on the findings of our study, we recommend that future research that investigates the PAP response in female athletes to consider the following: 1) the absolute strength of the athlete, 2) the relative strength of the athlete, 3) the level of competition that the athlete is at, and 4) for athletes who are unable to squat twice their body mass, the utility of pursuing such PAP complexes.

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