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Acute Effects of Heavy-Load Squats on Consecutive Squat Jump Performance

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Abstract

Postactivation potentiation (PAP) and complex training have generated interest within the strength and conditioning community in recent years, but much of the research to date has produced confounding results. The purpose of this study was to observe the acute effects of a heavy-load back squat [85% 1 repetition maximum (1RM)] condition on consecutive squat jump performance. Twelve in-season Division I male track-and-field athletes participated in two randomized testing conditions: a five-repetition back squat at 85% 1RM (BS) and a five-repetition squat jump (SJ). The BS condition consisted of seven consecutive squat jumps (BS-PRE), followed by five repetitions of the BS at 85% 1RM, followed by another set of seven consecutive squat jumps (BS-POST). The SJ condition was exactly the same as the BS condition except that five consecutive SJs replaced the five BSs, with 3 minutes' rest between each set. BS-PRE, BS-POST, SJ-PRE, and SJ-POST were analyzed and compared for mean and peak jump height, as well as mean and peak ground reaction force (GRF). The BS condition's mean and peak jump height and peak GRF increased 5.8% ± 4.8%, 4.7% ± 4.8%, and 4.6% ± 7.4%, respectively, whereas the SJ condition's mean and peak jump height and peak GRF decreased 2.7% ± 5.0%, 4.0% ± 4.9%, and 1.3% ± 7.5%, respectively. The results indicate that performing a heavy-load back squat before a set of consecutive SJs may enhance acute performance in average and peak jump height, as well as peak GRF.

Key Words complex training, postactivation potentiation, plyometric training

Introduction

The optimal protocol to maximize gains in muscular strength and power is highly sought among strength and conditioning professionals (6). As sports become more competitive, the demand for athletes to perform to the best of their physical ability is also greatly increased. Therefore, developing optimal training protocols that will maximize athletes' ability to perform the necessary movements of the sport should be the foremost concern of the strength and conditioning professional. One of the methods proposed to maximize muscular strength and power during both single and multiple bouts of training is the use of a complex training protocol. Complex training is defined as the set-for-set combination of a heavy resistance exercise (preload) followed relatively quickly by a biomechanically similar plyometric exercise (5). The optimal manner in which these exercises are performed, however, including the combination of mode, intensity, and rest interval to elicit maximal gains in both acute and chronic muscular strength and power, is yet to be discovered.

Complex training is based on the theory of postactivation potentiation (PAP). PAP refers to the enhanced neuromuscular state observed immediately after a bout of heavy resistance exercise (15). Both acute and chronic gains in muscular strength and power may be further enhanced by performing an explosive power exercise while the affected muscle is in this potentiated state. An example of a common protocol used to elicit and exploit PAP would be a 2- to 6-repetition maximum (RM) back squat, followed by a set of squat jumps or alternate-leg bounds. The challenge presented between the execution of the preload and the plyometric exercise is a balancing act between fatigue and potentiation. If the rest interval is too short, fatigue may outweigh potentiation. If the rest interval is too long, optimal potentiation effects may be lost; both situations typically result in less than optimal results. The rest interval used may be highly dependent on many factors, including age, relative strength, and modes and intensity of the complex protocol (4,5,7,8,12,15,18).

Extensive research has shown the effectiveness of training with heavy loads, high velocities, Olympic lifts, and plyometrics alone for strength and power gains, but a combination of these methods is highly recommended for optimal results (1,10,13). As research continues to grow supporting the use of multiple protocols, the question of how to combine these protocols for maximal results during acute and chronic training also arises, yet very few studies to date have examined the use of these protocols as a complex set.

Although alternate preloads, such as isometrics or high-velocity and agonist/antagonist movements (2,3,11), have

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shown instances of enhanced acute power production, more research supports the use of a heavy-preload exercise to elicit PAP and produce acute enhanced muscular power (7,12, 17,18). Young et al. (18) observed an acute enhancement of power performance in 10 resistance-trained men during a loaded countermovement jump (LCMJ) performed 4 minutes after a 5RM half squat. LCMJ after the squat set was significantly greater (2.8%) than the LCMJ performed before the preload. Smith et al. (17) also observed acute power facilitation during a 10-second sprint cycle test performed 5 minutes after 10 sets of one repetition at 90% 1RM back squat with 2 minutes' rest between sets. The investigators concluded that this complex protocol may have a potential carry-over effect to a 100-m sprint; however, the practicality of this method seems unlikely.

Research regarding PAP and its practical use within the strength and conditioning field is rather limited. Presently, many of the protocols used in the field are based on trial and error. As more research is done regarding the manipulation of rest intervals, modes, and intensities, we may be able to provide better guidelines for the most effective use of complex training protocols. Therefore, the purpose of this investigation was to examine the acute effects of heavy-load squats on consecutive squat jump performance.

Methods

Experimental Approach to the Problem

This study was a one-group experimental design with pre- and post-test measurements. The dependent variables (vertical jump height and ground reaction force) were chosen to best describe the explosive performance of athletes in this situation while also providing an insight into the neuromuscular potentiation effect.

Subjects

The subject population consisted of 12 male in-season National Collegiate Athletic Association Division I track and field athletes (age 20.3 ± 1.7 years, height 180.1 ± 8.8 cm, weight 72.9 ± 8.1 kg). The primary event of each participant in this study consisted of 100/200/400 m (n = 7), long/triple/high jump (n = 4), and pole vault (n = 1). All participants had at least 1 year of experience in strength/power training under a collegiate strength and conditioning training program. Because of the anaerobic nature of complex training, this population was chosen because it was thought that these participants would be most likely to respond, benefit, and utilize complex sets in a practical setting. Participants were required to attend three testing sessions. Each participant was required to sign a university institutional review board-approved informed consent document regarding the risks and requirements of the study before participation.

Procedures

A standard 20-kg Olympic-style barbell and weight plates were used for the back squat. Squat jumps were performed on a force platform (AMTI, Watertown, Mass.) and analyzed for peak and mean ground reaction force (GRF) and peak and mean jump height. All data were collected on a personal computer utilizing DataPak 2K2 acquisition software (Run Technologies, Mission Viejo, Calif.).

Approximately 1 week before testing, each participant performed a 1RM back squat protocol according to NSCA guidelines and was familiarized with the procedures of each condition. Each participant's five-repetition load was estimated according to their 1RM performance (85% 1RM). The study consisted of two randomized testing conditions: a five-repetition back squat at 85% 1RM (BS) and a five-repetition squat jump (SJ). All testing began with a general warm-up consisting of 5 minutes on a cycle ergometer and 10 repetitions of the back squat at 50% estimated 5RM. The BS condition consisted of seven consecutive squat jumps (pre) followed by five repetitions of the back squat at 85% 1RM, followed by another set of seven consecutive squat jumps (post). The SJ condition consisted of seven consecutive squat jumps (pre) followed by five consecutive squat jumps, followed by another set of seven consecutive squat jumps (post).

For the squat jumps, participants were instructed to assume a squat stance on the force platform while lightly interlocking their hands behind their head to control for arm assistance. Participants were told to jump continuously, as explosively as possible, as high as possible for the desired repetitions. Each condition was performed by every participant on non-consecutive days within 1 week of completing the first condition.

Statistical Analyses

Four separate 2 ×2 repeated-measures ANOVAs were used to determine significant pre- to post-test differences in peak jump height, mean jump height, peak GRF, and mean GRF between conditions. An α level of 0.05 was considered significant. One-way ANOVAs were used as follow-ups for any significant interactions.

Results

Jump Height

A 2 × 2 (condition × time) repeated-measures ANOVA revealed a significant ($P < 0.05$) interaction between the BS and SJ conditions. A one-way ANOVA for each condition revealed a significant increase in peak jump height for the BS condition, whereas peak jump height for the SJ condition significantly decreased (Figure 1). Similarly, mean jump height significantly increased for the BS condition (pre: 41.6 ± 5.3 cm; post: 43.9 ± 5.1 cm) but decreased for the SJ condition (pre: 42.7 ± 5.8 cm; post: 41.4 ± 5.1 cm). Figure 3 represents the intersubject percent change in peak jump height between pre and post BS and SJ conditions.

Ground Reaction Force

A 2 × 2 (condition × time) repeated-measures ANOVA revealed a significant interaction between the BS and SJ

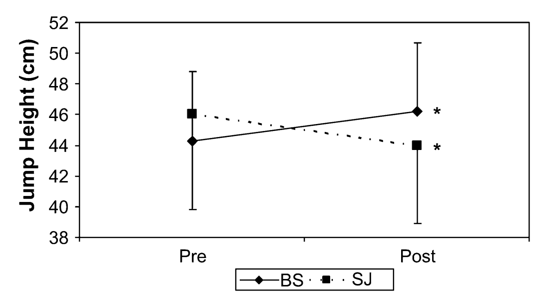

Figure 1. Comparison of peak jump height (cm) between back squat (BS) and squat jump (SJ) conditions. *Significantly different than pretest ($P < 0.05$).

conditions. A one-way ANOVA follow-up showed a significant increase for the BS condition, whereas no change was observed for the SJ condition (Figure 2). For mean GRF, there was no main effect for group but a significant total increase (pre: 1867.6 ± 259.7 N; post: 1942.2 ± 316.1 N). Figure 4 represents the intersubject percent change in peak ground reaction force between pre and post BS and SJ conditions.

Discussion

In this study, we demonstrated that performing a heavy-load back squat resulted in acute potentiation of muscular power in the lower extremities. The BS condition significantly improved mean and peak jump height and mean and peak GRF, whereas the SJ condition significantly decreased mean and peak jump height, significantly increased mean GRF, and elicited no change in peak GRF.

The goal of this study was to examine PAP as it applies to complex training by using a protocol that can be utilized in the various conditions that strength and conditioning coaches and athletes encounter on a daily basis. Much of the literature regarding PAP cannot be applied to an effective and efficient

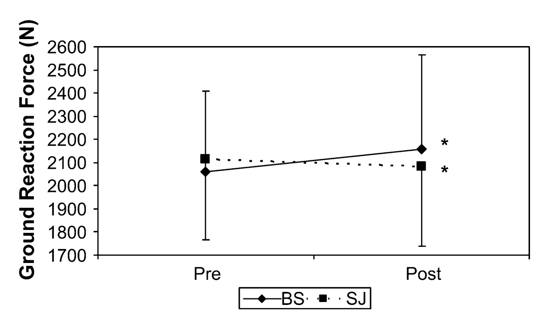

Figure 2. Comparison of peak ground reaction force (N) between back squat (BS) and squat jump (SJ) conditions. *Significantly different than pretest ($P < 0.05$).

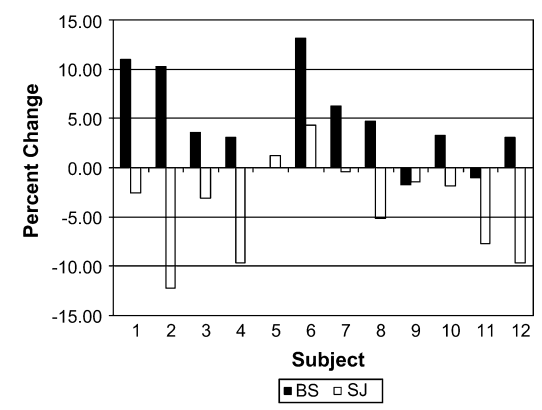

Figure 3. Intersubject percent change in peak jump height between pre and post conditions.

complex training protocol by using methods that are not preferred by strength coaches as optimal sport-specific training techniques. Regardless of their effectiveness or lack thereof, previous research that used a protocol that provided little practical application, although useful from a scientific point of view, are of little practical use to the strength and conditioning professional.

The significant improvement of all dependent variables for the BS condition can most likely be explained by the optimal conditions for PAP to exist. The sprinters/jumpers in this study utilize a great amount of fast twitch fibers (Type II a/x) during everyday training. The training adaptations associated with anaerobic training may indicate that the participants had the necessary motor units available for PAP to occur and may also be effective for other power athletes. According to Docherty et al. (5), the physiological mechanisms behind PAP

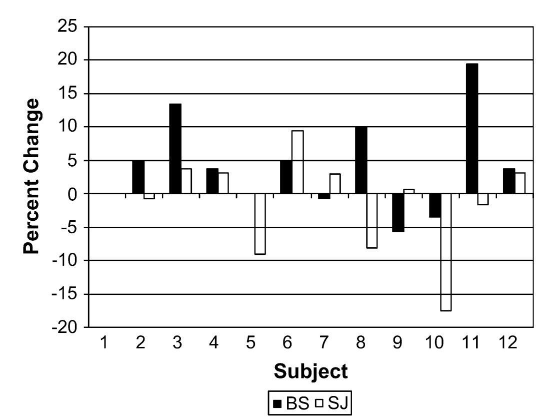

Figure 4. Intersubject percent change in peak ground reaction force between pre and post conditions.

can best be explained by enhanced neural activation. This includes an increase in motor unit stimulation/recruitment, enhanced motor unit synchronization, and/or decreased presynaptic inhibition. All of these mechanisms ultimately result in greater cross-bridge attachments within the muscle, allowing the muscle to generate more force.

This is not to say that this protocol either elicited or exploited the greatest potentiation possible or was effective for every participant observed. As a result of intersubject variability (e.g., relative strength, percentage of fast twitch muscle fibers, recovery time), it is highly unlikely for a single complex protocol to be effective for every participant/athlete in a group. Because no group is entirely homogeneous, it is imperative for future research to focus on what may be effective for most individuals. To accomplish this, we must look at what has generally shown to be effective and what characteristics seem to promote PAP to the greatest extent. For example, research has observed that PAP is more effective in biomechanically similar sets (15), athletes vs. non-athletes (4), individuals with greater relative strength (7) and greater proportion of FT muscle fibers (12), heavy loads (<6-RM) (7,12,17,18), and rest intervals between 2 and 5 minutes (15).

These findings are similar to the potentiation observed by Young et al. (18), who reported a 2.8% increase in a set of LCMJs after a 5-RM back squat. This study is also closely related to the findings of Smith et al. (17) and McBride et al. (14), who observed significant potentiation effects after a 90% back squat in a 10-second sprint cycle test and 40-m dash time, respectively. Both sets of authors suggested that the observed results may have a potential carryover effect to other maximal effort activities lasting up to 10 seconds, which was the approximate amount of time for each subject to complete seven squat jumps in the present study.

These results are dissimilar to the findings of Scott et al. (16), who found no improvement in a set of four horizontal and vertical jumps after a 5-RM back squat. In their study, however, the investigators used 5 minutes' rest between sets, which may have been too long for the potentiation effects to be sustained. These results also contradict the findings of Ebben et al. (9), who found no heightened excitability of the nervous system or increase in mean/maximal GRF on upper body power after a 6-RM bench press. Many of the studies that showed no potentiation effect did not use methods to promote optimal conditions for PAP. Often the participants were recreationally trained, when data have suggested a complex set may be most beneficial to athletes or individuals of greater relative strength (4,7,12,15,18). Rest intervals may have been shorter or longer than optimal, as most data suggest that PAP occurs 2–5 minutes after preload (5,8,15).

An interesting observation in the present study is the decreased performance seen with the SJ condition in all but one dependent variable (mean GRF). Participants were not able to recover from set to set using the rest interval provided, suggesting 3 minutes' rest between sets of consecutive squat jumps may not be sufficient, which was an unexpected result given our population. We speculate that fatigue existed in both conditions, but the 5-RM back squat created enough potentiation to override the fatigue response observed in the squat jump condition.

These findings also showed little correlation between GRF and jump height, as average GRF significantly increased and average jump height significantly decreased in the SJ condition. Anecdotally, the greatest jump height in each set did not always create the greatest GRF and vice versa. Future research should explore the relationship and reliability of GRF as it applies to vertical jumps.

These results suggest that performing a heavy-load back squat before a set of consecutive squat jumps may enhance acute performance in jump height and GRF. A 3-minute rest interval also may not be enough to recover between sets of consecutive squat jumps. For this reason, we recommend that future research compare rest interval lengths on consecutive maximal plyometric exercise.

Practical Applications

This protocol serves as a relatively reliable template for a complex training set that strength and conditioning professionals can utilize in their programs. Although there is no evidence of greater improvements over time with chronic complex training as opposed to the traditional method, this study provides insight as to the type of protocol that may be most effective and practical if a chronic study was to be undertaken. To improve practical use of the current study, future research should also investigate the same complex pair of exercises over multiple sets. As greater evidence to the existence of PAP becomes apparent, future studies should note that if the intention of a PAP study is to apply it to complex training, then the participants, modes, intensities, volumes, and rest intervals should be chosen with the greatest amount of practical use in mind.

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