Journal of Strength and Conditioning Research, 1998, 12(2), 82-84

Acute Enhancement of Power Performance From Heavy Load Squats

Warren B. Young, Andrew Jenner, and Kerrin Griffiths

School of Human Movement and Sport Sciences, University of Ballarat, PO Box 663, Ballarat, Victoria 3353, Australia.

Reference Data

Young, W.B., A. Jenner, and K. Griffiths. Acute enhancement of power performance from heavy load squats. *J. Strength and Cond. Res. 12(2):82-84. 1998.*

ABSTRACT

The purpose of this research was to determine whether a loaded countermovement jump (LCMJ) could be enhanced if preceded by a set of half-squats with a 5-RM load. Ten subjects experienced with the squat exercise performed 2 sets of 5 LCMJ, 1 set of 5 squat reps with a 5-RM load, and 1 set of 5 LCMJ with 4 min rest between all sets. There was no significant difference between the first 2 sets of LCMJ, and the repeatability between these sets was high. However, the jump height for the set of LCMJ after the squat set was significantly greater (2.8%) than for the LCMJ set immediately preceding the squats. It was concluded that squats with a 5-RM load produce dramatic improvements in power performance. In addition, there was a significant correlation between performance enhancement from the squats and the 5-RM load. This suggests that stronger individuals may benefit more from resistance training exercises that utilize contrasting loads.

Key Words: contrast method, countermovement jump, neural activation

Introduction

The contrast training method involves the use of heavy and light loads to train a muscle group in a single workout. Specifically, an exercise set that emphasizes speed or power such as a plyometric exercise is preceded by an exercise set that involves a heavy load. This alternating of heavy and light sets or exercises in a session is also known as complex training. According to Chu (3), power development can be up to three times greater using this method vs. conventional training methods.

The rationale for the contrast method is the suggestion that the performance of heavy loads activates the nervous system. According to Verhoshansky (7), a 5-RM load causes an excitation of the central nervous system and allows a greater explosive effort in subsequent exercises performed with light loads (e.g., 30% 1-RM). Despite the current practice of contrast loading and the claims about its effectiveness over conventional load sequencing, there is little research to substantiate the acute effects or the long-term training effects.

Baker (1) alternated squats (6- to 8-RM) and jump squats (17.5 kg) in training elite divers. He reported that the second set of jump squats, which was preceded by the heavier squats, yielded a 17.2% higher jump than the first set not preceded by heavy squats. Unfortunately, he gave no statistical evidence to support this claim. Radcliffe and Radcliffe (6) provided some evidence for short-term enhancement of power performance. A standing long-jump test was preceded by a variety of warm-up protocols using one's own body weight and weight training exercises to provide resistance. A warm-up that included 4 sets of 4 reps of the power snatch resulted in a significantly better standing long-jump performance (3.9 cm) compared to a normal warm-up with no high intensity exercise.

To investigate the effect of maximum voluntary contractions on subsequent power performance, Gullich and Schmidtbleicher (4) had power athletes do countermovement jumps (CMJ) and drop jumps (DJ) before and immediately after maximum isometric contractions of the leg extensors. The post-isometric contraction CMJ and DJ were significantly enhanced by 2.6% and 3.2%, respectively, compared to pre-isometric contraction jumps. The researchers speculated that the performance augmentation resulted from enzymatic changes and/or increases in neuromuscular activation.

One practical limitation of their research was that isometric contractions are not typical of the heavy loading usually performed when using the contrast method in practice. Therefore the purpose of the present study was to determine whether loaded CMJ (LCMJ) performance is enhanced when preceded by a relatively heavy set of squats.

Methods

Subjects and Design

Ten men between 18 and 31 years of age volunteered to participate in the study. To be eligible for participation, all subjects had to have at least 1 year experience in the half-squat exercise. All subjects were required to attend 2 sessions 5 days apart.

Session 1. This session served two functions. First, it was intended to familiarize subjects with the LCMJ and half-squat tests. After a thorough warm-up, subjects executed 3 sets of 5 reps of the LCMJ, which they performed with a 19-kg load resting on the shoulders. They used a modified Smith machine (Melbourne Gym Equipment) that was 3.0 m high so the LCMJ could be performed safely. The bar was fixed to poles so that it could only slide vertically via low friction linear bearings.

The 19-kg load is typical of the load used by athletes for this exercise (1), and this was the weight of the bar with no extra weights in the system. Subjects were instructed to execute a countermovement at a self-selected speed and depth and immediately jump upward for maximum height. These instructions encouraged subjects to find their own optimum jumping conditions. They were encouraged to bend the knees upon landing to absorb the impact and then pause briefly to mentally prepare for the next repetition. This resulted in a pause between jump repetitions of approximately 2–4 sec. There was a 3-min rest between sets.

The second purpose of this session was to determine the 5-repetition maximum load, that is, the maximum load that could be lifted only 5 times (5-RM) for the half squat (90° knee angle). One trial consisted of the 5 reps. If this trial was successful, the bar weight was increased after a 5-min recovery. Typically 3 to 4 trials were required to determine each subject's 5-RM.

Session 2. The purpose of this session was to assess LCMJ performance before and after a set of half-squats performed with a 5-RM load. All subjects underwent a warm-up consisting of a 3-min jog and stretches that emphasized the muscles of the lower extremities. The rest of the warm-up consisted of (a) half-squats, 10 reps at 50% of predetermined 5-RM and (b) 2 sets of 5 reps at 75% of predetermined 5-RM. A 3-min rest was provided between these submaximum sets. Following the warm-up, a testing sequence interspersed by 4-min rest intervals was administered to all subjects as follows:

- LCMJ: 1 set × 5 reps × 19 kg load
- LCMJ prior to squat set: 1 set × 5 reps × 19 kg
- Half-squats: 1 set × 5 reps × 5-RM
- LCMJ after squat set: 1 set × 5 reps × 19 kg

A rest of 4 min between sets was imposed because this is deemed necessary for recovery of the central nervous system (2). Also, in previous research (5) a 3-min rest interval failed to fully restore explosive force production for some 30 sec following relatively high intensity exercise. The height of all LCMJ repetitions was measured as the difference between the bar's position with the subject standing and its position at the peak of the jump.

A sliding pointer was positioned over the bar to read zero when the subject stood erect. During a jump when the bar descended, the pointer was at its highest point and the vertical height displaced was read from a steel tape to the nearest 1/2 centimeter. Subjects were instructed to maintain contact between the bar and the shoulders throughout each jump. Any loss of contact was deemed a false trial and was not included in the analysis. The jump technique described for Session 1 was also used for this session. The mean of the 5 repetition jump heights was retained as the score for each LCMJ set. The mean of the repetitions was used rather than the best repetition because it was felt that the mean would be more representative of the average muscular output of each set.

Data Analysis

An ANOVA with repeated measures was done to determine whether there was a significant difference between LCMJ sets. A Scheffé post hoc test was used to compare LCMJ, LCMJ pre, and LCMJ post. Of primary interest was a comparison of the 2 consecutive sets before the treatment (half-squats), and a comparison of LCMJ pre and LCMJ post. To assess for consistency between the first 2 sets of LCMJ (LCMJ and LCMJ pre), an intraclass correlation (ICC) and technical error of measurement (TEM) were calculated. Pearson correlations were also computed for selected variables. The 0.05 level of significance was adopted for all statistical tests.

Results

Mean and standard deviation 5-RM squat for the subjects was 152.2 ± 30.1 kg. The mean ± *SD* results for the 3 sets of LCMJ were as follows:

- LCMJ: 38.9 ± 3.7 cm
- LCMJ pre: 39.0 ± 3.3 cm
- LCMJ post: 40.0 ± 3.5 cm

ANOVA revealed a significant time effect ($F = 8.95$, $p = 0.002$). Post hoc analysis found no significant difference between the first 2 sets of LCMJ. To indicate the consistency between these sets, an intraclass correlation and percentage technical error of measurement were calculated. These results were 0.95 and 2.0%, respectively, which represent a high level of repeatability. LCMJ post was 2.8% greater than LCMJ pre, which was a statistically significant difference ($p < 0.05$).

Discussion

The comparison of primary interest was LCMJ pre (preceded by jumps) vs. LCMJ post (immediately preceded by squats). The significant difference between both sets of jumps suggests the squat set produced an acute potentiation in jump performance. Since LCMJ post was preceded by squats and jumps, another possibility is that the final set of jumps was influenced by these combined sets rather than just the squats. This seems unlikely, however, in light of the following evidence.

There was no significant increase in jump height from the first (LCMJ) to the second (LCMJ pre) set of jumps, indicating that the subjects were not becoming more warmed up or improving their jump skill. Indeed, the ICC and % TEM results indicated high consistency between these consecutive sets. Further, 4-min rest intervals between sets were intended to maximize recovery, yet any accumulation of fatigue that may have occurred would cause a reduction in jump height in the final set of jumps. To eliminate these potential ordering effects of testing in the research design, a future study should evaluate the squats and final set of jumps on a day separate from the first 2 sets of jumps, in randomized order. Within these limitations, the most plausible explanation for the increased jump height in LCMJ post is the influence of performing the 5-RM squats.

The findings of the present study are in agreement with Gullich and Schmidtbleicher (4), who reported a 2.6% augmentation in CMJ performance following maximum isometric contractions. While a set of squats at 5-RM would not be expected to produce as much muscular tension as maximum isometric contractions, athletes commonly use the squats for contrast loading. There were no tests on the level of neuromuscular activation, thus the mechanism by which power performance increased is subject to speculation. Since morphological changes to skeletal muscle in such a short time are unlikely, it could be hypothesized that high frequency stimulation of motoneurons associated with the heavy squat set increased the probability of individual motor unit activation (4).

Data observations revealed that the subject who had the greatest increase in mean jump height following the squat set (2.8 cm) also achieved the greatest 5-RM result, 246 kg. To determine if a group trend was apparent, the result in LCMJ post–LCMJ pre (gain from the squat set) was correlated with the 5-RM score. The correlation coefficient was 0.73, which was statistically significant ($p = 0.02$). This indicates that the stronger the individual—assuming a 5-RM can be considered an indicator of strength—the greater the gain in power potentiation from the squats.

Practical Applications

The results of this study indicated that power performance, as measured by a set of LCMJ, is enhanced when preceded by a set of half-squats at 5-RM. This supports the notion that contrast loading increases short-term power performance vs. a method that uses consecutive sets of power exercises. The positive relationship between the 5-RM results and performance enhancement suggests that stronger individuals would benefit more by contrast loading. It is possible that stronger, more experienced athletes are subject to less neural inhibition when lifting relatively heavy loads, but there is no research yet to support this proposition. Therefore the contrast method may be best reserved for athletes with a relatively sound strength training base rather than for beginners.

The present study only assessed power performance for one set following the squat set. Therefore, if multiple sets of squats and LCMJ were alternated, it is not known whether later sets of jumps would also be enhanced. For jumps that are enhanced, however, it could be that they are associated with more powerful muscular actions and that this would provide a superior training stimulus for developing muscular power. If this was the case, the contrast method would be expected to yield favorable long-term training effects. To determine whether contrasting loads are more effective than traditional power training methods, it is recommended that a longitudinal study be conducted to compare training methods directly.

The short-term enhancement of power performance following high intensity exercise also has implications for the design of competition warm-up routines. The results of this study suggest that inclusion of a set of squats with a 5-RM load in a warm-up might result in improved performance in activities dominated by the power output of the leg extensors. The design of high intensity warm-ups should be explored further by coaches and researchers.

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