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Short-Term Effects of Selected Exercise and Load in Contrast Training on Vertical Jump Performance

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Abstract. Smilios, I., T. Pilianidis, K. Sotiropoulos, M. Antonakis, and S.P. Tokmakidis. Short-term effects of selected exercise and load in contrast training on vertical jump performance. *J. Strength Cond. Res. 19(1):135–139. 2005.*—The present study examined the short-term effects of loaded half squats (HSs) and loaded jump squats (JSs) with low and moderate loads on the squat jump (SJ) and the countermovement jump (CMJ) performance using a contrast training approach. Ten men (mean ± *SD* age, 23 ± 1.8 years) performed the HS and JS exercises twice with loads of 30% of 1 repetition maximum (1RM) (HS30% and JS30%, respectively) and 60% of 1RM (HS60% and JS60%, respectively). On each occasion, 3 sets of 5 repetitions with 3 minutes of rest were performed as fast as possible. Vertical jump performance was measured before exercise, 1 minute after each set, and at the fifth and 10th minutes of recovery. The CMJ increased significantly after the first and second set (3.9%; $p < 0.05$) compared with preexercise values following the JS30% protocol and 3.3% after the second and third sets of the JS60% protocol. Following the HS60% protocol, CMJ increased after the first and the second sets (3.6%; $p < 0.05$) compared with preexercise values, whereas SQ increased only after the first set (4.9%; $p < 0.05$) in this condition. These data show that contrast loading with the use of low and moderate loads can cause a short-term increase in CMJ performance. The applied loads do not seem to present different short-term effects after loaded JSs. When the classic form of dynamic HS exercise is performed, however, at least a moderate load (60% of 1RM) needs to be applied.

Key Words. jump squat, countermovement jump, squat jump, ballistic exercise, contrast training

Introduction

Muscular power is a basic constituent of neuromuscular function and is of paramount importance for success in many sports. Several training modalities have been developed to improve muscle power, such as resistance training using heavy (80–100% of 1 repetition maximum [1RM]) or light (30% of 1RM) to moderate (60% of 1RM) loads, plyometrics, and ballistic training (1, 3, 18). Furthermore, the contrast loading method, which involves the execution of alternating sets of an exercise with a heavy load followed with sets of an exercise with a light load or body weight, is also suggested for power development (6, 18). The rationale of contrast loading is that an exercise set with a heavy load will increase the activation of the neuromuscular system and consequently enhance the performance of the next exercise. The highest performance in an unloaded explosive movement, such as a vertical jump, could be achieved if sets of an exercise using a heavy load and activating the same muscle groups, such as half squats (HSs), were executed in alteration with sets of vertical jumps. Indeed, studies have shown that the execution of maximal isometric contractions of the knee and hip extensors or HSs with a 5 repetitions maximum (5RM) load or with loads 20–90% of 1RM caused a short-term increase in countermovement jump (CMJ) performance by 2.4–3.3% (11, 12, 24). In contrast, other studies do not report any changes in CMJ following maximal isometric or dynamic contractions with similar loads (8, 14, 15). Furthermore, no data exist on the effects of heavy resistance exercise on squat jump (SJ), where there is no prestretching of the muscles and performance mainly resides on neural activation of the muscles without reflex and elastic energy contribution. It remains unclear if the alternate execution of HSs with vertical jumps in a contrast loading procedure can enhance vertical jump. The first objective of the present study is to examine whether the execution of loaded HSs can cause a short-term increase in SJ and CMJ height.

An important factor in a contrast-training program might be the selection of the most appropriate exercise in conjunction with a heavy load to obtain the greatest improvement in the performance of the vertical jump. Ballistic training with the use of loaded jump squats (JSs) has proven to be more effective in well-trained athletes or equally effective in recreation athletes for the improvement of vertical jump performance, such as the HSs (16, 19, 23). However, data that concern the short-term effects of loaded JSs on jump performance are limited to one study (21) where the execution of 4 sets of 4 loaded JSs with a load of 15–20% of body weight had no effect on standing long-jump performance. It is unknown whether higher intensities, such as 30% of 1RM or even higher (used effectively for long-term improvement) (16, 19, 23), would improve vertical jump. The second objective of the present study is to examine the short-term effects of a ballistic exercise for the lower body, such as the JSs, on vertical jump performance.

Another important parameter to consider in the design of a contrast training program may be the intensity used in exercises with the heavy load to increase the performance in a subsequent explosive movement. Previous studies have shown that the execution of HSs with heavy loads (5RM) can cause a short-term increase in CMJs. However, the use of 'explosive' or power-type training, performed with light to moderate loads (30–60% of 1RM) and maximal movement velocity in each repetition, is also suggested for power development and rapid force production (1, 13, 17). Baker (2) has shown that the alternate use of heavy and light loads from within the power training zone (30–60% of 1RM) increases the power output developed with the lighter resistance. The third objective of this study is to provide data on the short-term effects of HSs or JSs, executed with a light or moderate load, on vertical jump performance.

Training involves the execution of multiple sets of exercise. Young et al. (24) showed that a single set of HSs could increase vertical jump. However, it is not known whether the execution of multiple sets of HSs or JSs would increase or decrease vertical jump performance or even maintain it at the same level. In studies that used multiple sets (11, 12, 21), vertical jump was assessed only before and after the completion of all sets and not in between. Therefore, the fourth objective of the present study is to monitor vertical jump performance in a series of alternating sets of HSs or loaded JSs with vertical jumps.

Vertical jump is a motor task performed in many athletic activities and is commonly used to evaluate explosive strength performance. The study of the short-term effects of 2 common resistance exercises for power development on vertical jump would provide useful information about the controversial effects of contrast loading on vertical jump performance. In addition, the use of loads from within the recommended power training zone would show whether sufficient stimulus exists for a short-term potential effect on vertical jump. This information could be useful for the design of a more effective resistance training program. Thus, the primary purpose of the present study is to examine the short-term effects of multiple sets of HSs and ballistic loaded JSs executed with light and moderate loads on SJ and CMJ performance.

Methods

Experimental Approach to the Problem

This study has 4 objectives. The first objective is to determine if contrast loading has an effect on 2 types of vertical jumps: the SJ and the CMJ. For this reason, both types of jumps were performed between the executions of sets of exercise with an additional load. The second objective is to examine if 2 commonly used exercises for the development of leg power, the HS and the JS, have the same short-term effect on vertical jump performance. To achieve this, subjects performed alternate sets of HSs with vertical jumps and JSs with vertical jumps. The third objective is to determine if light and moderate loads from within the power training zone can cause a short-term increase in vertical jump height. To accomplish this, the subjects executed the HS and the JS exercises twice. The first with a load of 30% of 1RM in HS and the second with a load of 60% of 1RM. The fourth objective is to monitor vertical jump performance changes during the execution of each pair of contrast sets. Therefore, SJ and CMJ height were measured after the execution of each set of either the HS or the JS.

In particular, the subjects participated in 4 experimental sessions: 2 sessions involved the HS and JS with a load of 30% of 1RM (HS30% and JS30%, respectively), and the 2 other included the HS and JS with a load of 60% of 1RM (HS60% and JS60%, respectively). The 4 sessions were performed at least 5 days apart in random order and in a counterbalanced way. At each session, 3 sets of 5 repetitions of HSs or JSs with 3 minutes of rest were performed as explosively as possible. Two SJs and 2 CMJs were performed before exercise 1 minute after each set and at the fifth and 10th minutes of recovery.

Subjects

Ten men volunteered to participate in this study after signing a consent form approved by the institutional review board. The physical characteristics (mean ± *SD*) of the subjects were as follows: age, 23 ± 1.8 years; height, 182.5 ± 7 cm; body mass, 75.8 ± 11 kg; and HS 1RM, 127 ± 11.8 kg. Subjects participated in regional-level team sports (i.e., volleyball, basketball, and soccer) and were training for the last 2–3 years 2–3 times a week with loads of 40–70% of 1RM for the development of muscle power without following a periodic resistance training program. During the period of the measurements, the subjects were in a transition period of 1 month and were training with weights once or twice a week by performing 6–8 repetitions with loads 60–70% of 1RM.

Measurements

Before the experimental sessions, on a separate day, maximum strength in the HS exercise (knee angle 90°) was measured with the 1RM method. Briefly, the subjects warmed up with 5–8 repetitions with a load estimated by the subjects to be approximately 50–60% of 1RM. Subjects were familiar with the HS exercise and had previously trained on the lift. After 2 minutes of rest, 2–4 repetitions were performed with a load of 70–80% and 1 repetition with a load of 90% of the estimated 1RM. Thereafter, the load increased progressively when the subject performed 1 repetition to reach the maximum where the movement could not be completed with a full range of motion. Between single repetitions, subjects rested for 3–5 minutes. Two to 3 single trials were required until the 1RM load was reached.

Vertical jump performance was evaluated using a resistive platform connected to a digital timer (Ergojump, Psion CM, MAGICA, Rome, Italy), which recorded flight time and calculated jump height (3). Two forms of vertical jump were performed, a SJ initiated from a knee flexion of 90°) and a CMJ. During the performance of the jumps, the hands of the subjects were placed on the waist. Test-retest reliability of SJ and CJ performance under conditions similar to those of the present study was established with 10 men who performed SJs and CMJs before loaded JSs and following each set of 3 sets of 5 repetitions with a load of 45% of 1RM in the HS and 5 and 10 minutes during the recovery. Intraclass correlation coefficients were found to be high for SJ and CMJ (before exercise, 0.952 and 0.949; after the first set, 0.916 and 0.979; after the second set, 0.963 and 0.974; after the third set, 0.964 and 0.941; at the fifth minute of recovery, 0.974 and 0.964; and at the 10th minute of recovery, 0.956 and 0.96; for SJ and CMJ, respectively).

Experimental Procedure

The subjects arrived at the laboratory between 1100 and 1400 hours. Before the start of each experimental protocol, subjects performed a general warm-up that included 5 minutes of cycling with 60 W and 5 minutes of stretching the hip, thigh, and leg muscles. Next, SJ and CMJ height before exercise was measured. Then, a specific warm-up, including 2 sets of 4 repetitions of HSs with 3 minutes of rest, was performed with a load of 80% of the

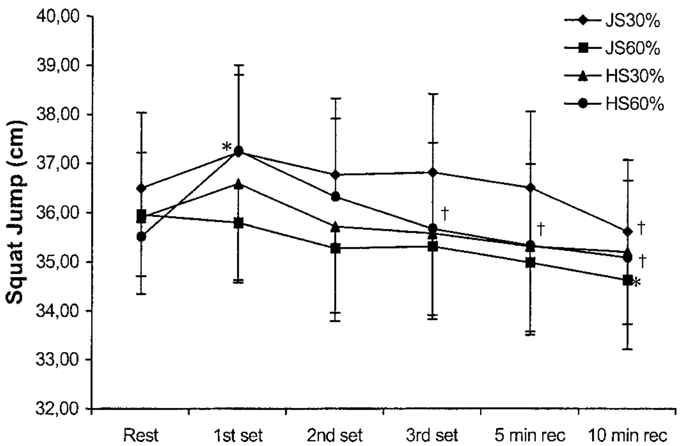

FIGURE 1. Short-term squat jump height (mean ± *SE*) changes with the execution of loaded jump squats (JSs) and half squats (HSs) with loads of 30 and 60% of 1 repetition maximum in the HS exercise. * $p < 0.05$ from rest. † $p < 0.05$ from the first set.

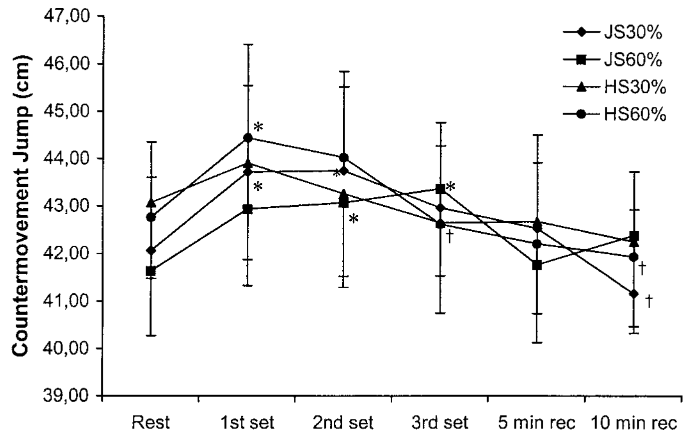

FIGURE 2. Short-term countermovement jump height (mean ± *SE*) changes with the execution of loaded jump squats (JSs) and half squats (HSs) with loads of 30 and 60% of 1 repetition maximum in the HS exercise. * $p < 0.05$ from rest. † $p < 0.05$ from the first set.

weight to be used in the experimental session. The experimental session included 3 sets of 5 repetitions with 3 minutes of rest during the predetermined exercise (HS or JS) with a load 30 or 60% of HS 1RM. The subjects were instructed and verbally motivated to perform each repetition as explosively as possible. One minute after each set of HSs or JSs and at the fifth and 10th minutes of recovery, 2 SJs and 2 CMJs were measured. The best trial for each jump was used for the analyses of the data.

Statistical Analyses

A 2-way analysis of variance (exercise protocol × sets-time point) with repeated measures in both factors was used to examine (a) the effects of the exercise protocol on vertical jump performance and (b) the differences among the 4 protocols in vertical jump performance at the various sets-time points. Separate analyses were performed for the SJ and the CMJ. Significant differences between means were located with the Tukey honestly significant difference procedure. The significance level was set at $p \leq 0.05$.

RESULTS

Squat Jump

The SJ height increased ($p < 0.05$) only with the HS60% protocol after the first set by 1.74 cm (4.94%) compared with the height before exercise (Figure 1). Thereafter, SJ height progressively decreased and was lower ($p < 0.05$) after the third set and at the fifth and 10th minutes of recovery compared with the height observed after the first set. The other exercise protocols did not enhance SJ performance. The SJ height at the 10th minute of recovery was lower ($p < 0.05$) than before exercise at the JS60% protocol and after the first set at the JS30% protocol. No significant differences ($p > 0.05$) were observed among the protocols in the SJ performance.

Countermovement Jump

The CMJ height increased with the JS60%, JS30%, and HS60% protocols (Figure 2).

JS60% Protocol. The CMJ height increased significantly after the second set by 1.43 cm (3.41%; $p < 0.05$) and after the third set by 1.73 cm (3.96%; $p < 0.05$) compared with the height observed before exercise.

JS30% Protocol. The CMJ height increased after the first set by 1.66 cm (3.8%; $p < 0.05$) and after the second set by 1.69 cm (3.93%; $p < 0.05$) compared with the height observed before exercise. At the 10th minute of recovery, CMJ height was lower ($p < 0.05$) than after the first, second, and third sets of exercise.

HS60% Protocol. The CMJ height increased after the first set by 1.67 cm (3.74%; $p < 0.05$) and remained high after the second set by 1.26 cm (2.84%; $p = 0.08$) compared with the height measured before exercise. Thereafter, CMJ performance decreased and was lower ($p < 0.05$) after the third set and at the fifth and 10th minutes of recovery compared with the height achieved after the first 2 sets.

HS30% Protocol. The CMJ performance did not change ($p > 0.05$) with the HS30% protocol.

The only difference observed among the protocols was that CMJ was higher ($p < 0.05$) after the HS60% protocol than after the JS60% protocol only after the first set.

DISCUSSION

The results of the present study show that the execution of loaded HSs and JSs with light and moderate loads can cause a short-term increase in CMJ performance. Ballistic exercise such as loaded JSs increases CMJ whether a light (30% of 1RM in HS) or a moderate (60% of 1RM) load is used. When the dynamic HS exercise is performed, however, a moderate load should at least be used. The SJ performance appears to be enhanced only with the HS exercise using a moderate load.

Loaded JSs constitute an effective exercise for the improvement of CMJ performance with long-term training (16, 19, 23). This may occur because of the short-term increase that JSs cause in CMJ height, as revealed in the present study. In a previous report, however, Radcliffe and Radcliffe (21) did not observe an improvement of standing long jump after the execution of loaded JSs, because performance was assessed with the standing long jump, where the movement pattern was not close to the JS. In our study, CMJ constitutes the same movement as the JSs that were used to enhance performance. The exercise used to improve performance in the short term probably has to be specific with regard to the muscle activation pattern. Furthermore, in the present study, the lowest load for the JSs was 30% of the 1RM, which corresponded to a load of 50.9 ± 4.9% of body weight (range, 43.6–57.5%), whereas Radcliffe and Radcliffe (21) used a load of 15–20% of body weight. In addition, the execution of repeated jumps with body weight alone had no effect on CMJ (12, 21). It is not known which is the lowest load that can be used for JSs to enhance CMJ height, but it seems that a certain level of intensity has to be achieved.

The results of the present study show that intensity appears to function up to a point as a stimulus for a short-term increase in CMJ performance with ballistic exercise. A load of 30% of 1RM was as equally effective as a load of 60% of 1RM to increase CMJ performance. Although no tests were taken to assess neuromuscular activation, the level of tension, which developed using the light load in the JS, was adequate enough to alter neuromuscular function and consequently increase CMJ. It is not known whether the use of a heavy load (e.g., 80% of 1RM) would have caused more of an increase in CMJ. The short-term increase of CMJ height following sets of ballistic exercise with light and moderate loads may be due to the fact that in this exercise the highest mechanical power is produced with loads approximately of 10–40% of 1RM (22, 23). It would be interesting to examine if the greatest short-term increase in CMJ is achieved when an individual executes the preceding JS set with the load that optimizes his mechanical power output.

The use of a moderate load (i.e., 60% of 1RM) with the traditional HS exercise can increase CMJ performance. We observed higher increases (3.7%) in our study compared with a previous study (2.8%), where a single set with a 5RM load was applied (24). According to the "size principle," the use of a heavy load is required to activate all motor units and probably achieve the greatest neuromuscular activation. However, it appears that the tension developed with the execution of explosive movement (using a load of 60% of 1RM) is probably sufficient to stimulate neuromuscular function and enhance CMJ performance. This increase was not stable, because after the third set the performance of CMJ decreased. Gourgoulis et al. (11), however, found a 2.4% increase in CMJ after 5 sets of HSs with loads of 20–90% of 1RM, using only 2 repetitions and 5 minutes of rest at each set vs 5 repetitions and 3 minutes of rest in our study. If we had used a longer rest interval between sets, CMJ height might have remained increased for a longer period.

The use of a light load (i.e., 30% of 1RM) for the execution of the HS did not enhance CMJ performance. The use of this load is probably too low to alter the neuromuscular function and improve a subsequent CMJ. On the contrary, when the same load was used for the ballistic execution of JSs, CMJ increased. Studies have shown that ballistic exercise involves higher muscle activity with acceleration and force exerted throughout the entire range of movement, whereas by using the classic form of exercise execution, the load is decelerated for a considerable portion of the concentric phase (4, 7, 20). This may explain the differences in the short-term effects of these 2 modes of exercise on CMJ performance.

The improvement in CMJ performance occurred in most occasions after the execution of the first loaded JS and HS set. Therefore, whatever the physiological mechanisms that contribute to the enhancement of muscular power, they seem to be activated very early in the exercise session. After the first set, CMJ performance did not increase more with consecutive sets but was either maintained at approximately the same level or even decreased (Figure 2). However, vertical jump performance was measured during the second minute of recovery following each set of JSs or HSs. This period may not have been enough for recovery, and any positive effects of the second and third sets were marked with fatigue. Short-spaced, 10-second maximal voluntary contraction (MVC) sets, known to enhance muscular function, did not increase knee extension performance, whereas CMJ height tended to increase from 10 seconds after squat to 4 minutes after squat with a 5RM load (10, 14). Furthermore, explosive force and H-reflex recovery following MVCs show a high interindividual variability (12). Further studies are needed to identify the appropriate rest interval between alternating sets of exercise with heavy and light loads when the contrast loading method is used, although an individual-based approach might be the most effective for each athlete.

In contrast to CMJ performance, SJ does not appear to be affected by the previous execution of a loaded exercise. We observed an increase only after the first set of the HS60% protocol. Duthie et al. (5) reported that the HS exercise with a 3 repetitions maximum load increased the performance of loaded JSs (30% of 1RM) performed with a purely concentric action, like the SJ, and only in persons with relatively high strength levels. To our knowledge, no other study has examined the short-term effects of a loaded exercise on a SJ performed with body weight, and no study has shown if these effects differ from those observed in CMJ. The differences in our results between the 2 types of jumps may be due to increases in H-reflex and stretch reflex activity following maximal voluntary contractions (9, 12). This indicates that CMJ performance probably increases following an exercise of a sufficient stimulus due to a greater reflex excitability during the eccentric phase of the jump. This would contribute to the muscular work in the concentric phase. In the SJ, no reflex mechanisms that would improve performance are activated.

Practical Applications

The CMJ performance is enhanced when vertical jump sets are alternated with loaded JS or HS sets performed with low to moderate loads from within the power training zone (30–60% of 1RM). Therefore, these exercises could be embodied in a more time-efficient contrast training program, which may solve the problem of performing exercises for the same muscle groups on consecutive days. When JSs are used, intensity does not appear to present different effects after loaded exercise on jump performance. Therefore, both light (i.e., 30% of 1RM in the HS) and moderate loads (i.e., 60% of 1RM) could be used to significantly increase CMJ height. When the HS exercise is used, however, a moderate load should at least be used. Further research regarding the physiological mechanisms that mediate this short-term increase in CMJ height following various forms of exercise and the proper configuration of a contrast training program and its long-term effectiveness are of scientific and practical importance.

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