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Effect of a Submaximal Half-Squats Warm-up Program on Vertical Jumping Ability

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ABSTRACT

The purpose of the current research was to study the effect of a warm-up program including submaximal half-squats on vertical jumping ability. Twenty physically active men participated in the study. Each subject performed 5 sets of half-squats with 2 repetitions at each of the following intensities: 20, 40, 60, 80, and 90% of the 1 repetition maximum (1RM) load. Prior to the first set and immediately after the end of the last set, the subjects performed 2 countermovement jumps on a Kistler force platform; the primary goal was to jump as high as possible. The results showed that mean vertical jumping ability improved by 2.39% after the warm-up period. Subjects were then divided into 2 groups according to their 1RM values for the half-squat. Subjects with greater maximal strength ability improved their vertical jumping ability (4.01%) more than did subjects with lower maximal strength (0.42%). A warm-up protocol including half-squats with submaximal loads and explosive execution can be used for short-term improvements of vertical jumping performance, and this effect is greater in athletes with a relatively high strength ability.

Key Words: vertical jump, warm-up, power

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Introduction

Explosive movements are dominant in many sports and are typically performed at high speeds against resistance provided by the weight and inertia of the body or equipment. In these sports, the explosiveness of the muscular actions or rate at which force can be applied (power) may be more important than maximum force production capability (12). In general, the level of explosive force mainly determines performances with an impulse duration of up to about 170 ms. Such performances are, for example, speed/strength efforts of the lower extremities in all sprinting and jumping events (1).

Vertical jumping contributes to some degree to performance in most sports (2). However, in some sports the successful athlete must be able to jump high and to reach that height as soon as possible. Success requires generation of power in a very short time (4). Therefore, the strength of muscles of the lower body is not the only determinant of vertical jump performance. According to Newton and Kraemer (3), the rate at which the muscles can develop force is the main determinant in vertical jump, together with the efficiency of the stretch/shortening cycle and the degree of coordination and skill in performing the movements. Moreover, an optimal warm-up is necessary to maximize the rate of force development, flexibility, and neuromuscular coordination. Empirical data indicate that a heavy resistance warm-up enhances athletic performance probably because of increased neural activation (1). According to Verhoshansky (11), a 5 repetition maximum (RM) load causes an excitation of the central nervous system and allows a greater explosive effort in subsequent exercises performed with light weights.

However, the research concerning optimal warm-up protocols for improving vertical jumping performance is limited. In a study conducted by Radcliffe and Radcliffe (5), subjects performed a standing long-jump test that was preceded by a variety of warm-up protocols using the weight of the body and various weight-training exercises to provide resistance. A warm-up that included 4 sets of 4 repetitions of the power snatch resulted in a significantly better standing long-jump performance (3.9 cm) compared with a normal warm-up with no high-intensity exercise.

Güllich and Schmidtbleicher (1) investigated the effect of maximum voluntary contractions on subsequent power performance by having 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 with pre-isometric-contraction jumps, and Güllich and Schmidtbleicher suggested that the performance augmentation resulted from increases in neuromuscular activity.

Young et al. (13) investigated whether a loaded countermovement jump could be enhanced when preceded by a set of half-squats with a 5RM load. Their results revealed that the squat set produced an acute potentiation in jump performance; jumping ability was increased 2.8%.

However, the effect of a warm-up protocol including half-squats against gradually increased resistance has not been studied. Such a warm-up protocol incorporates heavy weights to improve neural activation and lighter weights to enhance other components of explosive muscle action (12).

The purpose of the current research was to study the effect on vertical jumping performance of a warm-up protocol including half-squats with gradually increased intensity.

Methods

Subjects

Twenty physically active men (age: 21.8 ± 1.1 years; height: 1.78 ± 0.05 m; weight: 78.4 ± 9.3 kg) voluntarily participated in the study.

Testing Procedures

First, subjects practiced several countermovement jumps and half-squats to become familiar with these tasks. Then, the 1RM was determined for all subjects on the half-squat. Three days later, subjects performed 2 countermovement jumps prior to and immediately after a warm-up period including 5 sets of half-squats. Each set involved 2 repetitions each with 20, 40, 60, 80, and 90% of the 1RM load. This sequence involved both heavy (>80% of 1RM) and light (<60% of 1RM) loads, which affect different components of explosive muscle action (12). All repetitions were executed as quickly as possible. A rest period of 5 minutes was imposed between the sets for recovery of the central nervous system.

All jumps were performed on a Kistler force platform with the arms akimbo (sampling rate: 1,000 Hz). The starting position for all countermovement jumps was the upright posture (the degree of knee bend utilized by each subject was self-determined); the primary goal was to jump as high as possible. The height of the jumps was calculated from the impulse of the vertical ground reaction force during the stance phase, and the trial resulting in the highest jump (before and after the warm-up period) was selected for further analysis. The information derived from the force platform was also used to generate curves of vertical velocity of the total body center of mass and power output during each jump (Figure 1), according to the procedure described by Harmann et al. (2).

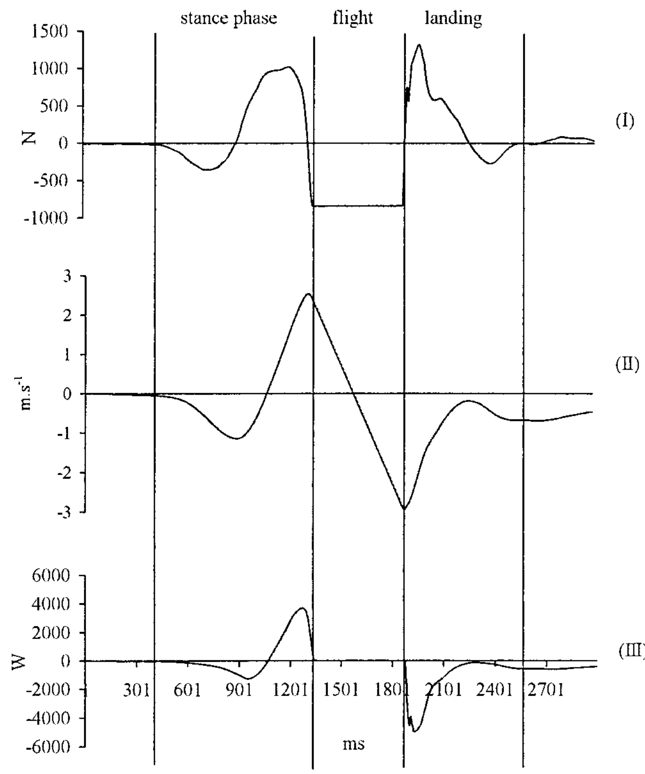

Figure 1. Typical data curves for the net vertical ground reaction force (I), the vertical velocity of the total body center of mass (II), and instantaneous power (III) during the countermovement jump.

Statistical Analyses

A *t*-test for dependent and independent variables was used for the statistical treatment of the data, and the level of significance was set at $p \leq 0.05$.

Results

After the warm-up period, the maximum positive power during the countermovemnet jumps was increased from 4025.5 ± 634.6 W to 4051.9 ± 661.71 W. However, this improvement was not significant (t_{19} = 0.638; $p > 0.05$). However, a significant improvement (t_{19} = 2.099; $p < 0.05$) was observed in the height of the countermovement jump. The mean height of the jumps before warm-up was 33.67 ± 5.14 cm, and the height increased to 34.48 ± 5.56 cm after the warm-up period. This improvement represented 2.39% of the vertical jumping ability before warm-up.

To investigate the effect of the warm-up protocol in subjects with different strength levels, the subjects were divided into 2 groups according to their 1RM value. The mean 1RM value of the total group was 160 kg. Subjects with 1RM value above 160 kg were assigned to the first group (n = 11) and subjects with 1RM below 160 kg were assigned to the second group (n = 9). The first group improved in vertical jumping ability by 4.01%, and the second group improved by only 0.42%. However, a *t*-test for independent samples showed that this difference was not significant (t_{18} = 1.628; $p > 0.05$).

Discussion

An acute positive effect on jumping ability was observed after a warm-up protocol that included half-squats with submaximal loads and explosive execution. The improvement of the vertical jumping ability was on average 2.39%, in agreement with the findings of other researchers (1, 5, 13).

The mechanism of this increase in power performance is a subject of speculation because there have been no tests of level of neuromuscular activation. Morphological changes in skeletal muscle are unlikely in such a short time (8), but high-frequency stimulation of motor neurons associated with the heavy squat set may increase the probability of individual motor unit activation. According to Güllich and Schmidtbleicher (1), such short-term changes leading to positive performance alterations are most probably caused by neuronal factors of speed/strength behavior.

Longitudinal studies have produced clear evidence that following a high-intensity strength training session there is an improvement in the ability to quickly mobilize greater innervation activities (6). The cause of this adaptation in the case of trained athletes has been assumed to be a rapid recruitment of motor units and an increased firing rate of motor neurons in comparison to that in untrained individuals (10). In the present study, the subjects with greater maximal strength showed a greater improvement in vertical jumping ability (4.01%), whereas the subjects with lower maximal strength showed an improvement of only 0.42%. Young (12) speculated that stronger and more experienced athletes are subject to less neural inhibition when lifting relatively heavy loads and concluded that the combination of high and low intensities would be best utilized for athletes with a relatively sound strength training base rather than for beginners.

Besides the ability of the motor neuron pool to tolerate higher activation frequencies, there might exist another adaptation phenomenon, i.e., a more synchronized discharge of the motor neurons so that activation bursts discharge a greater number of muscle fibers in a shorter time period (7). The result of this adapted innervation can be seen in a considerable improvement of rate of force development and therefore in power production (9).

Practical Applications

A warm-up protocol including half-squats with submaximal loads and explosive execution can be used for short-term improvements of vertical jumping performance. This effect is greater in athletes with relatively high strength ability. However, coaches and researchers should further explore high-intensity warm-up protocols in an attempt to investigate their acute effects under real competitive conditions.

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