Enhancing Jump Performance After Combined vs. Maximal Power, Heavy-Resistance, and Plyometric Training Alone

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Abstract
sáez Sáez de villarreal, E, Izquierdo, M, and Gonzalez-Badillo, JJ. Enhancing jump performance after combined vs. maximal power, heavy-resistance, and plyometric training alone. J Strength Cond Res 25(X): 000–000, 2011—The purpose of this study was to examine the effects of 5 different stimuli on jumping ability and power production after 7 weeks of training. Sixty-five (47 men and 18 women) physical education students were randomly assigned to 5 experimental groups that performed: combination of all training methods (A); heavy-resistance training using full-squat exercise (i.e., 56–85% of 1 RM for 3–6 repetitions) (B); power-oriented strength training using a parallel-squat exercise (i.e., 100–130% of load that maximizes power output for 2–6 repetitions) (C); power-oriented strength training using a loaded countermovement jumping (i.e., 70–100% of load that maximizes power output for 2–5 repetitions; countermovement jump [CMJ]) (D); and plyometric jumping (E). The CMJ (cm), loaded CMJ (cm), maximum rate of force development (RFD\textsubscript{max}) during early concentric phase of loaded CMJ (N\textcdot}s\textsuperscript{-1}) and power output during early concentric phase of loaded CMJ (watts) were measured before and after 7 weeks of training. Significant improvements in CMJ (from 7.8 to 13.2%) were observed in all groups. Significantly greater increases in power output during loaded jumps were observed in A (10–13%) and D (8–12%) groups compared with in the other groups. Significant increases in RFD\textsubscript{max} were observed in A (20–30%), C (18–26%), and D (20–26%) groups. The results of this study provide evidence to suggest that if training program is designed and implemented correctly, both traditional slow velocity training and faster power-oriented strength training alone, or in combination with plyometric training, would provide a positive training stimulus to enhance jumping performance.

Key Words combined training, performance, strength, weight training, specificity

Introduction
Vertical jump and strength or power enhancements are classically developed from training approaches that include (a) heavy-resistance-training programs, where relatively high loads (>70% 1 repetition maximum [1RM]) are lifted for relatively few repetitions (4–8 reps) using isoinertial exercises (i.e., bench press or squat) (1); (b) power-training programs generally using exercises such as loaded squat jumps and power clean (i.e., 0–80% of IRM for 3–6 repetitions) (16,21); and (c) plyometric training programs performed with no added external resistance to the body weight at various intensity levels (ranging from low-intensity double-leg hops to high-intensity unilateral drills) (13,25). Nevertheless, the results of a recent meta-analysis tend to indicate that combinations of these methods are more effective for enhancing vertical jump ability than either resistance training or plyometric training alone (26). These findings highlight the multifaceted nature of vertical jump performance with a mixed method approach being most effective because it develops more components of vertical jump (23). However, to our knowledge, no studies have compared the effectiveness of plyometrics vs. loaded squat jumps alone or combined with heavy-resistance training on vertical jump capacity.

Velocity specificity of resistance training is one of the most contentious issues in the science of muscle strength and power development (6). Heavy-resistance training using high loads and slow velocities of concentric muscle actions may lead primarily to improved maximal strength (high force and low velocity portion of the force velocity curve) (11). Power training, which uses lighter resistances and higher velocities of muscle action, may result in increases in force output at higher velocities and increased rate of force development (11). Training studies performed in isokinetic devices (17) and monoarticular power-oriented movements (16) have...
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demonstrated that strength increases are specific to the velocity at which one trains. Izquierdo et al. (14,15) reported long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports (e.g., weightlifting, handball players, amateur road cyclists, middle-distance runners, and age-matched controls subjects). Saez et al. (24) suggested that the use of resistance exercise protocols that include high-intensity dynamic loading (e.g., 80–95% of 1RM) lead to greater acute positive effects on explosive jumping performance (e.g., height in countermovement jump [CMJ] without and with extra load and in Drop Jump). However, a strength training study performed by means of isoinertial exercises has not observed this association between strength training velocity and the subsequent neuromuscular adaptation (6). It would seem that loading intensities associated with strength (>70% 1RM) and power training (30–60% 1RM) are equally effective in improving movement velocity. In this sense, Behm and Sale (3) observed that regardless of the actual velocity of movement, it was the intention to execute a high-velocity movement which resulted in a fast velocity-specific training effect. However, it is important to note that most of the longitudinal strength training studies performed, comparing different load intensities selected no professional athletes (23). Häkkinen and Komi (11) suggested that depending on the person’s training status, the response may not always follow the velocity-specific training principle. Indeed, it has been suggested that untrained subjects may obtain improvements throughout the force–velocity spectrum regardless of the strength training method used (11). Thus, further research is still needed to test the velocity-specific strength training principle, particularly using trained subjects. For this study, we selected moderately trained subjects and using the squat movement as the training exercise, compared the effects of different strength training programs with different load intensities (low, medium, and high-loading) and velocities of execution.

In view of these considerations, the purpose of this study was to examine the effect of 5 different strength training methods: (a) heavy-resistance training using full-squat exercise, (b) power-oriented strength training using parallel-squat exercise, (c) power-oriented strength training using a loaded CMJ, (d) plyometric jumping, and (e) the combination of all these methods. In doing so, we examined the effect of different typical training exercises characterized by their different velocity of execution and compared the use of traditional vs. power-oriented techniques (loaded and body weight only) on vertical jumping enhancement against different external loads.

**METHODS**

**Experimental Approach to the Problem**

This study was designed to address the question of how 5 different training stimuli affected vertical jump performance against different external resistances. These included the effects of 7 weeks (21 sessions) of treatment in 5 groups of subjects, each with different methods of training, using a randomized, balanced, test-retest design. All tests were executed before the treatment started (pretest) and at the end of the training period (posttest) including (a) anthropometric measures; (b) height in CMJ and in loaded CMJ jump (cm); (c) maximum rate of force development (RFDmax) during early concentric phase of the CMJ in loaded conditions (N·s⁻¹); and (d) power output during early concentric phase of loaded CMJ with each weight (17, 27, and 37 kg) (W). After these initial measurements, subjects were randomly assigned to 1 of the following 5 groups that performed: All types of training (group A, n = 14, 10 men [M] and 4 women [F]), heavy-resistance training using full-squat exercise (bringing the thighs to the ground; group B, n = 13, 9 M and 4 F), power-oriented strength training method using parallel-squat exercise (bringing the thighs until 90°; group C, n = 13, 9 M and 4 F), power-oriented strength training method using loaded CMJ exercise (group D, n = 13, 10 M and 3 F), and plyometric training based on continuous CMJs (group E, n = 12, 9 M and 3 F). Subjects (M and F) were selected to ensure that they had the recommended force (to be able squat 1.5 times their body mass) to accomplish the strength and plyometrics training. Before the initiation of the training periods, the subjects in all the groups were instructed as to the proper execution of all the exercises to be done during the training period for all training regimens. All training sessions were supervised. Every subject in the experimental groups executed the treatment between 10.00 and 15.00 hours. The subjects were instructed to avoid any strenuous physical activity and to maintain their usual dietary habits for the duration of the study.

**Subjects**

This study involved a group of 65 (47 M and 18 F) active physical education students between the ages of 18 and 24 (Table 1). All the subjects were regularly participating in some form of physical activity such as weight training (only upper body), running, swimming, cycling, or ball games (e.g., soccer) 2–3 times per week on average but were not competitive athletes. Exclusion criteria included the following: potential medical problems or a history of ankle, knee, or back pathology in the 6-month period preceding the study; lower extremity reconstructive surgery in the past 2 years; or unresolved musculoskeletal disorders. All subjects were carefully informed of the experimental procedures and possible risk and benefits associated with participation in the study. They were then invited to sign an informed consent document before any of the tests were performed. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University.

**Procedures**

The subjects were carefully familiarized with the voluntary force and power production test procedures during several submaximal and maximal exercise sessions a few days before the measurements were taken. The subjects also completed several rapid power-oriented exercises to become familiar with the action required to move different loads rapidly and
with correct jump technique. In addition, several warm-up sets were recorded before the actual maximal and explosive tests. All the tests selected to determine training effects (anthropometric measures, height in CMJ, power output and RFD_max during CMJ and CMJ with different loads) were carried out before and after 7 weeks of training intervention. These tests were completed in one day. Before the tests and after completing the anthropometric measurements subjects carried out a standardized warm-up consisting of 10 minutes' submaximal running at 9 km h\(^{-1}\) followed by light stretching. Subjects then performed a specific squat warm-up with low loads (2 sets of 10 repetitions at 20% of body mass) and 2 sets of 10 submaximal CMJs for familiarization trials with the assessment exercises. Additionally, care was taken to allow sufficient rest (2–3 minutes) between all tests to limit the effects of fatigue in subsequent tests.

**Anthropometric Characteristics.** Height was measured using a wall-mounted stadiometer (Seca 222, New York, NY, USA) recorded to the nearest centimeter. Body mass was measured to the nearest 0.1 kg using a medical scale (Tanita, BC-418MA, Tokyo, Japan). Fat mass, fat-free mass and percentage of body fat were estimated using bioimpedance (Tanita, Model BC-418MA).

**Table 1. Initial characteristics of the experimental groups (mean ± SD).**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>% Body fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n = 10 M + 4 W)</td>
<td>19.4 ± 1.9</td>
<td>175.6 ± 8.3</td>
<td>68.3 ± 10.4</td>
<td>12.7 ± 5.3</td>
</tr>
<tr>
<td>B (n = 9 M + 4 W)</td>
<td>20.4 ± 2.1</td>
<td>175.1 ± 7.5</td>
<td>71.6 ± 8.6</td>
<td>15.2 ± 4.4</td>
</tr>
<tr>
<td>C (n = 9 M + 4 W)</td>
<td>20.2 ± 1.9</td>
<td>170.1 ± 6.9</td>
<td>64.1 ± 10.2</td>
<td>15.4 ± 6.7</td>
</tr>
<tr>
<td>D (n = 10 M + 3 W)</td>
<td>19.6 ± 1.5</td>
<td>175 ± 9</td>
<td>70.6 ± 10.7</td>
<td>15.1 ± 6.2</td>
</tr>
<tr>
<td>E (n = 9 M + 3 W)</td>
<td>20.5 ± 3.7</td>
<td>176 ± 6.8</td>
<td>69.4 ± 9.9</td>
<td>11.6 ± 5.3</td>
</tr>
</tbody>
</table>

*M = men; W = women.

**Table 2. Training program for all the groups.**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Exercises</th>
<th>Weeks</th>
<th>Exercises</th>
<th>S1–S3</th>
<th>S4–S6</th>
<th>S7–S9</th>
<th>S10–S12</th>
<th>S13–S15</th>
<th>S16–S18</th>
<th>S19–S21</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Full squat (1 m/s(^{-1}))</td>
<td>3 × 6</td>
<td>Squat (MP)</td>
<td>3 × 3</td>
<td>3 × 3</td>
<td>4 × 4</td>
<td>3 × 3</td>
<td>3 × 3</td>
<td>4 × 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 × 5</td>
<td>6 × 5</td>
<td>7 × 5</td>
<td>8 × 5</td>
<td>4 × 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Full squat (1 m/s(^{-1}))</td>
<td>3 × 6</td>
<td>Squat (MP)</td>
<td>3 × 3</td>
<td>3 × 3</td>
<td>4 × 4</td>
<td>3 × 3</td>
<td>3 × 3</td>
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<td></td>
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<tr>
<td></td>
<td>5 × 5</td>
<td>6 × 5</td>
<td>7 × 5</td>
<td>8 × 5</td>
<td>4 × 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>CMJ(_{\text{loaded}}) +30% MP</td>
<td>3 × 6</td>
<td>CMJ(_{\text{loaded}}) +20% MP</td>
<td>3 × 6</td>
<td>4 × 4</td>
<td>3 × 4</td>
<td>4 × 4</td>
<td>3 × 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 × 5</td>
<td>6 × 5</td>
<td>7 × 5</td>
<td>8 × 5</td>
<td>4 × 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>CMJ(_{\text{loaded}}) +15% MP</td>
<td>3 × 6</td>
<td>CMJ(_{\text{loaded}}) +10% MP</td>
<td>3 × 6</td>
<td>4 × 4</td>
<td>3 × 4</td>
<td>4 × 4</td>
<td>3 × 2</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>5 × 5</td>
<td>6 × 5</td>
<td>7 × 5</td>
<td>8 × 5</td>
<td>4 × 5</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>E</td>
<td>Plyometric</td>
<td>No jumps</td>
<td>Plyometric</td>
<td>No jumps</td>
<td>5 × 5</td>
<td>6 × 5</td>
<td>5 × 5</td>
<td>6 × 5</td>
<td>7 × 5</td>
<td>8 × 5</td>
</tr>
</tbody>
</table>

\((\text{m/s}) = \text{Velocity of displacement of the bar during concentric phase of the full-squat (1 m/s = 60\% 1RM); (0.9 m/s = 74\%); (0.8 m/s = 80\%); (0.7 m/s = 86\%); MP = weight which the maximal power in CMJ\(_{\text{loaded}}\) \(\times\) obtained; S = Session, sets and rep. Full-Squat: Bring the thighs to the ground, while Squats do until 90° degrees.\)}
Unloaded Countermovement Jump. The CMJ test was performed using an infrared curtain system (Ergo Jump Plus Bosco System®, Muscle Lab. V7 18, Langesund, Norway) to measure flight and contact times. Jump height was determined using standard flight-time calculation. Five trials were completed with 1 minute of rest between trials. The 2 extreme values of the 5 trials were eliminated (best and worst), and the average of the 3 central values was used for the subsequent statistical analysis. The intraclass correlation coefficient (ICC) was 0.96 (0.94–0.98).

Loaded Countermovement Jump. The load that maximizes power output during CMJ loaded was also determined by adjusting the added loads until the highest power output was obtained. Warm-up consisted of a set of 5 repetitions with the weight of the bar. The bar weight of the Smith machine (17 kg) was then progressively increased in 10-kg increments for each set (i.e., bar only; bar + 10 kg; bar + 20 kg; bar + 30 kg) with 2 trials executed with each weight. CMJ loaded power output was determined using a squating apparatus (Smith machine, Model Adan Sport, Set 0.04., Madrid, Spain) in which the barbell was attached at both ends with linear bearings on 2 vertical bars allowing only vertical movements. A force plate (Isonet 500, Version 2.0 JLML, Seville, Spain) mounted in the base of the Smith machine was used to determine the flight time of the jump and power output. Further, bar displacement, peak, and mean power (watts) were recorded by using a distance encoder attached to one end of the bar. The distance encoder recorded the position and direction of the bar to an accuracy of 0.0003 m. A dynamic measurement system (T-Force System, Ergotech, Murcia, Spain) automatically calculated the relevant kinematic and kinetic parameters of every repetition of CMJ loaded performed throughout the whole range of motion, provided real time information on screen and stored data on a disk for subsequent analysis. The RFD max was assessed in the concentric phase—the portion of the jump before takeoff in which the change in displacement is positive. Adequate recovery was allowed between all trials (2–3 minutes). Strong verbal encouragement was given to all subjects to motivate them to perform each test action as maximally and rapidly as possible. The best trial with each weight was recorded for the subsequent statistical analysis. The ICC was 0.90 (0.88–0.92).

Training Procedures
Training took place 3 d wk⁻¹ (Monday–Wednesday–Friday) for every group during 7 weeks of the intervention (21 sessions). The training was individualized for each subject based on their results in the maximal strength and power test, with a printed schedule of volume, density, and intensity of training (number of sets and repetitions, rest intervals, daily load). Each session lasted 30–45 minutes, depending on the

**Table 3.** Height (cm) with each weight in loaded CMJ performance for the A, B, C, D, and E groups at pretraining and posttraining.* †

<table>
<thead>
<tr>
<th>Groups</th>
<th>17 kg</th>
<th>27 kg</th>
<th>37 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>A</td>
<td>17.5 ± 2.6</td>
<td>21.2 ± 2.5‡</td>
<td>17.2 ± 4.3</td>
</tr>
<tr>
<td>B</td>
<td>17.1 ± 2.6</td>
<td>19.1 ± 3</td>
<td>18.3 ± 4.4</td>
</tr>
<tr>
<td>C</td>
<td>16.9 ± 3</td>
<td>19.9 ± 2.9‡</td>
<td>18.1 ± 4.4</td>
</tr>
<tr>
<td>D</td>
<td>17.3 ± 1.9</td>
<td>20.6 ± 2.8‡</td>
<td>18.9 ± 3.3</td>
</tr>
<tr>
<td>E</td>
<td>16.5 ± 2.8</td>
<td>18.2 ± 2.9</td>
<td>16.8 ± 3.3</td>
</tr>
</tbody>
</table>

* A = combined training group; B = slow-high resistance full-squat group; C = ballistic squat group; D = loaded CMJ group; E = plyometrics group.
† Values are reported as mean ± SD.
‡ Significant difference between pre and posttraining values (p < 0.05).
training group and consisting of the following components: 10 minutes of standard warm-up (5 minutes submaximal running at 9 km·h⁻¹, stretching exercises for 5 minutes and 2 submaximal jumps [20 vertical jump, 10 long jumps]), 15–30 minutes of specific strength training, and 5 minutes of cool down including stretching exercises. All training sessions for all groups were fully supervised, and training diaries were maintained for each subject. All subjects were instructed to maintain their normal daily activities throughout the 7-week study, including participation in recreational sporting activities. However, no additional strength or plyometric training was permitted. The training program followed by each group is outlined in Table 2.

**Heavy-Resistance Training.** The heavy-resistance training program involved full-squats (group B). The range of motion of the full-squats was 180° for the starting point and 60° for the end point. Subjects from group B were instructed to move the weight at the same velocity in the concentric and eccentric phase of the movement using a Smith machine (see Table 2 for further details).

**Power-Oriented Strength Training.** The power-oriented training groups used parallel-squat (group C) or loaded CMJ (CMJ laden) (group D) as a main exercise using a Smith machine. In both training conditions, the training load was designated as the load at which maximum mean mechanical power was achieved. Group C was instructed to move the weight as fast as possible in the concentric phase. Subjects in group D were instructed to jump for maximum height on each jump.

**Plyometric Training.** The plyometric training consisted of rebound jumps using body weight as the overload with an emphasis on short contact time and maximum jump height. Subjects were encouraged to jump explosively for maximum height on each jump.

**Combined Training.** The combined program consisted of heavy resistance in conjunction with power and plyometric training methods outlined above.

### Statistical Analyses

Descriptive statistics (mean ± SD) for the different variables were calculated. The ICC was used to determine the reliability of the measurements. The training-related effects and the differences between the groups were assessed using an analysis of covariance with the contrast F of Snedecor. When a significant F-value was achieved, Bonferroni post hoc procedures were performed to locate the pairwise differences between the means. The effect sizes (ESs) were calculated. Statistical significance was accepted at an α level of p < 0.05.

### RESULTS

At baseline, no significant differences between groups were observed in any of the anthropometrics, strength or muscle power variables tested.
Anthropometric Characteristics

After 7-week training interventions, no significant changes were observed in any of the anthropometric characteristics.

Height in Countermovement Jump

Significant \((p < 0.001)\) increases were observed in height in CMJ in groups A (ES = 0.4), B (ES = 0.42), C (ES = 0.69), D (ES = 0.32), and E (ES = 0.36). No significant differences were observed in the magnitude of the increase in height in CMJ between the groups after 7 weeks of training (Figure 1).

Load Countermovement Jump Height

Significant \((p < 0.001)\) increases were observed in the CMJ height with each weight in the A (ES = 1.45), B (ES = 0.71), C (ES = 1), D (ES = 1.34), and E (ES = 0.62) groups. No significant differences between groups were observed in the magnitude of increase in the height with different loads (i.e., loaded CMJ with 17, 27, and 37 kg) (Table 3).

Power Output in Loaded Countermovement Jump

Significant increases \((p < 0.01)\) were observed in the improvement of the power output with each weight in loaded CMJ for groups A (ES = 0.65) and D (ES = 0.73). No significant differences between the groups were observed in the magnitude of the increase in the power with different weights (i.e., 17, 27, and 37 kg) (Table 4).

Maximum Rate of Force Development in Loaded Countermovement Jump

Significant \((p < 0.05)\) increases were observed in the \(RFD_{\text{max}}\) in A (ES = 0.41), B (ES = 0.28), C (ES = 0.43), D (ES = 0.38), and E (ES = 0.21) groups. No significant differences were observed in the magnitude of the increase in the \(RFD_{\text{max}}\) with each weight (17, 27, and 37 kg) in the loaded CMJ between the groups (Table 5).

Discussion

The outcomes of this experiment provide further information related to neuromuscular performance adaptations as a consequence of traditional heavy resistance, power-oriented strength, and plyometric training approaches (1,12,14,15,18,27,28). The overall findings of this study were that 7-week training program of different training stimuli to enhance jumping ability and power production in physically active subjects led to similar increases in jumping height with neither any additional load nor with different loading conditions.

Several studies have shown the effectiveness of plyometric and heavy-resistance training in improving vertical jump and strength performance (4,8,10,25). Other studies have also shown improvement in motor performance when plyometric and weight training (i.e., typically performing full-squat, parallel-squat, squat jump, or Olympic exercises) were combined or used separately (1,5,7,10,18). The significant results of this research concur with those of previous studies (1,3,8), showing that a combined program of different modalities of heavy-resistance training and power-oriented...
strength training (i.e., using full-squat or parallel-squat exercise) and plyometrics can significantly increase vertical jump performance.

A combined training approach (i.e., using full-squat, parallel-squat, loaded CMJ and plyometric exercises) resulted in a similar improvement in vertical jump performance to those observed after heavy-resistance, or power-oriented strength training alone (i.e., using plyometric or loaded CMJ training approaches). Therefore, an interesting result of this study was that the magnitude of increases in vertical jump was almost the same for each of the experimental groups, despite the fact that the average number of exercises and repetitions completed by group that combined all types of training (group A) was more than double that performed by each of the experimental groups. This is not compatible with the results of previous studies (1,8,18,25), which suggested that a combination training program provides the most powerful stimulus in improving the various parameters for vertical jumping ability. The discrepancy between these results and results from previous studies might be attributed to the fact that the subjects in this study were not specialists in plyometric and weight training in contrast to the greater training experience and initial training status of subjects in previous research. Specifically, some authors have shown that subjects with low levels of strength exhibit significant improvement in vertical jump ability, regardless of the training stimulus (1,8,25), while previously strength-trained subjects may exhibit limited improvements in vertical jump ability (11). Furthermore, the great improvements in vertical jump ability in the experimental studies by Adams et al. (1) and Fatouros et al. (10) could be related to the use of power-oriented exercises (i.e., snatches, cleans, snatch pull, clean pull, and jump squats) to produce a positive effect for the improvement in vertical jump. These special types of strength training exercises are characterized by a more forceful and rapid execution of stretch-shortening cycle, producing therefore enhancement of mechanical power output. Indeed, these types of exercises have been proposed as ideal exercises for developing vertical jump ability because of the similarity between movement patterns, velocities and power output and high mechanical specificity (7,19).

As occurs in previous research (1,10,27), in this study, we expected combined training to be superior to each training mode alone; however, the differences, although favorable to the group that trained with the combination of exercises, were lower than expected. One plausible explanation could be related to the residual fatigue effect of an excessive number of exercises to ensure a sufficient recovery of subjects’ neuromuscular and metabolic systems. Thus, it could be speculated that greater improvement would have been achieved by reducing the number of exercises to 2 or 3, as was the case in the studies by Adams et al. (1) and Fatouros et al. (10).

Second, one may also speculate that the limited improvements observed after heavy-resistance training alone (group B) in all the variables measured (i.e., height of the jump in CMJ, height of the jump with each weight, power output during the loaded CMJ and RFD_{max}) could be because of the lower velocity of execution used during the training with full-squat, which was produced by the use of high loads (i.e., 60–85% of 1RM). Indeed, the full-squat exercise, despite quite high force development in the initial part of the concentric phase of the movement, was executed at a relatively low velocity. This agrees with several studies that showed the importance of high velocity of execution on improvement of power performance (2,9,12,20,22). Thus, the improvement of group that trained with loaded CMJ (group D) could be accounted for the use of light loads (15–30% 1RM) and the high movement velocity attained during the training, as this group tried to move the weight as quickly as possible for each repetition. According to Wilson et al. (28), by training at a speed that is closer to the actual speed of dynamic athletic performance movements (using light loads [20–40% of 1RM]), one may maintain training speed specificity and maximize mechanical power output (16,19,21). Furthermore, in this study, specificity of training was observed because both groups (A and D) show better results over the other groups, particularly in the loaded jump squat testing. The resemblance between movement patterns and the velocity of movement common to the training and testing clearly contributed to the greater performance improvement being observed for these training groups.

On the other hand, the specificity principle of training is particularly highlighted in what is referred to as the velocity of movement execution during training. The RFD_{max} only improved in groups where the velocity of execution during the concentric phase was high (groups A, C, and D). This may suggest that the principle of specificity shows that there seems to be a series of kinetic and kinematic factors which characterize each exercise (i.e., through a specific range of movement, execution velocity, movement patterns, and execution techniques) which should be appropriately respected in the choice and execution to improve performance.

In summary, the results of this study suggest that a 7-week training program of different training stimuli to enhance jumping ability and power production in physically active subjects led to similar increases in jumping height with no additional load or different loading conditions. Furthermore, the nonsignificant improvement in jumping ability and power production in group A (i.e., combined training) could be because of the synergistic effect of training approaches that used full-squat exercise at velocities of ≤1 m·s⁻¹ (i.e., high load intensity) compared to the jumping performance gains produced by others that were performed at higher velocities (>1 m·s⁻¹) using parallel squat (i.e., with moderate loads ranging from the load that maximizes power output during loaded CMJ up to a 30% more than this load), jumps with light loads (using loads that oscillate between the 70 and 100% of the load that maximizes power output) or plyometric training with one’s own body weight. This may
suggest that training with different movement velocities and movement patterns would not contribute to the greater improvement in performance.

**Practical Applications**

Research findings on the optimal training methodology to enhance vertical jump and force development are still conflicting. The present results provide evidence to suggest that if training program is designed and implemented correctly, both traditional slow velocity training and faster power-oriented strength training alone, or in combination with plyometric training, would provide a positive training stimulus to enhance jumping performance. The lack of between-group differences in the research presented in this article may be the result of the limited 7-week training period, or the insufficient training stimulus (i.e., training intensity, volume, and exercise selection) or the relatively low training status of the subjects before commencing the interventions. Similar studies using larger group numbers plus more extensive preparatory strength programs may produce results indicating the superiority of one or more of these training modes.

**References**


