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SHORT-TERM EFFECTS ON LOWER-BODY FUNCTIONAL POWER DEVELOPMENT: WEIGHTLIFTING VS. VERTICAL JUMP TRAINING PROGRAMS

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ABSTRACT. Tricoli, V., L. Lamas, R. Carnevale, and C. Ugrinowitsch. Short-term effects on lower-body functional power development: Weightlifting vs. vertical jump training programs. *J. Strength Cond. Res. 19(2):433–437. 2005.*—Among sport conditioning coaches, there is considerable discussion regarding the efficiency of training methods that improve lower-body power. Heavy resistance training combined with vertical jump (VJ) training is a well-established training method; however, there is a lack of information about its combination with Olympic weightlifting (WL) exercises. Therefore, the purpose of this study was to compare the short-term effects of heavy resistance training combined with either the VJ or WL program. Thirty-two young men were assigned to 3 groups: WL = 12, VJ = 12, and control = 8. These 32 men participated in an 8-week training study. The WL training program consisted of 3 × 6RM high pull, 4 × 4RM power clean, and 4 × 4RM clean and jerk. The VJ training program consisted of 6 × 4 double-leg hurdle hops, 4 × 4 alternated single-leg hurdle hops, 4 × 4 single-leg hurdle hops, and 4 × 4 40-cm drop jumps. Additionally, both groups performed 4 × 6RM half-squat exercises. Training volume was increased after 4 weeks. Pretesting and posttesting consisted of squat jump (SJ) and countermovement jump (CMJ) tests, 10- and 30-m sprint speeds, an agility test, a half-squat 1RM, and a clean-and-jerk 1RM (only for WL). The WL program significantly increased the 10-m sprint speed ($p < 0.05$). Both groups, WL and VJ, increased CMJ ($p < 0.05$), but groups using the WL program increased more than those using the VJ program. On the other hand, the group using the VJ program increased its 1RM half-squat strength more than the WL group (47.8 and 43.7%, respectively). Only the WL group improved in the SJ (9.5%). There were no significant changes in the control group. In conclusion, Olympic WL exercises seemed to produce broader performance improvements than VJ exercises in physically active subjects.

KEY WORDS. speed, agility, sport

INTRODUCTION

A wide discussion of the most efficient training methods for speed strength development can be found in sports science literature. Speed strength, also known as power, is crucial for the performance of different sport actions involving changes of direction, accelerations, and jumps (20).

Training to improve power traditionally uses different vertical jump (VJ) programs, whether or not they are associated with heavy strength training exercises (1, 3, 8, 18, 24, 25). Training that uses jumping movements has been shown to produce significant gains in lower-body muscle power (12, 13, 21, 27). Despite the relatively small overload, usually represented by the subject's body weight, there is a high power production, given the high rate of force development (RFD) and the peak force achieved during the concentric phase of the movement (20). The power produced enables the hip, knee, and ankle joints to reach high angular velocities at the end of the concentric phase (600, 860, and 716°·s^{-1}, respectively) during countermovement jumps (CMJs) (2). Furthermore, it seems that the combination of heavy strength training and plyometric training (jump training) improves lower limb power the most (16). This combination develops both components of the power equation, maximal strength and RFD, which is analogous to the velocity of the contraction.

Currently, a "new" power training procedure that involves exercises related to Olympic-style weightlifting (WL) has become quite popular. Its use as a training method is increasingly found among athletes involved in power events. Some studies have described the behavior of strength, power, and speed in WL movements (6, 10, 11, 17). However, little is known about the effects of such exercises on power and speed development and their transfer to performance in different sport skills (6, 19). Some information was found in one study with 2 groups of college football players who participated in either a WL training or a traditional strength training program. However, only nonsignificant differences were found intragroup and intergroup when the 2 groups were tested for 1 repetition maximum (1RM) bench press, 40-yd sprint speed, agility (AG), VJ height, and VJ power (14). Therefore, there is not enough evidence to conclude what the effects of WL techniques are on varied motor skills.

Those who believe in the efficacy of WL and its pedagogic exercises as a power training method emphasize the fact that such movements are multijoint, with "explosive" actions that allow for additional overload in a manner similar to sport requirements (6). One important factor related to this training method may be that it facilitates neural learning as it relates to optimal motor unit recruitment and control and, consequently, maximization of the RFD and energy transfer between the segments of movement (11). In addition, the development of balance, coordination, and flexibility is a further advantage that accrues as a result of this training (15). This belief is strengthened by evidence that associates speed intention in a strength movement with enhancement of the variables associated with high power performance (5, 22, 29). According to such evidence, every movement should be performed with the intention of producing force as fast as possible, regardless of the actual movement speed. This strategy would allow beneficial adjustments to take place during the production of powerful movements.

Table 1. Training programs.*

Groups	Exercises	Weeks 1–4	Weeks 5–8
Weightlifting	High pull	3 × 6RM	4 × 6RM
	Power clean	4 × 4RM	6 × 4RM
	Clean and jerk	4 × 4RM	6 × 4RM
	Half-squat	4 × 6RM	4 × 6RM
Vertical jump	Double-leg hurdle hops	6 × 4	10 × 4
	Alternated single-leg hurdle hops	4 × 4	6 × 4
	Single-leg hurdle hops	4 × 4	6 × 4
	40-cm drop jump	4 × 4	6 × 4
	Half-squat	4 × 6RM	4 × 6RM

* 6RM = 6 repetition maximum; 4RM = 4 repetition maximum strength.

In WL movements, despite the great overload used, speed intention is always maximal, which may induce greater motor unit synchronization (29) and seems to increase the RFD but not the maximum force. Even though WL exercises do not increase maximum force, the overload added to the movement execution appears to be a determining factor in power training (9). In that aspect, WL techniques enable overload to be added without neglecting rapid movement intention. The rate at which strength is applied (RFD) seems to be more important than the maximum strength generation capacity. The WL program allows the application of heavy loads along with fast movement (14).

As an example, Canavan et al. (6) found many relationships between VJ programs and the hang snatch in kinematic and kinetic parameters, which means that these 2 skills are mechanically very similar. Thus, the combination of heavy resistance training and Olympic-style lifting could also increase the rate of work production, even when heavy loads are used.

Sport professionals are convinced that Olympic WL exercises are extremely efficient for developing functional power. However, we question the cost-benefit ratio of this training method when compared to a more traditional approach, such as the VJ training program.

Thus, the purpose of this study was to compare the short-term effects of power training programs that involve either VJ or Olympic WL exercises when combined with heavy strength exercises with respect to the performance of motor tasks for speed, AG, and lower-body muscular power. It was hypothesized the WL training program would result in similar performance improvements when compared to the VJ training program.

Methods

Experimental Approach to the Problem

This study was primarily designed to investigate the short-term effects of Olympic-style WL exercises in the development of lower-body muscle power. To address this issue, we selected a group of 3 WL exercises that we deemed easy to learn and most efficient for developing lower-body muscle power. A repeated-measures design was used to assess the physical adaptations in the subjects during an 8-week training intervention. We selected physically active male subjects with no experience in Olympic WL exercises because we could expect a greater training effect in these kinds of subjects.

Subjects

The sample comprised 32 male college physical education students, characterized as physically active individuals with similar demographics and activity backgrounds. They should have spent the past 3 months undergoing no lower-body–specific strength training. However, all subjects had previous strength training experience at a recreational level. Nutritional intake was not controlled, but subjects were asked to maintain their normal diet during the study. Individuals consuming any type of nutritional supplement were not selected to participate in the study. Mean (±*SD*) for age, weight, and height were 22.0 (±1.5) years, 73.4 (±10.4) kg, and 179.4 (±8.8) cm, respectively. All subjects were informed in detail about the risks and benefits involved in the study and signed an informed consent form. They were randomly assigned to 3 groups, namely: WL group = 12 individuals, VJ group = 12 individuals, and control group = 8 individuals. Prior to the 8-week training period, all subjects underwent 3 familiarization sessions that gave them an overview of the tests and training procedures. The time interval between sessions was at least 48 hours. Each subject performed all tests and training procedures several times. In particular, the WL group performed 3 practical sessions so that they could learn the specific training movements. The content of such sessions was established on the basis of the pedagogic sequence proposed by Cervera (7). By the end of the 8-week training period, 10 subjects abandoned the program because of personal reasons. Only one of them reported discomfort and pain in the lower-back region. Thus, the final composition of the 3 groups was WL, $n = 7$; VJ, $n = 8$; and control, $n = 7$.

Training Programs

All subjects in the WL and VJ groups attended 24 training sessions held throughout 8 weeks, 3 times a week, every other day. The criteria for noncompliance were established as missing 2 sessions in a row or 3 sessions during the 8-week training period. Each group had a specific training protocol (Table 1), which was always complemented by 4 sets of 6RM of the half-squat exercise. This exercise was selected because it is a safe and effective strength training exercise for the lower-body muscle groups directly involved in the power tasks investigated in this study (1). Traditional strength training with heavy loads and a low number of repetitions (4–8RM) seems to increase strength, power, and movement speed (1, 19, 24).

The specific exercises and their respective volumes and intensities are as set forth in the paragraphs that follow.

WL Group. Training consisted of 3 × 6RM high pull, 4 × 4RM power clean, and 4 × 4RM clean and jerk. These exercises were named "Olympic-style weightlifting exercises" (i.e., they derive from the pedagogic exercises applied in the practice of this sport). After 4 weeks, training volume was increased to 4 × 6RM, 6 × 4RM, and 6 × 4RM, respectively.

VJ Group. Training consisted of VJ drills over 4 hurdles: 6 × 4 double-leg hurdle hops, 4 × 4 alternated single-leg hurdle hops, 4 × 4 single-leg hurdle hops, and 4 × 4 40-cm drop jumps. At the end of week 4, similar to the WL group, the VJ group's training volume was adjusted to 10 × 4, 6 × 4, 6 × 4, and 6 × 4 jumps, respectively. The intensity of the first 3 drills was established by the height of the hurdle, which was determined by adding 25% to the height achieved in the CMJ pretest. The 4 hurdles were arranged so that the exercises were performed in sequence, with the average distance between the hurdles being 1.5 m.

Control Group. This group underwent no training, only pretest and posttest sessions.

Tests

Pretests and posttests were composed of 2 sessions with at least a 24-hour interval between them. On day 1, the following tests were performed: a squat jump (SJ), a CMJ, an average sprint speed measured over a distance of 10 and 30 m, and an AG test that featured changes of direction. On day 2, the subjects underwent a maximum strength test in the half-squat and clean-and-jerk exercises; the latter was performed for the WL group only. For the VJ tests (SJ and CMJ) "Jump Test Pro" device version 1.6 was used. This piece of equipment calculates the jump height on the basis of the subject's flight time. The subjects stood with their hands on their hips on a contact platform attached to a laptop computer (Toshiba Satellite). Starting from the half-squat static position (knees at approximately 90°) (SJ test) or with the free countermovement position (CMJ test), subjects were told to jump as high as possible in every one of the 3 attempts required. After take-off, the loss of contact with the mat would activate the system, which would then record the flight time, converting it into the height in centimeters. There was a 15-second interval between attempts and a 3-minute interval between the different tests.

The 10- and 30-m tests measured sprint speed (in meters per second) through 3 pairs of photocells placed at the start (0 m), 10 m, and 30 m from the starting line. The system was automatically activated as the test subject went through the space delimited by 2 photocells placed opposite each other and separated by a space of approximately 1.5 m. The passage of the subject through the first pair activated the system, and the passage through the second and third pairs recorded the average speed achieved at 10 and 30 m, respectively. Every subject made 2 maximum attempts with a minimum 2-minute interval in between.

The AG test measured the time to complete a course involving a sudden change of direction in a space delimited by a 4-m square, as shown in Figure 1.

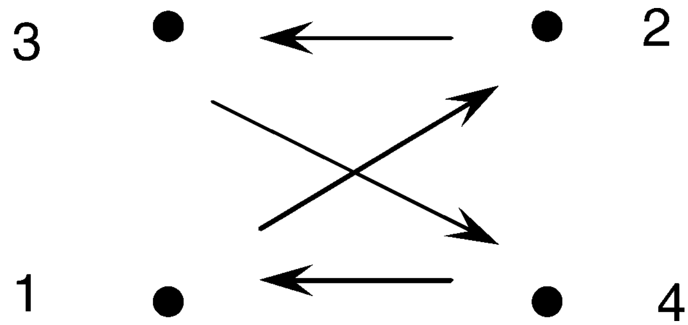

FIGURE 1. Graphic representation of the agility test (AG test) and its sequence of execution.

For the AG test, the subjects were instructed to follow a predetermined sequence (Figure 1), repeating it 3 consecutive times. To complete a valid sequence, the subjects were required to touch the delimiting cones with one hand while simultaneously changing direction. At the end of the third lap, the time spent (in seconds) was recorded. Each subject made 2 maximal attempts with a 3-minute interval between them.

For the maximum strength test in the half-squat exercise, subjects performed a complete repetition, starting from the standing position with extended knees, next squatting in such a fashion that their knees were bent at 90°, and then returning to the initial position. This sequence was performed with the bar positioned on the subject's shoulders. The researcher visually controlled the knee flexion degree, and verbal feedback was provided to the subjects. The initial load was subjectively estimated by the researcher, and from such estimates, heavier weights were added until the maximum load was achieved in no more than 4 attempts. In case the movement was not fully completed, the previous load was considered representative of the subject's maximum strength.

The maximal strength test in the clean-and-jerk exercise consisted of raising the greatest amount of weight over the head with extended elbows in a 2-phase movement. The first phase was started with the weight bar on the floor. Subjects would approach the bar and, with their knees bent, hold the bar with both hands with a pronated grip, trying to keep their backs upright and at 45° in relation to the floor. From that position, they raised the bar with a single movement to their shoulders, resting it in that region for a few seconds before the second phase. In the second phase, the bar was raised above their head with an elbow extension movement that was combined with a rapid hip and knee flexion/extension movement. As in the half-squat maximum strength test, the initial load was estimated subjectively by the researcher, and from that, heavier weights were added until the maximum load was achieved in no more than 4 attempts. In case the movement was not fully performed to completion, the load previous to the failure was considered representative of the maximum strength. In both tests, there was a minimum 3-minute interval between attempts.

All test sessions were preceded by a general warm-up period that consisted of 5 minutes of jogging, which was followed by stretching exercises and a warm-up period specifically oriented to each test's activities. The best result achieved among the attempts was used for statistical analysis in all tests.

An intraclass correlation coefficient was calculated for each test (10-m running speed = 0.90; 30-m running speed = 0.97; SJ = 0.94; CMJ = 0.96; AG = 0.80; half-squat = 0.82), and the results demonstrated a high level of test-retest reliability.

Statistical Analyses

Mean (±*SD*) relative to the results of each test administered within each group was calculated. An analysis of

Table 2. Comparison of motor test results mean (± *SD*) among the 3 groups in pre- and posttest conditions.*

Test	Olympic weightlifting		Vertical jump		Control	
	Pre	Post	Pre	Post	Pre	Post
SJ (cm)	38.9 (±2.4)	42.6 (±4.4)†	36.5 (±4.4)	37.5 (±2.2)‡	38.5 (±2.9)	38.1 (±4.9)
CMJ (cm)	42.2 (±2.1)	45.0 (±2.6)†	40.2 (±3.9)	42.5 (±3.0)†‡	42.2 (±4.9)	42.6 (±5.2)
10 m (m/s)	5.19 (±0.2)	5.38 (±0.3)†	5.20 (±0.3)	5.34 (±0.3)	5.31 (±0.2)	5.34 (±0.3)
30 m (m/s)	7.97 (±0.3)	7.98 (±0.3)	7.94 (±0.4)	8.00 (±0.4)	7.99 (±0.4)	7.94 (±0.3)
AG (s)	16.38 (±0.7)	15.92 (±0.8)	15.94 (±0.7)	15.36 (±0.4)	15.96 (±0.6)	15.54 (±0.7)
Half-squat (kg)	146.3 (±30.5)	210.3 (±22.3)†	165.8 (±21.5)	245.1 (±35.9)†‡	149.5 (±24.6)	159.1 (±22.2)
Clean/Jerk (kg)	57.4 (±5.8)	77.4 (±11.7)†				

* SJ = squat jump; CMJ = countermovement jump; 10 m = 10-m running speed; 30 m = 30-m running speed; AG = agility.
† Significant difference from pre to post ($p < 0.05$).
‡ Significant difference between groups ($p < 0.05$).

variance with repeated measures was used to identify the presence of differences among the performances in the 3 groups. Fisher's least significant difference post hoc test was applied for comparisons when so required. The established significance level was $p \leq 0.05$.

Results

The control group did not improve in any of the physical tests, as expected. The SJ and 10-m sprint speed improved significantly for the WL group only (9.56 and 3.66%, respectively). The results of the CMJ test showed an increase for both groups, but the WL group had a higher increment than the VJ group (6.6 and 5.72, respectively). Both groups showed an increase in the half-squat 1RM, but the VJ group had superior improvement when compared to the WL group (47.8 and 43.7%, respectively) (Table 2).

Discussion

The major finding of this study was that the WL training program significantly improved the 10-m sprint speed, SJ, CMJ, and half-squat 1RM, whereas the VJ training program improved only the CMJ and half-squat 1RM. Therefore, it appears that the short-term effects of the WL training program on the lower-body power development of physically active male individuals were greater than those of the VJ training program.

Although there is a positive correlation between maximum strength and power performance (1, 4, 9, 13, 19, 27), the higher improvement in maximum strength shown for the VJ group failed to increase its performance in a similar fashion when compared with the WL group in the 10-m speed sprint and SJ tests. These results may indicate that a WL training program develops a broader spectrum of physical abilities, which may be better transferred to either performance (11, 15, 22) or the RFD.

Plyometric drills are believed to be the bridge to explosiveness so that the athlete can optimize power production. Therefore, the combination of plyometrics with heavy resistance training should be adopted by power athletes (1). However, our results indicate that power transfer may be specific to the plyometric training exercise, since only the CMJ increased significantly in the VJ group.

The lack of differences in the AG test may indicate that power transfer to complex tasks is difficult, although many coaches train for muscle strength and power with the expectation of a linear transfer to motor performance. AG tasks are relatively complex and could be more influenced by motor control factors than by muscle strength or power capacity (30).

Our results showed an improvement in the 10-m sprint speed for the WL group only. These results are difficult to explain, because the VJ group showed an increase in 1RM to a greater extent than did the WL group. It has been shown that there is a high correlation between the 1RM and 10-m sprint speed (26, 28). A possible explanation is that the greater coordination required for the WL exercises as well as their RFD leads to a greater improvement in sprinting techniques for this untrained population, decreasing the shared variance due to maximal strength.

Regarding SJ performance, movement is started as soon as the force produced reaches the body weight. The time required to generate this force is shorter than in the CMJ, and there is no potentiation mechanism involved, because the eccentric phase is suppressed. Consequently, the RFD is more important for the SJ than for the CMJ because the latter has more time to build force (23). In addition, if force is not built quickly, its peak and, consequently, take-off velocity will be low, resulting in a lower jumping height. Therefore, it seems reasonable to conclude that the WL group improved the RFD to a greater extent than did the VJ group. Another possible explanation is the similarity of the kinetics and kinematics that exist between SJ and Olympic lifting exercises (6). Thus, training adaptations might be specific to the exercise used.

In conclusion, this study is, to our knowledge, the first one that compares the short-term effects of training programs involving heavy resistance training and VJ with heavy resistance training and WL lower-body power development. In physically active subjects, Olympic lifting exercises seemed to produce broader performance improvements than VJ exercises. This difference could be due to the development of more physical abilities and/or greater RFD. In addition, training effects due to the VJ seemed to be specific to the training exercises.

Practical Applications

Even though Olympic lifting exercises require more time for the learning of specific skills, the short-term training effects seem to be more beneficial for improvement in the performance tests used than in traditional jump training in physically active subjects. The greater skill complexity required for the Olympic lifting exercises facilitates the development of a broader physical abilities spectrum, which seems to be better transferred to performance.

Thus, the combination of heavy lifts and Olympic lifts should be preferred over the combination of the former and VJs to enhance lower-body power performance.

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