Effect of Olympic and Traditional Resistance Training on Vertical Jump Improvement in High School Boys

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Abstract

Channell, BT and Barfield, JP. Effect of Olympic and traditional resistance training on vertical jump improvement in high school boys. *J Strength Cond Res* 22(5): 1522–1527, 2008–The purpose of this study was to compare the effects of a ballistic resistance training program of Olympic lifts with those of a traditional resistance training program of power lifts on vertical jump improvement in male high school athletes. Twenty-seven male student athletes were recruited from a high school football program at a small, rural school in the Southeast. The subjects were divided into an Olympic training group (OT, $n = 11$), a power training group (PT, $n = 10$), and a control group ($n = 6$). Analysis of variance was used to determine whether a significant mean difference existed among groups on vertical jump improvement after 8 weeks of group-specific training. Effect size of vertical jump improvement between groups, and correlations between strength and vertical jump performance, were also examined. There was no significant mean difference ($p \geq 0.05$) among OT, PT, and control groups, but large effect sizes between OT and control (d = 1.06) and PT and control (d = 0.94) demonstrate that both OT and PT are effective in improving vertical jump performance in male high school athletes. Moderate to high correlations were noted between squat score and vertical jump after adjusting for body weight ($r = 0.42$) and between power clean and vertical jump after adjusting for body weight ($r = 0.75$). Findings from the current study indicate that Olympic lifts as well as power lifts provide improvement in vertical jump performance and that Olympic lifts may provide a modest advantage over power lifts for vertical jump improvement in high school athletes.

Key Words power, power clean, training effect, squat

Introduction

Vertical jump performance has been a standard assessment of athletic strength and power in the lower body (2). Coaches and athletes have looked on this test as a predictor for athletic potential in many sports including weightlifting, football, basketball, volleyball, and track. Low strength attributable to poor muscular development hinders athletic performance including vertical jump and should be the primary training objective for the less-trained individual (13). Resistance training using near one-repetition maximum (1RM) weight at low velocity has been found to improve the muscle's ability to generate force, but the increase in strength may not be effective at velocities that simulate the speed of sport performance (3). Essentially, high-resistance exercise leads to increases in power (through increases in force production), but maximal gains are inhibited without training specific to movement velocity.

Traditional exercises, such as squats and squat variants, have been determined to be excellent exercises for improving lower-body strength, but they have a low correlation to vertical jump performance (1). To maximize athletic performance, athletes must increase strength in the hip, knee, and ankle joints and improve the rate of force development. Training with low resistance (30–50% of 1RM) at high velocity results in an increase in the rate of force development, and the gains in strength compare with the speed of sport performance and result in more powerful, explosive movements (12,15). Although traditional resistance training has been shown to improve vertical jump performance as much as 2–8 cm or 5–15%, it seems that lighter, more explosive lifts may be more effective than heavier lifts that are performed at lower velocities (7).

The specificity of training model suggests that exercises with similar movement patterns and joint angels to vertical jumping should elicit the greatest improvement in vertical jump performance (1,14). In contrast to traditional, low-speed power lifts, ballistic resistance exercises (i.e., Olympic lifts) require moving with lower resistance at higher velocities, result in acceleration through the entire movement, and may actually project an object or body into free space (11). Low-resistance ballistic exercises may produce

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smaller gains in strength compared with heavy resistance training, but they also may produce significantly higher gains in speed strength or power as measured by the force-time curve (16). As a result, when training for explosive movements, relatively light ballistic resistance exercises may be the most appropriate training model and offer the greatest potential for improvement in vertical jump performance (9,12). Power output during Olympic lifts has been reported to be nearly four to five times greater than that experienced during either the squat or deadlift (8), and it has been suggested that experienced athletes in power sports should deemphasize general strength-development exercises and focus primarily on speed training exercises (14).

Olympic lifts are commonly used in college and professional sport organizations to train for explosiveness and power, but they have received less study in high school populations (5,6,9). The last few decades have been periods of dramatic change in high school athletics, with an increased emphasis on off-season resistance training. Considering the wide variety of lifts and training protocols available, the current study was important to determine whether the effects of ballistic lifts that included Olympic-style weightlifting exercises were more advantageous for improving vertical jump performance in high school athletes as compared with traditional power lifts. The purpose of the current study, therefore, was to compare the effects of a ballistic resistance training program of Olympic lifts with those of a resistance training program of power lifts on vertical jump improvement in male high school athletes

Methods

Approach to the Problem

All subjects (except control) participated in 4 weeks of general strength training before being assigned to a training group that included either Olympic lifts (OT) or traditional power lifts (PT) during an 8-week training period. Safety and health precautions precluded the assessment of deadlift pretest assessment; therefore, training volume was not equated between groups. However, in an effort to maintain training equity, the number of lifts, as well as the sets per lift and repetitions per set, were controlled between OT and PT as recommended by Newton and colleges in a study on vertical jump improvement in elite collegiate volleyball players (12). The dependent variable, vertical jump improvement, was compared among both training groups and a control group (males not participating in any training sessions). The independent variable was speed of movement. Olympic lifts are ballistic in nature (i.e., they influence both the force and time components of power), and power lifts tend to be much slower (i.e., they influence the force component of power but not necessarily the time component).

Subjects

Twenty-seven male student athletes ($n = 27$) were recruited from a rural high school football program in the southeast United States. Subjects ($M = 15.9 \pm 1.2$ years, 179.3 ± 5.0 cm, 86.63 ± 19.45 kg) participated in football during the fall season but did not participate in a winter or spring sport. In general, subjects had limited weight training experience ($M = 1.87 \pm 0.81$ years) but were supervised by a strength training coach for each training session. Student and parental consent was obtained as well as principal, school board, and university institutional review board approval before data collection. All participants were informed of the purpose of the study and received continual feedback and supervision relevant to proper lift techniques and weight-room procedures.

Procedures

Members of the Olympic training and power training groups participated in 4 weeks of general strength training activities before beginning 8 weeks of group-specific training. During the initial 4 weeks of general strength training, an emphasis was placed on ensuring that each subject perform every lift with proper form. After completion of the 4-week general strength training program and before initiating a group-specific training protocol (OT and PT), each subject's vertical jump was measured using the Vertec (Sports Imports, Columbus, Ohio.). Subjects were then assigned a training group, and each group participated in an 8-week, group-specific training program (Table 1). Group one ($n = 11$) trained using Olympic lifts (OT), and group two ($n = 10$) trained using power lifts (PT). A group of student athletes who concluded their high school football playing careers at the conclusion of the fall season and who did not participate in 1) any off-season training program, 2) winter sport program, or 3) spring sport program were used as a control group ($n = 6$). Vertical jump was again assessed after the 8-week group-specific training. The study period was delimited to this 12-week structure to eliminate practice effects (via sufficient generalized training) while simultaneously accommodating state high school athletic association regulations specific to out-of-season activities.

Group assignment was based on the quality of the power clean technique after the initial 4 weeks of generalization training. Participants demonstrating better form were assigned to the OT group, with a participant of similar relative strength correspondingly assigned to the PT group. At the start of the training program, OT and PT groups were similar in mean relative strength (1RM/weight) on the power clean (0.83 and 0.84, respectively) and squat (1.50 and 1.66, respectively). Olympic training and PT groups performed three core lifts daily that were unique to their training protocol, but they did share several auxiliary lifts (Table 2). Members of the control group refrained from all strength training during the entire research project.

Newton and colleagues (12) discuss the difficulty of controlling volume between groups when the rate of force production was a central issue. The controlling factor between training groups in the current study, as it was in

Table 1. Examples of Olympic (OT) and traditional power lift (PT) training weeks.

OT			PT		
Exercise	Sets × reps	Intensity	Exercise	Sets × reps	Intensity
Day 1					
Bench press	3 × 3	~95% 1RM	Bench press	3 × 3	~95% 1RM
Power clean	5 × 5	~70% 1RM	Squat	5 × 5	~70% 1RM
Push jerk	5 × 5-6	RM	Dead lift	5 × 5	
Leg press	3 × 10, 8, 6	RM	Leg press	3 × 10, 8, 6	RM
Incline	3 × 10, 8, 6	RM	Incline	3 × 10, 8, 6	RM
Push-ups	5 × 20		Push-ups	5 × 20	
Back extensions	5 × 20		Back extensions	5 × 20	
Abdominals	5 × 20		Abdominals	5 × 20	
Day 2					
Bench press	5 × 5	~75, 80, 85, 90, 95% 1RM	Bench press	5 × 5	~75, 80, 85, 90, 95% 1RM
Power clean	3 × 10	~60% 1RM	Squat	3 × 10	~60% 1RM
Push jerk	3 × 10	RM	Dead lift	3 × 10	
Lunges	3 × 10, 8, 6	RM	Lunges	3 × 10, 8, 6	RM
Decline	3 × 10, 8, 6	RM	Decline	3 × 10, 8, 6	RM
Push-ups	5 × 20		Push-ups	5 × 20	
Back extensions	5 × 20		Back extensions	5 × 20	
Abdominals	5 × 20		Abdominals	5 × 20	
Day 3					
Bench press	3 × 10, 8, 6	~80, 85, 90% 1RM	Bench press	3 × 3	~100% 1RM
Power clean	5 × 5	~75% 1RM	Squat	5 × 5	~75% 1RM
Push-jerk	5 × 5	RM	Dead lift	5 × 5-6	
Attacker	3 × 10, 8, 6	RM	Attacker	3 × 10, 8, 6	RM
Military press	3 × 10, 8, 6	RM	Military press	3 × 10, 8, 6	RM
Push-ups	5 × 20		Push-ups	5 × 20	
Back extensions	5 × 20		Back extensions	5 × 20	
Abdominals	5 × 20		Abdominals	5 × 20	

the study by Newton et al., was equating the number of exercises, sets per exercise, and repetitions per set. Each training session was monitored by the investigator and by coaches from the football program. Each of the weight-room supervisors, including the primary investigator, had a minimum of 10 years of experience instructing, supervising, and monitoring weight-room training programs.

Vertical Jump. Pretraining and posttraining vertical jump performance was assessed for each subject. Using the Vertec, vertical jump performance was calculated as the difference between the height of the highest vane displaced during a vertical jump and standing reach. Before testing, the subjects were allowed to warm up on their own (e.g., jogging, calisthenics) but were requested not to engage in static stretching. The Vertec, distributed by Sports Imports, was used to collect vertical jump performance data. A two-handed reach was used to displace the maximum number of vanes possible from a flat-footed, standing position. After the stand and reach, a countermovement jump was performed to displace the highest reachable vane. Vertical jump performance was measured as the difference in vane displacement between the vertical jump and the stand and reach.

One-repetition Maximum. Squat 1RM and power clean 1RM were recorded for each subject before initiating, and again after completion of, OT and PT training programs. The subjects' 1RM represented the maximum amount of weight that could be lifted a single repetition using proper form (10). The primary investigator or a school athletic coach was required to witness the execution of the 1RM attempt. The procedure for a 1RM attempt included warm-up with a self-selected resistance of approximately 50% of perceived maximum, which was followed by attempts for a new 1RM beginning at previous 1RM plus an additional 3–5% after successful lifts. Rest periods of 3–5 minutes were used between all lifts.

Statistical Analyses

Analysis of variance (ANOVA) was used to test for significance among the OT, PT, and control groups' mean

Table 2. Examples of Olympic (OT) and traditional (PT) core lifts and shared auxiliary lifts.

Example of OT core lifts	Examples of PT core lifts	Examples of shared auxiliary lifts
Power clean	Squat	Bench press
Hang clean	Overhead squat	Military press
Clean pulls	Dead lift	Lunges
Snatch	Leg press	Attacker
		Push-ups
		Sit-ups
		Back extensions

improvements in vertical jump performance ($p \leq 0.05$). In addition, effect size (Cohen's d) was used to evaluate meaningfulness between the change in vertical jump performance among the OT, PT, and control groups. In an effort to identify any possible correlations, Pearson's product-moment correlation was used to evaluate relationships between vertical jump performance and the squat 1RM (relative to body weight) and between vertical jump and power clean 1RM (relative to body weight). An intraclass correlation coefficient (ICC) from a one-way ANOVA was used to establish test-retest reliability of the vertical jump (two trials administered at the completion of the strength program). All statistical analyses were computed with Microsoft Excel (2003) or SPSS 14.0 (Chicago, Ill).

Results

As demonstrated in Figure 1, both OT and PT improved vertical jump performance ($M_{OT} = 2.4 \pm 4.7$ cm; $M_{PT} = 1.1 \pm 3.1$ cm). The control group experienced a decrease in vertical jump ($M_{Control\ Group} = -1.7 \pm 2.9$ cm), which is likely

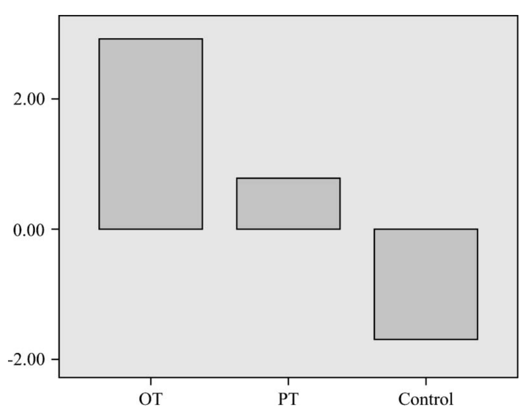

Figure 1. Mean vertical jump increases (cm) by group.

a detraining phenomenon that occurred as a result of not engaging in resistance training for a 12-week period. The change in vertical jump performance represented a 4.5% increase for OT, a 2.3% increase for PT, and a 2.8% decrease for control (Table 3). Single-factor ANOVA indicated no significant mean difference in vertical jump improvement among the OT, PT, and control groups ($p \geq 0.05$). However, large effect sizes (OT vs. control, d = 1.06; PT vs. control, d = 0.94) demonstrate a meaningful difference in the gains made by both training groups compared with the control group. A low to moderate effect size between OT and PT (d = 0.34) represents a less meaningful difference between these training groups, but it is noteworthy that the mean improvement of the Olympic group was 56% greater than that of the power lift group.

Relationship of Vertical Jump to Measures of Strength

Pearson's product-moment correlation was used to examine possible relationships between vertical jump performance and 1RM capabilities in the squat and power clean exercises. For the subjects in the current study, a moderate correlation existed between vertical jump and squat performance corrected for body weight ($r = 0.42$), but a high correlation existed between vertical jump and power clean performance corrected for body weight ($r = 0.75$). Interestingly, a high correlation ($r = 0.88$) also existed between squat 1RM corrected for body weight and power clean 1RM corrected for body weight. Table 4 demonstrates that vertical jump performance increased as squat 1RM and power clean 1RM increased.

Instrument Reliability

The test-retest ICC for the Vertec was very high ($R = 0.95$). When adjusted for a single trial, as the Vertec would normally be used as a field test of vertical jump ability, the ICC remained very high ($R = 0.91$). The high reliability coefficients indicate that the Vertec collects consistent vertical jump performance data among male high school athletes.

Discussion

Vertical jump performance is dependent on factors such as strength, power, and the ability to utilize the stretch-shortening cycle. It has been demonstrated that 30–50% of the 1RM is optimal for development of mechanical power (12,15). The subjects in the current study used 1RM variations ranging from 30% up to 100% across a variety of exercises, and the results indicate that power lifts and Olympic lifts both elicit vertical jump improvement in a population of male high school athletes. The justification for using intensities greater than 30–50% rests within the recommendations that low strength attributable to poor muscular development hinders athletic performance and should be the primary training objective for the less-trained individual (13). Although Olympic lifts contain a speed component similar to that of plyometric training and have been reported to be more effective than traditional resistance training for developing athletic power (9), there was only a

TABLE 3. Vertical jump scores (cm) by group.

		Group		
		Olympic resistance training	Traditional resistance training	Control
Pretest	Mean	57.5	47.2	59.1
	SD	7.2	9.5	9.1
Posttest	Mean	60.1	48.3	57.4
	SD	3.9	8.9	7.7
Vertical jump improvement	Mean	2.6	1.1	−1.7
	SD	4.7	3.1	2.9

modest difference between types on vertical jump improvement in the current sample. Of interest, the squat and power clean exercises were related to vertical jump performance in the current population, likely a result of the biomechanical similarities between the movement of the vertical jump, squat, and power clean. Although many factors have been documented in the literature that may explain strength improvements (adaptations to endocrine system, enhanced anaerobic stores, muscular hypertrophy), it is likely that neural factors contributed to vertical jump gains in the current study. Although cross-sectional area and cellular-level mechanisms were not assessed (e.g., enzyme activity), it seems likely that training resulted in improved motor unit recruitment and inhibition of protective antagonist muscle action, especially given the short time frame. The greater gains experienced by the OT group also demonstrate the importance of movement velocity to neural-related adaptations in the current population (Table 5).

TABLE 4. Relationship of strength increases and vertical jump performance.

	Increase in vertical jump performance (cm)
Squat increase 0–50 lb	4.0
Squat increase 50–100 lb	6.4
Squat increase 100–150 lb	6.6
Squat increase > 150 lb	10.4
Power clean increase 0–20 lb	3.7
Power clean increase 20–45 lb	3.9
Power clean increase 45–60 lb	6.5
Power clean increase > 60 lb	9.5

Criteria adapted from Hedrick (1996).

Results are consistent with other resistance training studies that have measured changes in vertical jump performance. Duke and BenEliyahu (4) report a 3% increase in a weight training group and a surprising 11% increase for a weight training plus plyometric group of high school athletes that trained for 6 weeks. In a study similar to the current research design, Hoffman and researchers (9) investigated the effects of 15 weeks of resistance training using Olympic lifts vs. power lifts in NCAA division III football players and found a significant difference in vertical jump improvement. Vertical jump performance increased 6.8 cm (15%) for the Olympic group and 0.5 cm (< 1%) for the power lift group. The authors conclude that the difference in vertical jump improvement between an Olympic training group over a power training group was likely attributable to the large number of pulls (power clean, snatch, clean pulls, etc.) included in the Olympic group training protocol. In an investigation of elite male volleyball players trained with ballistic lifts, Newton et al. (12) report a 5.9% increase in vertical jump from 67.6 to 71.5 cm. Considering the current study and review of previous research, vertical jump performance can be expected to improve as a result of training, and the degree of improvement is relative to the mode, frequency, and intensity of training as well as the training experience of the subjects.

In a study of first-year collegiate athletes, Peterson and others (13) observed that the quotient of muscular strength and body weight was more highly correlated to power and performance measures ($r = 0.67$; vertical jump to squat 1RM/body weight) than absolute muscular strength ($r = 0.54$; vertical jump to squat 1RM). Hoffman and others (9) report a moderate correlation ($r = 0.50$) between changes in squat 1RM and an increase in vertical jump performance during a 15-week training program in NCAA Division III football players, and a moderate correlation ($r = 0.52$) between squat 1RM and vertical jump performance was also reported by Carlock et al. (2) in an investigation of men and women elite weightlifters at the Olympic training center. In a longitudinal study of NCAA Division I collegiate football players, Hedrick and Anderson (8) found a positive developmental correlation between strength performance and vertical jump ability (Table 4). Results of the current study are consistent with this previous work, but it is important to note that the population studied may contribute to the stronger relationship between Olympic lifts (i.e., power clean) and vertical jump than demonstrated between traditional power lifts (i.e., squat) and vertical jump.

TABLE 5. One-repetition maximum (1RM) improvement (kg) by group.

		Olympic resistance training		Traditional resistance training	
		Pretest	Posttest	Pretest	Posttest
Squat	Mean	144	161.6	132.6	28.3
	SD	41.6	29.3	30.94	26.01
Power clean	Mean	72.6	84.3	69.2	70.1
	SD	17.8	15.6	17.8	12.9

Reliability for vertical jump score was high in the current study and contributes to the appropriateness of this measure among high school males. High ICC has been reported for vertical jump performance using the Vertec across other populations as well, including elite NCAA Division I men's volleyball players ($R = 0.98$) (12) and male and female elite weightlifters at the Olympic training center ($R = 0.98$) (2). Strong reliability indirectly supports the validity of posttest jump scores (and, therefore, the validity of improvement) because the effect of the training program was stable after the conclusion of the study.

Practical Applications

Within the design of the current study, several conclusions can be drawn. First, Olympic lifts as well as power lifts provide meaningful improvement in vertical jump performance compared with a control group. Second, Olympic lifts may provide a modest advantage over power lifts for vertical jump improvement in high school athletes. Lastly, Olympic lifts offer a stimulus that is uniquely different from power lifts, and they should be included in a resistance training program for high school athletes who require quick, powerful movements.

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