A Comparison of the Effects of Short-Term Plyometric and Resistance Training on Lower-Body Muscular Performance

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Abstract

Whitehead, MT, Scheett, TP, McGuigan, MR, and Martin, AV. A comparison of the effects of short-term plyometric and resistance training on lower-body muscular performance. *J Strength Cond Res* 32(10): 2743–2749, 2018—The purpose of this study was to compare effects of short-term plyometric and resistance training on lower-body muscular performance. A convenience sample of 30 male subjects aged 21.3 ± 1.8 years (height, 177.3 ± 9.4 cm; mass, 80.0 ± 2.6 kg; body fat, 16.1 ± 1.2%) participated in this investigation. Participants were grouped, and they participated in progressive plyometric (PLT) or resistance training (SRT) twice per week for 8 consecutive weeks or a control (CNT) group that did not participate in any training. Performance tests were administered before and after the training period, and it included measures of high-speed muscular strength (standing long jump, vertical jump), low-speed muscular strength (1-repetition maximal back squat), running speed (20-m sprint), and running agility (505 agility test). Analysis of variance followed by post hoc analyses was performed to determine significant differences between the groups. Significance set at $p \leq 0.05$ for all analyses. Significant improvements were observed in the PLT group for standing long jump, vertical jump, and 1-repetition maximal back squat compared with the CNT group and for vertical jump as compared with the SRT group. Significant improvements were observed in the SRT group 1-repetition maximal back squat compared with the CNT group. There were no differences observed between any of the groups for the 20-m sprint or the 505 agility test after the training. These data indicate that 8 weeks of progressive plyometric training results in improvements in parameters of high-speed and low-speed muscular strength with no appreciable change in speed or agility. Additionally, the improvement in low-speed muscular strength observed from 8 weeks of progressive plyometric training was comparable to the results observed from 8 weeks of progressive strength training.

Key Words short-term training, high-speed muscular strength, low-speed muscular strength

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Introduction

Strength and conditioning professionals use a variety of training modalities over the course of a season and most agree that plyometric and resistance training should be part of an overall season plan. These professionals are tasked with determining which method is best used based on age, sport, skill level, and desired training outcomes. Time constraints of coaches and athletes need to be considered because it is important to use the available time training effectively, efficiently, and in the training mode most appropriate to achieve the desired specific performance outcomes. For many strength and conditioning professionals, scheduling issues for the use of limited training equipment and facilities by multiple athletic teams presents considerable challenges. Considering these factors, the selection of mode of training is critical and needs to be carefully considered. Resistance training requires facilities that can be occupied by a limited number of athletes at a given time and spaces must be scheduled accordingly. Comparatively, many smaller floor spaces can be used to train small or large groups of individuals using plyometric training techniques, which can be implemented using very little equipment.

Most forms of athletic competition involve lower-body performance whether in the stance or active phase of the activity. Training modes that improve lower-body performance are highly regarded by strength and conditioning professionals, athletes, coaches, and trainers. Plyometric and resistance training are 2 of the primary non–sport-specific methods used in strength and conditioning programs to improve lower-body performance. Numerous research reports have supported the role of both plyometric and

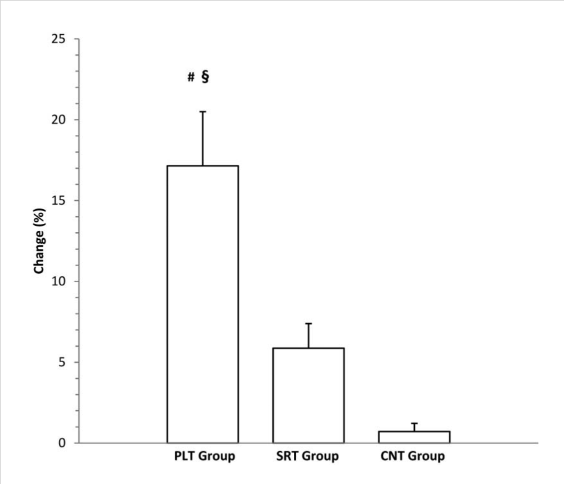

Figure 1. Percent change in vertical jump after 8 weeks of plyometric and resistance training. #Significantly different from control (CNT) group ($p \leq 0.05$). §significantly different from resistance training (SRT) group ($p \leq 0.05$).

resistance training as part of an overall seasonal training program. There are limited research reports that have compared the results of short-term plyometric and resistance training on lower-body muscular performance.

Lower-body performance includes high- and low-speed muscular strength, speed and agility, and other parameters. High-speed strength, also known as maximal aerobic muscular power (or anaerobic power), is the ability of a muscle to exert high force while contracting at a high speed and can be evaluated by testing standing long jump and vertical jump distances (1). Low-speed muscular strength, also known as maximum muscular strength, is the force that a muscle or muscle group can exert in 1 maximal effort and can be evaluated by the administration of single repetition maximal tests (1). Another important component of sport training is speed, which is distance covered per unit time by running in 1 direction and can be evaluated by short distance sprints. Agility consists of both physical and cognitive components and is the ability to stop, start, and change direction quickly, and tests of agility must be short in duration and include these components (1,10).

Plyometric training uses the stretch-shortening cycle of a muscle that can be divided into 3 phases. Phase I is the eccentric phase that involves the preloading agonist muscle groups, phase II, which is the time between the eccentric and concentric muscle actions, is also called amortization, and phase III is the concentric phase (10). A muscle can produce more contractile force when the muscle is optimally stretched before the desired movement (2–4). Athletes of all ages benefit from plyometric training (8,11,18). Lower-body plyometric training consists of 3 phases during each movement: eccentric muscle action, amortization, and concentric muscle action. Typical plyometric exercises include jumps in place, standing jumps, multiple hops and jumps, bounding, box drills, and depth jumps. Isotonic resistance training typically uses alternating cycles of eccentric and concentric muscle actions to cause joint motion and move loads as a training stimulus. Both plyometric and resistance training modes follow the principle of progression where frequency, volume, and intensity are manipulated to gain the desired training effect. Plyometric training may be important for enhancing the rate of force development during jumping and sprinting, whereas resistance training is needed to enhance muscular strength and acceleration (9). Plyometric training has been shown to be a safe and effective training mode for a variety of populations, provided that developmentally appropriate training guidelines are followed (8,15,19). Anecdotal evidence indicates that plyometric training may be as useful in developing some parameters of lower-body performance as resistance training. Therefore, the purpose of this study was to compare the effects of short-term plyometric and resistance training on lower-body muscular performance including high-speed muscular strength (standing long jump, vertical jump), low-speed muscular strength (one-repetition maximal back squat), running speed (20-m sprint), and running agility (505 agility test). These 2 types of training are being compared to offer an alternative to short-term resistance training for coaches and athletes with time and space constraints. We hypothesize that similar lower-body muscular performance results will be obtained from short-term either plyometric or resistance training.

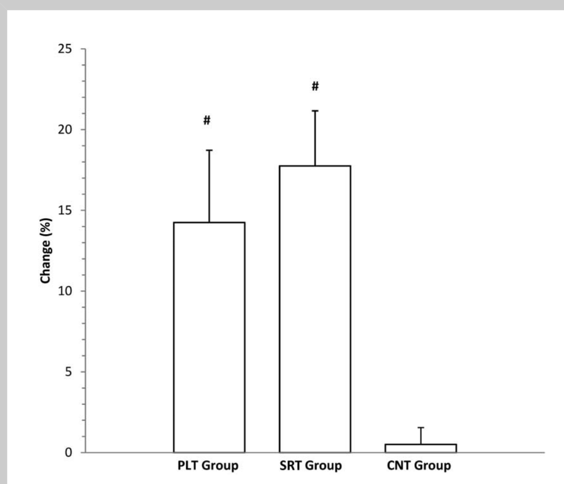

Figure 2. Percent change in 1-repetition maximal back squat after 8 weeks of plyometric and resistance training. #Significantly different from control (CNT) group ($p \leq 0.05$).

Table 1. Repetition-based plyometric training protocol.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	Sets × repetitions							
Leg lifts	1 × 8	1 × 8	1 × 12	1 × 12	1 × 16	1 × 16	1 × 20	1 × 20
Plank kicks	1 × 8	1 × 8	1 × 12	1 × 12	1 × 16	1 × 16	1 × 20	1 × 20
Leg Flexes	1 × 20	1 × 20	1 × 25	1 × 25	1 × 30	1 × 30	1 × 35	1 × 35
Leg Kicks	1 × 4	1 × 4	1 × 8	1 × 8	1 × 12	1 × 12	1 × 16	1 × 16
Skip hops	2 × 4	2 × 4	2 × 5	2 × 5	2 × 6	2 × 6	2 × 7	2 × 7
Skips	4 × 4	4 × 4	4 × 6	4 × 6	4 × 8	4 × 8	4 × 10	4 × 10
Freezes	2 × 4	2 × 4	2 × 6	2 × 6	2 × 8	2 × 8	2 × 10	2 × 10
High knees	1 × 4	1 × 4	1 × 8	1 × 8	1 × 12	1 × 12	1 × 16	1 × 16
Ankle hops	1 × 4	1 × 4	1 × 8	1 × 8	1 × 12	1 × 12	1 × 16	1 × 16
Split jumps	1 × 4	1 × 4	1 × 5	1 × 5	1 × 6	1 × 6	1 × 7	1 × 7
Cone Hops	4 × 4	4 × 4	4 × 6	4 × 6	4 × 8	4 × 8	4 × 10	4 × 10

Methods

Experimental Approach to the Problem

To determine the effects of effects of short-term plyometric and resistance training on lower-body muscular performance and to offer an alternative to some of the limitations of short-term resistance training for coaches and athletes with time and space constraints, 30 male subjects were grouped and participated in training twice per week for 8 consecutive weeks as follows: plyometric training (PLT), resistance training only (SRT), or a control group (CNT) who did not participate in a training intervention. Performance tests were evaluated before and after the training period and included vertical and standing long jump as tests of high-speed muscular strength, a 1-repetition maximal (1RM) back squat as measure of low-speed muscular strength, a 20-m sprint as a test of speed, and 505 agility test as a measure of agility.

Subjects

Thirty male subjects aged 21.3 ± 1.8 years (body height, 177.3 ± 9.4 cm; body mass, 80.0 ± 2.6 kg; body fat, 16.1 ± 1.2%; 1RM back squat or body mass, 1.40 ± 0.3) participated in this investigation. Any volunteer with known cardiac or respiratory disease, major injury, or history of surgery to the lower extremities was excluded from the study. Participants were grouped SRT ($n = 10$) and PLT ($n = 10$) and participated in training twice per week for 8 consecutive weeks or CNT ($n = 10$) and did not train. In accordance with the Declaration of Helsinki, all subjects were carefully informed about the possible risks and benefits of the study, and all subjects signed a written informed consent form before participation in the study. The Human Subjects Protection Review Committee of each participating university approved the study.

Procedures

Participants in the PLT and SRT groups trained with a supervised lower-body plyometric or resistance program 2 times per week with a minimum of 48 hours of recovery between each training session but no more than 72 hours between consecutive sessions. Participants in the CNT group did not participate in any training, only the pre- and posttesting sessions. Each plyometric training session was composed of 2 components with one controlled by the number of repetitions completed and the other by timed intervals. The sequence of individual drills performed, number of repetitions, and weekly progression for the lower-body plyometric training is described in Tables 1 and 2. Training protocols were designed to be comparable in volume and intensity. The strength training protocol involved both single joint and multijoint lower-body exercises. The sequence of exercises, repetitions, load, and progression for the resistance training sessions is described in Table 3.

Testing. Performance tests were administered before and after the 8-week training period. Participants were asked not to engage in any strenuous physical activity for 24 hours and to abstain from caffeine for 4 hours before each testing session. Before the initial pretesting, participants were allowed familiarization trials with the testing protocols. Performance testing occurred over 2 sessions and was separated by 24 hours. All testing sessions were preceded by a 15-minute standardized warm-up with stretching and dynamic movements included. Tests that occurred on day 1, in sequence, were body mass, body height, body composition, 20-m sprint, and the 505 agility test. Tests that occurred on day 2, in sequence, were standing long jump, vertical jump, and 1RM back squat. Body mass (in kilograms) and height (in centimeters) were measured by a standard calibrated medical scale and stadiometer, respectively. Body composition (% fat) was determined by the measurement of 7 skinfold sites (Lange skinfold caliper; Beta Technology Incorporated, Cambridge, MD, USA) and body density calculations (12). Measures of high-speed muscular strength included the standing long jump (in centimeters) and vertical jump (in centimeters). For the standing long jump test, participants stood with feet apart behind a reference line and using an arm swing and countermovement jumped horizontally as far

Table 2. Timed interval plyometric training protocol.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	Repetition × time (s)							
Skips	2 × 20	2 × 20	2 × 20	2 × 20	2 × 20	2 × 20	2 × 20	2 × 20
Back	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20
High knee	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20
Side slide	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20
Karaoke	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20
Lunge	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20
Backpedal	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20	1 × 20
Front hops	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60
Side hops	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60	2 × 60
Dot drills	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30

as possible with the distance from back of the heel closet to the reference line recorded from the best of 3 trials. Vertical jump height was measured with a Vertec device (Vertec; Sports Imports; Hillard, OH, USA) by subtracting standing reach height from the highest of 3 consecutive arm swing and countermovement jump attempts. For the 20-m sprint separate start and finish gates were setup, and time to complete the distance was measured with a laser-timing device (TC-System; Brower Timing Systems, Draper, UT, USA). Participants performed each trial from a standing still position with the best of 3 trials recorded as the criterion measure. The 505 agility test was performed according to methods previously described and validated (21). The best of 3 trials was used with time to complete the run measured with a laser-timing device (TC-System; Brower Timing Systems). The 1RM back squat was performed according to the method previously described and accepted by the National Strength and Conditioning Association (1). Intraclass correlation coefficients were calculated for between the pre and post measures for each test (standing long jump = 0.96; vertical jump = 0.95; 1RM back squat = 0.91; 20-m sprint = 0.89; 505 agility run test = 0.94), and the results demonstrated a high level of test-retest reliability.

Statistical Analyses

Analysis of variance was performed on all baseline test data to identify any significant differences between the groups. There were significant pretraining differences between the groups on vertical jump ($F = 8.752$; $p = 0.001$) and agility ($F = 94.981$; $p < 0.001$) only. Because of these pretraining differences, all data were converted to pre-post percent change to address the initial between-group differences. Analysis of variance was performed on pre-post percent change data to determine significant between-group differences and was followed by Bonferroni's post hoc test to determine where differences occurred. Significance was set at $p \leq 0.05$ for all analyses.

Results

The data collected before and after training for all variables and groups are presented in Table 4. Results of the analysis of variance indicated significant main group effects for vertical jump ($F = 15.347$; $p < 0.001$) and 1RM back squat ($F = 7.651$; $p = 0.002$), with no differences found for standing long jump ($F = 2.287$; $p = 0.121$), 20-m sprint ($F = 0.021$; $p = 0.979$), or the 505 agility test ($F = 0.016$; $p = 0.984$). Results of post hoc multiple comparisons indicated that vertical jump improved in the PLT group and was significantly different from both the SRT ($p = 0.001$; effect size

Table 3. Resistance training protocol.*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	70% 1RM	70% 1RM	70% 1RM	75% 1RM	75% 1RM	75% 1RM	80% 1RM	80% 1RM
	Sets × repetitions							
Squat	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Leg press	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Extension	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Leg curl	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Lunges	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Calf raises	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8

*RM = repetition maximum.

Table 4. Mean results ± *SD* of effects of training on standing long jump, vertical jump, 1RM back squat, 20-m sprint, and agility.*

	PLT		SRT		CNT	
	Pre	Post	Pre	Post	Pre	Post
Long jump (cm)	1.9 ± 0.4	2.1 ± 0.4	2.1 ± 0.4	2.3 ± 0.4	2.3 ± 0.2	2.3 ± 0.1
Vertical jump (cm)	41.0 ± 11.4	47.7 ± 12.8	58.5 ± 7.0	61.8 ± 6.7	62.1 ± 16.0	62.3 ± 15.4
Back squat (kg)	97.5 ± 38.3	109.6 ± 37.0	118.8 ± 18.2	139.0 ± 18.9	118.8 ± 31.8	119.3 ± 31.7
20-m sprint (s)	3.5 ± 0.3	3.5 ± 0.2	3.5 ± 0.2	3.5 ± 0.2	3.3 ± 0.4	3.3 ± 0.4
Agility (s)	2.7 ± 0.3	2.6 ± 0.2	3.8 ± 0.3	3.8 ± 0.3	4.7 ± 0.4	4.7 ± 0.5

*CNT = control group; PLT = plyometric training group; RM = repetition maximum; SD = standard deviation; SRT = resistance training group.

[ES], 0.56; 95% confidence interval [CI], 5.04–17.48) and the CNT ($p < 0.001$; ES, 0.70; 95% CI, 10.21–22.65) groups, as shown in Figure 1. Finally, 1RM back squat was improved in both the PLT and SRT groups as compared with the CNT group ($p = 0.007$; ES, 0.50; 95% CI, 4.18–23.30 and $p = 0.001$; ES, 0.70; 95% CI, 7.67–26.80, respectively) with no significant difference demonstrated between PLT and SRT groups, as shown in Figure 2.

Discussion

These data indicate that 8 weeks of separate plyometric and resistance training result in significant improvements in both low- and high-speed muscular strength as compared with a nontraining control group. The greatest improvement in high-speed muscular strength was observed in the plyometric group, although there was no significant difference in improvement in low-speed muscular strength regardless of training protocol.

The most important result of the present investigation is the similar muscular strength adaptations resulting from short-term plyometric and resistance training in recreationally trained male subjects. This finding is supported by previous research that demonstrated no difference in improvements in muscular strength with 6 weeks of plyometric or resistance training (13). There is a large body of literature that has investigated the effects of plyometric training on various populations (7), but a very few studies have directly compared the effects of plyometric training and more traditional resistance training, particularly in untrained individuals (22). Plyometric training is commonly combined with resistance training during training programs to allow for maximal efficiency and optimizing improvements. However, we chose to compare the effects of plyometric and traditional resistance training directly. Our results indicate that either training approach could significantly improve muscular strength in recreationally trained male subjects. A study by Vissing et al. (22) investigated muscular adaptations to 12 weeks of plyometric vs. traditional resistance training. Only the traditional resistance training seemed to increase muscle cross-sectional area. Future studies using more advanced body composition measures are needed to confirm any differential body composition changes in similar populations.

The type of jumps performed in a training program seems to be an important consideration in the program design (7). In the present study, there were no between-group differences in improvement in standing long jump (Table 4). Some researchers have suggested that training programs need to have a greater emphasis on horizontal force production (5). However, our data suggest that neither short-term plyometric or traditional resistance training with a predominance of vertical movements is sufficient to increase horizontal jumping performance in recreationally trained male subjects.

One of the most common outcome measures in studies of plyometric training is the vertical jump. In the present study, vertical jump improved 17.5% in the PLT group and was significantly different from both the SRT (5.87%) and the CNT (0.71%) groups (Figure 1). These results are similar to the findings of Vissing et al. (22), which also showed large improvements in countermovement jump height using plyometric training but not with traditional strength training. The results of a meta-analysis have shown that plyometric training significantly improved vertical jump height from 4.7% (ES = 0.44) to 8.7% (ES = 0.88) depending on the type of vertical jump measured (7).

One-repetition maximal back squat was significantly improved in both the PLT (14.3%) and SRT (17.8%) groups with no significant difference found between the 2 training modes (Figure 2). It would appear in untrained men that either stimulus is effective for increasing maximal strength. This is similar to a previous research in similar populations who also showed similar gains in lower-body muscular strength with either plyometric or traditional resistance training (22). Interestingly, in the study by Vissing et al. (22), there were larger increases in lower-body muscular power in the plyometric training group, which supports our finding of increased vertical jump height in the PLT group.

Our results did not show any improvement in 20-m sprint time or agility after 8 weeks of training. This could be the result of the length of the training program or the types of exercises that were employed in the program. Rimmer and Sleivert (17) have previously shown that a sprint-specific plyometric program can improve 40-m sprint performance. Their plyometric intervention appeared to have the greatest effect on sprint performance in the initial acceleration phase. Markovic et al. (14) showed that plyometric training improved jump performance but not to the same extent as sprint training. De Villarreal et al. (6) also showed improved sprint ability in moderately trained men after 7 weeks of depth jump training. There is some evidence to suggest that resistance training can improve agility, but this is very limited (20). Our training interventions were unable to bring about changes in agility performance in these subjects, and it may be that longer periods are needed to increase motor performance.

Responses to plyometric training, similar to other modes of exercise, result in differing magnitudes of improvements (23). High responders and low responders are often reported in response to plyometric training programs. A study by Wilson and Murphy (23) found that there were good (+10%) and poor (−5%) achievers in training-induced changes in cycling performance following a 10-week plyometric training program involving depth jumps. The underlying mechanisms for these differential changes between individuals are not well understood. What is clear is that plyometric training improves vertical jump height, muscular strength, and other measures of performance in most individuals. Plyometrics are not a recent development in exercise prescription (16). Historically, jumping, throwing, hopping, and bounding have formed the basis of many training programs. Like any other training component, plyometrics need to be considered within the context of the overall program.

Practical Applications

In an effort to optimize performance and maximize time spent in training, coaches, trainers, and athletes are continuously seeking effective training methods. Questions frequently arise as to which training method is best for a given performance parameter. Plyometric training programs similar in duration and intensity to the one used in the current study should result in an improvement in body composition and vertical jump. Both plyometric and resistance training appear to result in improvements in lower-body muscular performance in untrained men. More specifically, there are equal increases in standing long jumping ability and maximal strength. What this means is that decisions can be effectively made regarding time spent in an individual training mode based on the individual needs of the athlete, equipment, and facility limitations.

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