Enhancing sprint and strength performance: Combined versus maximal power, traditional heavy-resistance and plyometric training

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\textbf{Abstract}

Objectives: This study compares the effect of five different training stimuli on sprinting ability and strength production.

Design: Sixty physical education students were randomly assigned to five experimental groups: all types of training (A), full-squat (B), parallel-squat (C), loaded countermovement jumping (D) and plyometric training (E). Participants in each group trained three days a week for a total of seven weeks.

Methods: Sprint performance (30 m), maximal dynamic strength (1RM) (kg) and velocity of displacement in the concentric phase of full-squat (m/s) were measured before and after seven weeks of training.

Results: Pre-training results showed no significant differences among the groups in any of the variables tested. After seven weeks no significant improvement in sprint performance was found, however, significant improvement in maximal dynamic strength, velocity of displacement were observed in all the groups: combined methods group A (20%), heavy-resistance group B (11%), power-oriented group C (17%), ballistic group D (14%) and plyometric group E (6%).

Conclusions: A combined training approach using full-squat, parallel-squat, loaded countermovement jumping and plyometric training results in a light improvement in maximal strength, velocity of displacement and sprint performance and the resemblance between movement patterns and the velocity of displacement common to the training and testing methods also contributes to greater performance improvement.

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1. Introduction

Improving sprint and strength performance is beneficial for increasing muscle power output and athlete performance and is an important determinant of success in sports. Strength and sprint enhancement are developed through a myriad of training methods including traditional heavy-resistance training programs, ballistic and non ballastic training programs, speed training and sprint drills, combined resistance and speed training and plyometric training (PT).\textsuperscript{1-3} Meanwhile, a common trend in training programs indicate that a combination of methods are more effective for enhancing performance\textsuperscript{4} rather than stand-alone approaches. However, to our knowledge, no studies have compared the effectiveness of combined training (i.e. full-squat [FS], loaded squat jumps and PT) on maximal strength and sprint capacity.

The strength exercises used in a training program should match the individual needs of the athletes in relation to the biomechanical and physiological characteristics of the athletic/sporting activity they are involved in. Therefore, to optimize transference to sport performance strength, exercises should reflect the type of activity required in that sport. The importance of training specificity in science of muscle strength and power development can never be overemphasized.\textsuperscript{3-5} In fact, studies have demonstrated that strength increases are specific to the velocity at which one trains.\textsuperscript{6-8}

Although athletes and coaches involved in sprint training continue to use strength exercises,\textsuperscript{9} there have been few studies describing the transfer of the training effects from different strength training methods in the horizontal plane to sprint performance in the acceleration phases of a sprint. Findings from small number of studies in the literature regarding the effects of combined and strength training methods on sprinting have also been inconsistent.\textsuperscript{5,10,11} Perhaps, due to the fact that strength exercises employed in these studies were not specific to sprinting. Hence, lack of specificity to sprinting in these exercises may well have been responsible for the absence or small improvements in sprint times.

The purpose of this study was to examine the effect of five different strength training methods characterized by their different velocity, displacement and the use of traditional versus
2. Methods

This study was designed to look at how five different training stimuli affected sprint and strength performance against different external resistances. We compared the effects of 7 weeks (21 sessions) of treatment in 5 groups of participants with each different method of training using a randomized, balanced, test-retest design. All tests were carried out before (pre-test) and after the training period (post-test). These include 1) anthropometric measures; 2) sprint performance (30 m); 3) maximal strength (1RM) (kg) and 4) velocity of displacement during the concentric phase of FS (m/s).

Sprint times were recorded for 30-m distances, indoors on a synthetic running surface. Participants were positioned one meter behind the starting line, before they were beckoned to sprint with a random sonorous sound. Infrared beams were stationed at the sprint distance (0, 15 and 30 m) to be measured with photoelectric cell (Muscle Lab. V7. 18. Ergotest Technology (Langesund, Norway)). Participants were given 2 practice trials performed at half speed after a thorough warm-up to familiarize them with the timing device. Three trials were completed, with 3 min of rest between trials and the best performance trial was used for the subsequent statistical analysis. Times were reported to the nearest 0.01 s.

For the maximal dynamic strength (1RM) test, FS was selected to provide data on maximum strength through the full range of motion of the muscles involved. Participants performed a FS assuming an extended position starting from the knee angle (about 180°), with shoulders in contact with a bar. On command, the participants performed a controlled eccentric leg flexion until 60°. Then a concentric leg extension (as fast as possible) starting from the flexed position (60°) to reach full extension of 180° against the resistance determined by the weight plates added to both ends of the bar. The trunk was kept as straight as possible. Safety belt was used by all participants. The tests were performed in a squatting apparatus (Smith machine, Model Adan Sport, Set 0.4 Spain).

Warm-up consisted of the set of ten repetitions at loads of 40–60% of the perceived maximum. The last acceptable extension with highest possible load was determined as 1RM. The rest period between actions was always 2 min.

Velocity of displacement during concentric phase of FS (m/s) was determined by adjusting the added load until the highest velocity was obtained. Velocity index was calculated as an average value of the peak velocity obtained with all the loads. The bar weight was then progressively increased in 10 kg increments for each set (i.e. bar only; bar + 10 kg; bar + 20 kg, until the highest possible load) with two trials executed with each weight. Warm-up consisted of a set of five repetitions with the weight of the bar (17 kg). Velocity of displacement was determined using a squatting apparatus in which the barbell was attached at both ends, with linear bearings on two vertical bars allowing only vertical movements. Further, bar displacement, peak, and mean velocity (m/s) were recorded 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 computer program (Isocontrol Dinámico, Version 3.6. JLML, Spain) was used to calculate the velocity of displacement for each repetition of FS performed throughout the whole range of motion. Adequate recovery was allowed between all trials (2–3 min). The best trial with each weight was recorded for the subsequent statistical analysis.

Training took place 3 days a week (M–W–F) for every group during 7 weeks of the intervention (21 sessions). The training was individualized for each participant based on their maximal strength with a printed schedule of volume, density and intensity of the training (number of sets and repetitions, rest intervals, daily load). Each session lasted 30–45 min, 10 min of standard warm-up (5 min submaximal running at 9 km h\(^{-1}\)), stretching exercises for 5 min and 2 submaximal exercises of jump (20 vertical jump, 10 long jumps), 15–30 min of specific strength or power training and 5 min of cool down including stretching exercises. The training program employed by each group is outlined in Table 1. All training sessions for all groups were fully supervised and training diaries were maintained for each participant. All participants were instructed to maintain their normal daily activities throughout the 7-week study, including participation in recreational sporting activities. However, no additional strength or PT was permitted.
Descriptive statistics (mean ± SD) for the different variables were calculated. The intraclass correlation coefficient (ICC) was used to determine the reliability of the measurements. The training-related effects and the differences between the groups were assessed using an ANCOVA with the contrast F of a contrast. The intraclass correlation coefficient (ICC) was 0.90 (0.88–0.92).

No significant differences were observed after training in the magnitude of the changes among all treatment groups. The intraclass correlation coefficient (ICC) was 0.94 (0.91–0.96).

Maximal dynamic strength 1RM FS (kg) significantly increased (p < 0.01) in all groups ([A: (17.4 ± 2.2 kg); ES = 1.26], B (10.88 kg; 11.04%; ES = 0.99), C (14.88 kg; 17.9%; ES = 0.85), D (12.12 kg; 14.3%; ES = 0.93) and E (5.91 kg; 6.8%; ES = 0.48)). Significant differences (p < 0.05) were observed after training in the magnitude of the increase between the A and E groups. (Fig. 1). The intraclass correlation coefficient (ICC) was 0.90 (0.87–0.92).

Velocity of displacement in FS (m/s) significantly increased (p < 0.01) in all groups ([A (0.14 m/s); 15.2%; ES = 1.45], B (0.06 m/s; 6.6%; ES = 0.79), C (0.17 m/s; 19.5%; ES = 2.56), D (0.07 m/s; 8.1%; ES = 1.05) and E (0.08 m/s; 8.6%; ES = 1.18)). Significant differences (p < 0.05) were observed after training in the magnitude of the increase with the A and C groups (Fig. 2). The intraclass correlation coefficient (ICC) was 0.90 (0.88–0.92).
4. Discussion

The outcome of this experiment adds value to previous studies on different performance adaptations through the use of traditional heavy resistance, power-oriented strength, plyometric and combined training approaches. Our findings illustrate that a 7-week combined training approach results in a light improvement in maximal strength performance than any other standalone training. The results also show that a combined training program produces more powerful stimulus in improving the various parameters of strength ability than any lone program.

A great deal of research has focused on the development of sprint performance using a myriad of training methods. Some studies have found that the PT causes significant improvements in the sprint performance, while others show contrary results. Several studies have also suggested that combined resistance training with PT and heavy-resistance training alone can improve the sprint ability. Interestingly, results in the present study indicate that significant improvements may be attributed to the lack of specificity in the training. Possibly a training program that incorporates greater horizontal acceleration (i.e., skipping, jumps with horizontal displacement) or combined with strength/power training may give a more beneficial effect.

Several studies have shown the effectiveness of power-oriented and heavy-resistance training in improving strength and motor performance. The results of this investigation concur with those studies, showing that a combined program can significantly increase strength performance. Interestingly, the study also illustrates that the magnitude of increases in maximal strength performance was almost the same for A (combined training) and C (non-ballistic PS) experimental groups, despite the fact that the average number of exercises and repetitions completed by group (A) more than doubled that performed by each of the experimental groups. This finding is at variance with the results of previous studies, which suggested that a combined training program provides the most powerful stimulus in improving various parameters of strength ability. This discrepancy may be attributed to the fact that the participants in this study were not specialists in plyometric and weight training in contrast with the greater training experience and initial training status of participants in previous research. Moreover, some authors have shown that participants with lower levels of strength exhibit significant improvement in strength ability, regardless of the training stimulus, while previously strength-trained participants may exhibit limited improvements in strength ability.

It is also true that the great improvements in strength ability are related to the use of power-oriented exercises (i.e., snatches, cleans, snatch pull, clean pull, and jump squats) characterized by a more forceful and rapid execution of stretch-shortening cycle, which therefore enhances mechanical power output and maximal strength performance. Indeed, these types of exercises have been proposed as ideal exercises for developing maximal strength because of their similarity in movement patterns, velocities, power output and high mechanical specificity.

As is habitual with similar research, we hypothesized here that combined training is superior to one training mode alone. However, the differences, although favorable to the group that trained with the combination of exercises, were lower than expected and not significant. One plausible explanation could be related to the residual fatigue effect of an excessive number of exercises to ensure a sufficient recovery of participants’ neuromuscular and metabolic systems. Thus, it can be argued that greater improvement could have been achieved by reducing the number of exercises to 2 or 3.

One may also contend that the limited improvements observed after heavy-resistance training (group B) in all the variables measured could be because of the lower velocity of displacement used during the training with FS, which was produced by the use of high loads (i.e., 60–85% of 1RM). The FS 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 and displacement on improvement of power performance. Thus, the improvement of group C (i.e., power oriented strength training using PS exercise) could be accounted for the use of loads (i.e., 100–130% of load that maximizes power output for 2–6 repetitions) 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., by training at a speed that is closer to the actual speed of dynamic athletic performance movements, one may maintain training speed specificity and maximize mechanical power output. Furthermore, in this study, specificity of training was observed because both groups (A and C) show better results over the other groups, particularly in the maximal dynamic strength in FS and in velocity of displacement in FS testing.

Furthermore, the specificity principle of training is particularly highlighted in what is referred to as the velocity of movement execution during training. The improvement in velocity of displacement during the concentric phase of FS was high (groups A and C) in comparison to that observed in the rest of the experimental groups (B, D and E). This may suggest that the principle of specificity shows that there seems to be a series of biomechanical factors (i.e. kinetic and kinematic movement patterns) 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.

5. Conclusion

Research findings on the optimal training methodology to enhance sprint performance (30 m) and force development have shown conflicting results. Some studies suggest that if training programs designed and implemented correctly, both non-ballistic high velocity training and faster power oriented strength training alone, or in combination with PT, would provide a similar positive training stimulus to enhance maximal strength performance. The similarity of results may be related with the training stimulus (i.e., training intensity, volume, and exercise selection) or the relatively low training status of the participants before commencing the interventions. Similar studies using larger group numbers but shorter distances to measure the acceleration and sprint performance, plus more extensive preparatory strength–power programs may produce results indicating the superiority of one or more of these training modes.

Practical implications

- After 7-week of training program our findings reveal that a combined training approach (i.e., using FS, PS, loaded CMJ and plyometric exercises) will result in a light, though insignificant, improvement in maximal strength performance to those observed after heavy-resistance, or power-oriented strength.
training alone (i.e., using plyometric or loaded CMJ training approaches) in active physical education students with no background in regular strength training or competitive sports.

- The study also illustrates that the resemblance between movement patterns and the velocity and displacement common to the training and testing method contributes to greater performance improvement these training groups.

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