# Effects of Sprint and Plyometric Training on Muscle Function and Athletic Performance

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# Effects of Sprint and Plyometric Training on Muscle Function and Athletic Performance

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**Abstract.** Markovic, G., I. Jukic, D. Milanovic, and D. Metikos. Effects of sprint and plyometric training on muscle function and athletic performance. *J. Strength Cond. Res. 21(2):543–549. 2007.*—The purpose of this study was to evaluate the effects of sprint training on muscle function and dynamic athletic performance and to compare them with the training effects induced by standard plyometric training. Male physical education students were assigned randomly to 1 of 3 groups: sprint group (SG; $n = 30$), plyometric group (PG; $n = 30$), or control group (CG; $n = 33$). Maximal isometric squat strength, squat- and countermovement jump (SJ and CMJ) height and power, drop jump performance from 30-cm height, and 3 athletic performance tests (standing long jump, 20-m sprint, and 20-yard shuttle run) were measured prior to and after 10 weeks of training. Both experimental groups trained 3 days a week; SG performed maximal sprints over distances of 10–50 m, whereas PG performed bounce-type hurdle jumps and drop jumps. Participants in the CG group maintained their daily physical activities for the duration of the study. Both SG and PG significantly improved drop jump performance (15.6 and 14.2%), SJ and CMJ height (~10 and 6%), and standing long jump distance (3.2 and 2.8%), whereas the respective effect sizes (ES) were moderate to high and ranged between 0.4 and 1.1. In addition, SG also improved isometric squat strength (10%; ES = 0.4) and SJ and CMJ power (4%; ES = 0.4, and 7%; ES = 0.4), as well as sprint (3.1%; ES = 0.9) and agility (4.3%; ES = 1.1) performance. We conclude that short-term sprint training produces similar or even greater training effects in muscle function and athletic performance than does conventional plyometric training. This study provides support for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

Key Words. muscle contraction, power, force, sprinting, jumping

## Introduction

Performance of a number of individual and team sports that require jumping, kicking, and sprinting rely heavily on explosive leg power. Consequently, during the past decades much effort from both coaches and researchers has been focused on determining the optimal training methods for the development of leg power and dynamic athletic performance. Currently, to enhance muscle power and dynamic performance athletes commonly use (a) heavy resistance training (80–90% of maximal load) and (b) explosive-type training in a form of either explosive (ballistic) resistance training (30–60% of maximal load) or plyometric training (32).

Although both heavy resistance and explosive-type resistance training programs can improve explosive leg power and dynamic athletic performance (16, 32), most researchers and practitioners seem to agree that plyometric training represents a method of choice when aiming to improve athletes' explosiveness and dynamic performance, particularly those involving the stretch-shortening cycle (SSC) (8). Previous studies evaluating the effects of plyometric training showed that this training method improves leg extensor power (8, 17, 26) and (to a lesser degree) strength (20), as well as high-power dynamic movement performance, particularly vertical jump ability (8, 10, 17, 20). Although these findings are not universal (35), plyometric training has been widely accepted as a standard training method used for the improvement of leg muscle power and athletic performance.

Sprint running is also an explosive movement and is commonly used as a testing exercise in many individual and team sports. However, possible use of this potentially useful explosive exercise for the training purpose has been neglected within sports science literature. Still, biomechanical studies of sprint running (for review, see 22), as well as studies comparing the performance characteristics of sprinters with other athletes and/or controls (11, 21), suggest that sprint training could lead to improvements in human muscle power capabilities, as well as to improvements in dynamic athletic performance.

Sprint running represents a multidimensional movement skill consisting of 3 different phases: (a) initial starting phase, (b) acceleration phase, and (c) maximum running speed phase (6). Because of changes in the lean of the body, the involvement of leg muscles and their respective regimes of muscle action, as well as force and power produced, differ among these 3 particular sprint phases (5). Specifically, during the start and acceleration phases, an athlete is accelerating the body primarily through an explosive concentric force production of both knee and hip extensor muscles (6). Thus, at the beginning of the sprint run, the ability to produce a great concentric force/power and to generate high velocity during acceleration is of primary importance (22). During the maximum running speed phase, forward propulsion of the body is determined mainly by the action of the hip extensors and ankle extensors (22, 30). However, in full speed sprinting, the events before and during the braking (i.e., eccentric) phase are also important in increasing explosive force/power of movement in the propulsive (i.e., concentric) phase (22). Thus, SSC muscle function, particularly of ankle extensors, is accentuated during this sprint phase. Furthermore, it has been demonstrated that peak vertical ground reaction forces during foot contact in maximal sprinting (less than 0.1 second) can be higher than 5 times body weight (22), advocating the importance of both high force and high power production. These data suggest that sprint running represents a complex ballistic movement that requires both concentric and SSC explosive force production of most leg extensor muscles. For comparison, plyometric-type jumping also requires explosive force production but involves less active muscle mass that operates mainly in the SSC regime.

In addition to the aforementioned specific biomechanical characteristics of sprint running, several authors also showed that sprinters have highly developed leg muscle strength and power capabilities (11, 21). Specifically, maximal leg strength of sprinters is higher than that of endurance athletes (11) or untrained subjects (21) and is comparable to that of highly trained strength athletes (21). Moreover, along with Olympic lifters (9), sprint athletes also are known as the most powerful athletes, particularly when overcoming low to moderate resistance (21).

All stated suggest that sprint running could be an effective training method for the development of leg extensor strength and power, as well as dynamic performance of athletes. In addition, due to concentric and SSC force production during sprinting (22), it can be expected that sprint training might lead to improvements in both concentric and SSC muscle function. However, studies evaluating the effects of sprint running training on human muscle function and performance are lacking. Therefore, the purpose of this study was to evaluate the selective effects of 10-week sprint training on muscle function and athletic performance and to compare these effects with the one induced by conventional plyometric training. We hypothesized that, due to its multidimensional nature (see previous text), sprint running will produce greater selective effects on both concentric and SSC muscle functions, as well as on athletic performance compared with conventional plyometric training.

## Methods

### Experimental Approach to the Problem

The study was a randomized controlled trial. Subjects were assigned randomly to 2 experimental groups and 1 control group. The control group was instructed to maintain regular activities and to avoid any strenuous physical activity during the study. Subjects in both experimental groups completed 10-week exercise training on alternate days (i.e., 3 days a week) with a pause of 1 week in the middle of the training study. Performance tests were performed in the week before and the week after the 10-week training period. All testing and training took place at the same time of day to control for circadian variation in performance. In order to remove possible learning effects that could confound the results of the study, all individuals participated in a 1-week familiarization period before initiation of the study to accustom themselves to the testing and training procedures. Subjects showed 100% compliance with exercise training.

### Subjects

Ninety-three male physical education students (mean ± *SD*; age: 20.1 ± 1.1 years; body mass: 76.7 ± 8.6 kg; body height: 181.0 ± 6.8 cm; body fat: 8.7 ± 4.1%) volunteered to participate in this study after having all of the risks explained to them before the investigation. They were allocated randomly into 1 of 3 groups: sprint group (SG; $n = 30$), plyometric group (PG; $n = 30$), and control group (CG; $n = 33$). Following randomization, the 3 groups did not differ significantly ($p > 0.05$) in any of the dependent variables. All subjects were physically highly active and were experienced in performing various sprints and SSC jumps through participation in various explosive-type sports activities (i.e., soccer, handball, basketball, track and field) through their regular academic program. Specifically, their weekly volume of regular physical activity ranged between 8 and 10 hours. It also should be pointed out that all the subjects had at least 1 year of experience in resistance training, but never selectively trained sprints or SSC jumps for a longer period of time. The study was approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb, and all subjects signed an informed consent document according to the Helsinki Declaration. None of the subjects reported any medical or orthopedic problems that would compromise his participation and performance in the study.

### Testing Procedure

In order to evaluate the effects of sprint and plyometric training on muscle function and performance, we applied a testing procedure that included measurements of 4 specific motor qualities: muscle strength, muscle power, SSC muscle function, and athletic movement performance. The tests applied proved to be highly reliable (see the "Results" section) and are used routinely for the assessment of human muscle function and dynamic athletic performance by both the researchers and practitioners in various human movement–related areas, particularly in sport (e.g., 24, 25, 33).

*Muscle Strength.* Leg extensor muscle strength was assessed by an isometric squat test. A modified testing procedure applied previously (32) was used to measure isometric squat strength. A squat rack was secured into the floor above the force platform (Kistler type 9290AD; Winterthur, Switzerland). An Olympic bar was fixed at a selected point above the force platform with an accuracy of 2 cm by means of mechanical stops. The subject was positioned in the squat rack with his heels directly under the bar, and the angle of the knee was set to 120° (33). The subject was instructed to gradually exert force until no further increase was detected (33). All subjects wore a lifting belt during the test. The force plate was reset to zero prior to the test in order to cancel out the subject's weight (32). The force was sampled at a rate of 500 Hz over 5 seconds following the initiation of the contraction.

*Muscle Power.* Muscle power of leg extensor muscles was assessed through both the mean concentric power calculated from the recorded ground reaction force and through jumping height using 2 different vertical jump tests: squat jump and countermovement jump. Squat jump (SJ) was performed from a semisquat position, with the arms held akimbo in order to avoid arm swing (14). Squat jump trials were repeated if a preparatory dip was observed on the force-time graph. Countermovement jump (CMJ) was performed in a similar way to the SJ, except that the subject was instructed to perform an unconstrained vertical jump from a standing upright position that includes the initial countermovement (14). The force platform measurements were used to calculate the muscle power as a product of the vertical component of the ground reaction force and velocity of the center of mass (4). The velocity was obtained from the integral of the acceleration provided by the force signal, whereas the final result was the muscle power averaged over the propulsive jump phase (i.e., the time interval from the instant of the velocity turning upward to the end of the feet's contact with the platform). The vertical component of the measured ground reaction force also served for calculation of the jump height.

*Stretch-Shortening Cycle Muscle Function.* Stretch-shortening cycle leg extensor muscle function was assessed using a drop jump (DJ) performed on a force plate (Kistler type 9290AD). The test was conducted with the arms akimbo to eliminate any contribution from arm swing. The subject dropped from box height of 30 cm. Upon landing from a drop, the subject was instructed to jump for maximum height and minimum ground contact time. Flight time and contact time were recorded from the force-time signal and performance was calculated as flight time-to-contact time ratio (25). Due to the relatively short contact times and the need to quickly attenuate the eccentric phase, this test was considered a measure of reactive strength capacities (35).

*Athletic Movement Performance.* Three tests previously used to measure jumping (18), sprinting (19), and agility performance (23, 24) were used for the assessment of athletic performance. Horizontal jump performance was assessed using a long jump from a standing position with arm swing (SLJ) (18). Subjects performed SLJ on a long jump mat (Elan, Slovenia), and the distance from the starting point to the landing point at heel contact was used as the result. Although both vertical and horizontal jumps are usually considered as explosive power tests, we decided to include SLJ in analysis as an athletic performance test.

Sprinting performance was assessed using a sprint over a distance of 20 m (19). The test was performed from a standing start and measured by means of infrared photocells (RS Sport, Zagreb, Croatia). The subject was initially standing with his rear (swing) leg on a contact mat. He was instructed to accelerate as quickly as possible through the timing gate positioned 20 m from the starting line. Moving the rear leg from the contact mat initiated a digital timer (resolution, 0.001 second).

Subjects' agility performance was assessed using 20-yd shuttle run as follows (23, 24): on an indoor surface a 2-ft piece of tape was placed to mark a center line. From the center line, 5 yds (i.e., 4.57 m) was measured in both directions and these spots also were marked with the tape. The subject was instructed to straddle the center line with his feet and to place one hand on the line. On the command of the timekeeper, the subject ran toward the line of his choice and touched it with his hand and foot, changed direction, and ran past the center line to the opposite line and also touched it with his hand and foot. Again, the subject changed direction and ran through the center line. The drill was over when the subject crossed the center line with his body. Time was measured with a manual stopwatch (0.01 second).

Each test was performed with 3 trials, and the best performance in each test was used in further analysis.

### Training Procedure

The SG and PG groups were required to perform 3 sessions per week on alternate days (i.e., on Monday, Wednesday, and Friday) for 10 weeks. Thus, the program entailed 30 training workouts for each subject in both experimental groups. One unloading week was introduced between the two 5-week cycles (see also Table 1). Training sessions in both experimental groups lasted 60 minutes and began with a standard 15-minute warm-up: 5 minutes of jogging, calisthenic exercises, and stretching. All sprints and jumps were performed on an indoor athletic running track. The training program employed by each experimental group is outlined in Table 1. It should be stressed that many previous studies used plyometric or sprint training in combination with strength training. However, to be able to evaluate the selective effects of sprint training and to compare these effects with the one induced by conventional plyometric training, we decided not to include the strength training in our study. We specifically advised all subjects to avoid any other type of training during the study.

**TABLE 1.** Training program for the plyometric- and sprint-training group.

| | Plyometric group | Sprint group |
|---|---|---|
| Week | Exercise × sets* × reps | Exercise × sets† × reps† |
| 1 | 40-cm hurdle jumps × 5 × 10 | 10-m sprint × 3 × 3 |
| 2 | 40-cm hurdle jumps × 7 × 10 | 10-m sprint × 4 × 3 |
| 3 | 40-cm hurdle jumps × 10 × 10 | 20-m sprint × 3 × 3 |
| 4 | 60-cm hurdle jumps × 5 × 10 | 20-m sprint × 4 × 3 |
| 5 | 60-cm hurdle jumps × 7 × 10 | 30-m sprint × 3 × 3 |
| 6 | Unloading week (rest) | |
| 7 | 60-cm hurdle jumps × 10 × 10 | 30-m sprint × 4 × 3 |
| 8 | 40-cm drop jumps × 4 × 10 | 40-m sprint × 3 × 3 |
| 9 | 40-cm drop jumps × 4 × 10 | 40-m sprint × 4 × 3 |
| 10 | 40-cm drop jumps × 4 × 10 | 50-m sprint × 3 × 3 |
| 11 | 40-cm drop jumps × 4 × 10 | 50-m sprint × 4 × 3 |

* Rest intervals between sets for PG were 3 minutes.

† Rest intervals between sets and repetitions for SG were 3 and 1 minutes, respectively.

Subjects in both experimental groups were instructed to perform exercises in each training session with maximum effort (i.e., maximal intensity). For the PG, this meant that each jump should be performed to reach maximal height with minimal ground contact time (i.e., so called "bouncing-type" jumps; 1). Specifically, both hurdle jumps and DJs were performed with small angular knee movements, touching the ground with the ball of the feet only (15), thereby stressing the calf muscles particularly. Each set of hurdle jumps consisted of 10 continuous jumps over hurdles placed in front of the subject with an interdistance of about 1 m. Each set of DJs consisted of 10 maximal rebounds after the drop from the 40-cm box, with the pause between each rebound being about 5 seconds (i.e., time needed for the subject to step on the box again). For the SG, this meant that each sprint run should be performed with maximum acceleration and speed.

Because plyometric training included bilateral force production and sprint running included unilateral, it is impossible to match the overall training volumes for the 2 training methods applied. However, the duration of each training session, as well as the duration of pauses between sets, was the same for both groups. Moreover, the total number of ground contact times for each leg per session was similar in both groups. Thus, we considered that the difference in training volume would not represent an important factor when comparing the effects of these 2 training methods. All subjects were instructed to maintain their normal dietary practices throughout the investigation.

### Statistical Analyses

Measures of centrality and spread are shown as mean ± *SD*. Reliability of all muscle function and athletic performance tests was expressed by intraclass correlation coefficients (ICC) and coefficients of variation (CV). The ICCs were calculated from repeated measures analyses of variance (ANOVA), whereas the CVs were derived by 2-way ANOVA in the following way: the participants represented a random effect, the number of test in sequence was a fixed effect, whereas the log-transformed performance measure was the dependent variable. The mean CV was calculated from the root mean square error (RMSE) using the following formula: $CV = 100\ (e^{RMSE} - 1) \approx 100 \times RMSE$ (12). The 95% confidence intervals for

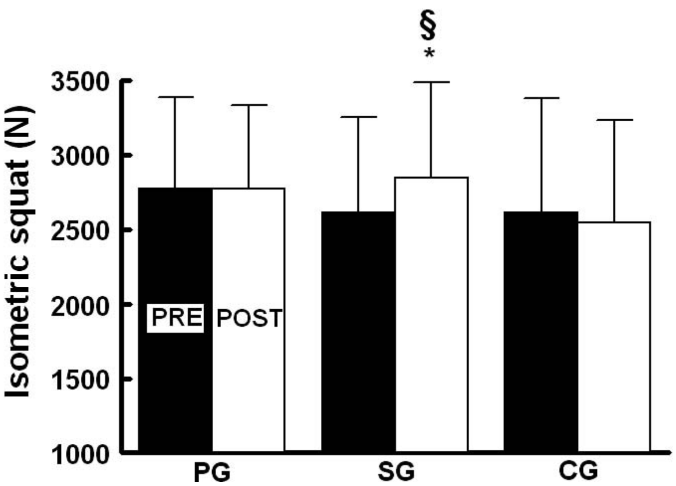


**FIGURE 1.** Training associated changes in maximal isometric force of leg extensors (mean ± *SD*). * Within group, post value significantly different from pre value; $p < 0.0167$. § Significantly different from both plyometric (PG) and control group (CG); $p < 0.05$.

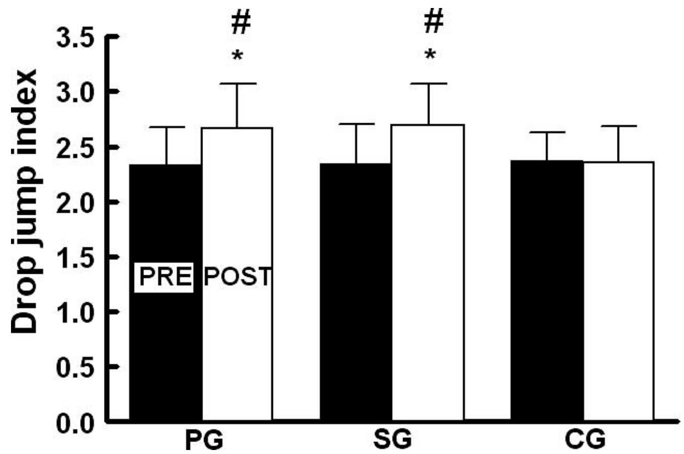


**FIGURE 3.** Training associated changes in SSC muscle function as assessed from drop jump index (mean ± *SD*). * Within group, post value significantly different from pre value; $p < 0.0167$. # Significantly different from control group (CG); $p < 0.05$.

both ICC and CV were calculated also. Magnitude of changes in the 3 groups was compared using a 1-way ANOVA on the difference (post minus pre) scores. When significant treatment effects occurred, Tukey post hoc tests were employed to locate specific significant differences between groups. The level of statistical significance was set at $p < 0.05$. Effects of training within each group were assessed using Dunn's multiple comparison procedure incorporating the Bonferroni correction to maintain the family-wise type I error rate at 0.05. By using the Bonferroni correction, the 0.05 significance level was divided by 3 (3 *t*-tests), yielding a type I error rate of 0.0167 for each *t*-test. Magnitude of treatment effects both within and between groups were estimated with Cohen's effect size (ES) (29). The within-group ES is defined as the difference between posttest mean and pretest mean divided by pretest *SD* (29). The between-group ES is defined as the difference between experimental group posttest mean and control group posttest mean divided by control group pretest *SD*.

## RESULTS

The CVs and ICCs for all selected tests ranged between 1.9 and 4.1% (95% confidence interval, 1.7–4.8%) and between 0.91 and 0.96 (95% confidence interval, 0.88–0.97), respectively, indicating high absolute and relative reliability.

*Muscle Strength.* Differences in isometric squat strength are presented in Figure 1. Only the SG group significantly improved leg extensor strength by 10% ($p = 0.002$; ES = 0.4) and this improvement was significantly greater than that of PG ($p = 0.04$) or CG ($p = 0.02$).

*Muscle Power.* Changes in muscle power were assessed through either jumping height or mean concentric power in SJ and CMJ. Differences in SJ and CMJ height are presented in Figure 2a and b, respectively. Both SG and PG significantly ($p < 0.001$) improved jumping height in SJ (10%; ES = 1.1 vs. 6.5%; ES = 0.5) and CMJ (7.4%; ES = 0.8 vs. 6.3%; ES = 0.5) and these improvements were significantly higher ($p < 0.001$) compared with CG. There were no significant differences ($p = 0.1$) in the training effects in jumping height for SJ and CMJ between SG and PG. However, when mean concentric power in SJ and CMJ was used as an index of muscle power (Figure 2c,d), significant improvements ($p < 0.005$–$0.001$) were found only in SG (4%; ES = 0.2 and 7%; ES = 0.4 for SJ and CMJ, respectively), and this improvement was significantly greater ($p = 0.02$) than in CG.

*SSC Muscle Function.* Differences in DJ performance are presented in Figure 3. Both SG and PG significantly ($p < 0.001$) improved DJ performance (15.6%; ES = 1.0 vs. 14.2%; ES = 0.9), and this improvement was significantly greater ($p < 0.001$) compared with CG. There was no significant difference in the training effects ($p = 0.88$) for DJ between SG and PG. When analyzing changes in the flight time and contact time separately, we found that improvement in DJ performance in PG is the result of shortening the contact time only (13.7%; ES = 0.8; $p < 0.001$), whereas the flight time (i.e., jump height) re-

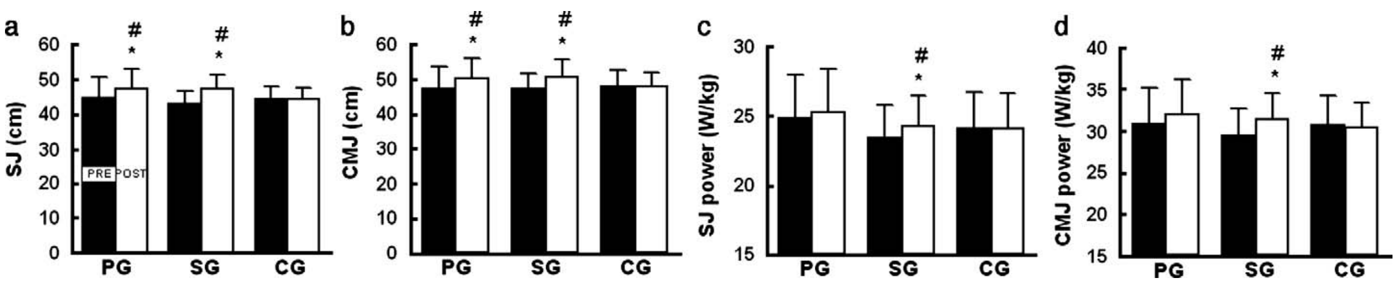


**FIGURE 2.** Training associated changes in muscle power as assessed through squat jump (SJ) height (a) and power (c), as well as in countermovement jump (CMJ) height (b) and power (d) (mean ± *SD*). * Within group, post value significantly different from pre value; $p < 0.0167$. # Significantly different from control group (CG); $p < 0.05$.

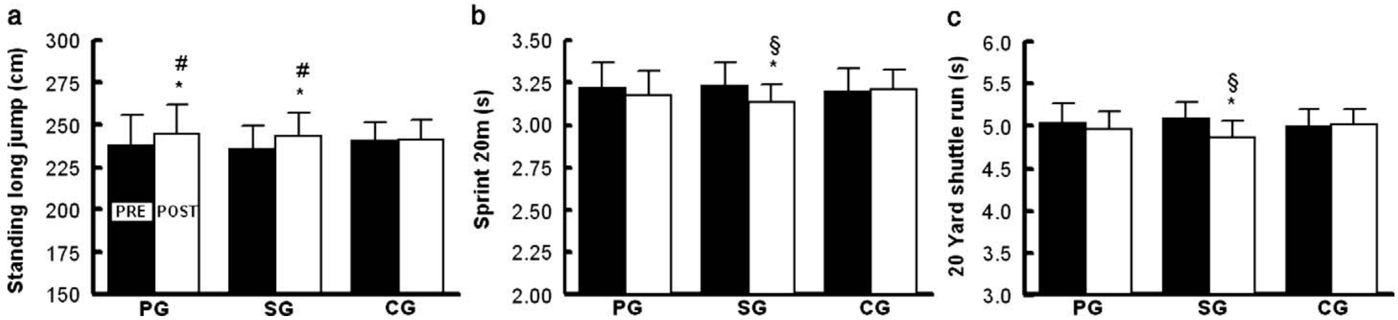


**FIGURE 4.** Training associated changes in athletic performance as assessed from standing long jump (a), 20-m sprint (b) and 20-yd shuttle run (c) (mean ± *SD*). * Within group, post value significantly different from pre value; $p < 0.0167$. § Significantly different from both plyometric (PG) and control group (CG); $p < 0.05$.

mained generally unchanged. For the SG, an improvement in DJ performance is the result of concurrent shortening the ground contact time (11.2%; ES = 0.7; $p < 0.001$) and lengthening the time spent in the air (~4%; ES = 0.3; $p < 0.01$).

*Athletic Performance.* Changes in the 3 measures of athletic performance are depicted in Figure 4. Both SG and PG groups significantly ($p < 0.001$) improved SLJ (3.2%; ES = 0.5 vs. 2.8%; ES = 0.4), and these improvements were significantly ($p < 0.001$) higher compared with CG (Figure 4a). No significant difference in the training effects ($p = 0.78$) for SLJ between SG and PG were found. In the 20-m sprint test, only SG significantly improved (3.1%; ES = 0.9; $p < 0.001$) the performance (Figure 4b) and this effect was significantly higher compared with either PG ($p = 0.02$) or CG ($p < 0.001$). Finally, significant improvement (4.3%; ES = 1.1; $p < 0.001$) in agility performance, estimated by means of the 20-yd shuttle run, was found only in SG (Figure 4c), and this improvement was also significantly greater compared with either PG ($p = 0.008$) or CG ($p < 0.001$).

For significantly higher treatment effects observed in SG over CG, ES ranged from small values (i.e., ES = 0.2–0.4; SJ power), over moderate values (i.e., ES = 0.5–0.8; isometric squat strength, SLJ, CMJ power) to large values (i.e., ES > 0.8; DJ, SJ, CMJ, 20-m sprint, 20-yd shuttle run). For significantly higher treatment effects observed in PG over CG, ES also ranged from low values (SLJ) over moderate values (SJ, CMJ) to high values (DJ).

## DISCUSSION

This study evaluated the selective effects of 10-week sprint training on muscle function and athletic performance in physically active men. A comparison with the frequently used plyometric training also was conducted. The main result of this study is associated with the sprint training–induced changes in muscle function and athletic performance. In particular, we demonstrated that 10-week sprint training significantly improved leg extensor strength (Figure 1) and power (Figure 2), as well as SSC muscle function (Figure 3). In addition, significant improvements in muscle function as a result of sprint training also were accompanied with significant positive changes in all 3 dynamic movement performance tests (Figures 2 and 4). Hence, our data represent a rather novel finding that could be of considerable importance for improving training methods aimed at enhancing athletic performance.

Information regarding the effects of sprint training on muscle function and athletic performance is generally lacking. Few studies showed significant improvements in sprint performance as a result of short-term sprint training (3, 34), supporting our findings and the well-known principle of training specificity (28). In order to get more insight into sprint training–induced effects, we compared the sprint training with the popular, extensively studied, and widely used plyometric training. In general, we found that sprint training produces similar or greater training effects than does plyometric training. Specifically, it was found that both training groups improved to a similar extent in jumping height, jumping distance and SSC performance over a 10-week period. Yet only SG significantly improved leg extensor strength, SJ and CMJ power, as well as sprint and agility performance, and these effects (except for SJ and CMJ power) were significantly higher than those for PG. It is also important to note that, in the DJ performance (i.e., SSC muscle function), both training groups significantly decreased ground contact time, but only SG significantly increased flight time as well. Albeit speculative, our results suggest that the changes in performance resulting from either sprint or plyometric training could have different neuromuscular origin. In particular, it appears that the improvements in jumping (but also in sprint and agility) performance as a result of sprint training could be partly the result of improved leg extensor strength and power. In contrast, plyometric training–induced positive changes in jumping performance were not accompanied with the positive changes in leg extensor strength or power. This is in contrast to some (8, 20), but not all (32, 35), previous studies on plyometric training. Therefore, it is possible that the plyometric training used in this study could have improved subjects' jumping performance primarily by improving muscle coordination (2). However, this is only an assumption, because the recorded parameters do not provide the bases for a more specific interpretation of the obtained results. By including electromyographic (EMG) measurements in the evaluation of muscle function, future studies should test this conjecture. In addition, EMG muscle evaluation also would allow researches to examine whether sprint training–induced changes in leg extensor strength and power are the result of neural or muscular adaptation.

Most previous studies compared the effects of plyometric training with the effects of strength training alone (32) or of their combination (8). To the best of our knowledge, only 1 study compared the effects of sprint and plyometric training on human muscular performance (27). In contrast to our findings, the authors reported that plyometric training can improve short sprint performance to the same extent as standard sprint training (27). However, it must be noted that the authors used sprint-specific plyometric exercise (i.e., hopping and bounding exercises) in the plyometric group, thereby increasing the degree of specificity of training exercises. Moreover, the sample size of the sprint group was rather small ($n = 7$), reducing the statistical power of the study (see also further discussion).

An important point that deserves to be discussed is related to high reliability of all tests together with the sample size in our study. Our results reveal exceptionally high reliability of all selected muscle function and athletic performance tests. In particular, CVs and ICCs together with their corresponding 95% confidence intervals indicate high within-individual and between-individual reliability. This can be explained partly by an extensive familiarization of our subjects with testing procedures before initiation of the study. Moreover, in our case, sample size within each group considerably exceeded the usual sample size in studies evaluating training intervention programs. Specifically, in most previous studies dealing with the effects of plyometric training, the number of subjects per group was usually between 8 and 12 (1), or 3 times fewer than the number of subjects applied in our study. Sample size is one of factors directly influencing the power of detecting the real and meaningful effect in treatment studies (29). In our case, for both within-group and between-group comparisons statistical power (1-β) exceeded 0.8 for medium effect sizes (mean difference / $SD > 0.5$), supporting the appropriateness of the sample size applied. Therefore, in addition to the high reliability of measurements in our study, the sample size applied allows us to conclude with high confidence that sprint running produces similar or greater training effects on muscle function and dynamic performance compared with conventional plyometric training.

It is also important to emphasize the extent of generalization of our findings. Evidently, we cannot generalize our findings to highly trained athletes. However, it should be highlighted that our subjects, albeit not belonging to the athletic population, were highly physically active (see also "Methods" section). Moreover, their results in some strength and power measures were in line with the results obtained on trained athletes (7, 13, 31). Specifically, subjects' SLJ performance was similar to the results obtained on trained sprinters and jumpers (13), whereas their mass-specific SJ power was comparable to the values reported for trained strength and power athletes (7). In addition, maximal isometric squat strength was even higher than the values previously reported for athletes of different specialization (31). Therefore, it is reasonable to assume that similar findings also could be obtained on novice or moderately trained athletes of similar age and physical characteristics.

In summary, our study provides evidence that, when the aim is to improve athletes' muscle function and dynamic performance, sprint training may be comparable or even superior to standard and widely used plyometric training. Although further study definitely is required, it is reasonable to suggest sprint training as an applicable training method of improving explosive performance of athletes in general. Superiority of sprint training over plyometric training in our study is particularly evident for improvements in leg extensor strength and power, as well as for improvements in sprint and agility performance. This can be explained partly by the multidimensional nature of sprint running that activates greater proportion of the leg musculature and requires both concentric and SSC rapid force production. Further research is needed in order to describe the specific mechanisms responsible for the muscle function and performance improvements induced by the sprint training, as well as to test the validity of our findings on trained athletes. In addition, future studies also should address the synergistic effects of combining sprint and plyometric training with the resistance training. These data will enable us to give more general recommendations for the use of sprint and plyometric training in the development of muscle power and dynamic athletic performance.

## PRACTICAL APPLICATIONS

Improving muscle function and athletic performance is of the utmost importance for strength and conditioning professionals. To enhance explosive muscle power and dynamic athletic performance, several training strategies can be used, such as heavy-resistance training, explosive-type resistance training, and plyometric training (32). The findings of this research indicate that sprint running also can be used effectively as a training method for improving explosive leg power and dynamic athletic performance. Therefore, in addition to the well-known training methods such as resistance training and plyometric training, strength and conditioning professionals may well incorporate sprint training into an overall conditioning program of athletes striving to achieve a high level of explosive leg power and dynamic athletic performance.

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