The Effects of Treadmill Sprint Training and Resistance Training on Maximal Running Velocity and Power

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Abstract

Ross, RE, Ratamess, NA, Hoffman, JR, Faigenbaum, AD, Kang, J, and Chilakos, A. The effects of treadmill sprint training and resistance training on maximal running velocity and power. *J Strength Cond Res* 23(2): 385–394, 2009—The purpose of the present study was to examine the independent and combined effects of resistance and treadmill sprint training on maximal sprint velocity and power. Twenty-five male athletes (age = 19.8 ± 1.5 years, height = 181.2 ± 7.9 cm, body mass = 88.9 ± 10.9 kg) were matched for 30-m sprint times and assigned to 1 of 3 training groups: 1) sprint training only (ST), 2) resistance training only (RT), or 3) combined sprint and resistance training (SRT) for 7 weeks. Periodized resistance training was performed 4 $d{\cdot}wk^{-1}$ (3–4 sets of 6–10 repetitions). The treadmill sprint training program was performed 2 $d{\cdot}wk^{-1}$ and consisted of 8–12 sets of maximal sprints for 40–60 m at 0–25% of each athlete's body mass, with rest intervals of 2–3 minutes on a treadmill that was user driven and that enabled loading via a magnetic braking system. Peak 30-m sprint times, power and average velocity attained during maximal sprint trials on the treadmill, and 1-repetition maximum (1RM) squat were determined pre and post training. The 30-m sprint times improved significantly only in the SRT group, and a trend for improvement ($p = 0.06$) was observed in the ST group. All groups significantly increased treadmill sprint velocity. However, the SRT and ST groups increased significantly more than RT. Only the SRT group increased treadmill sprint peak power. All training groups increased 1RM squat strength significantly by 6.6–8.4 kg, with no differences observed between groups. The results of this study showed that 7 weeks of sprint training on a newly designed treadmill resulted in significant kinematic and kinetic improvements in sprint performance. Of practical significance, treadmill sprint training enhanced land-based sprint performance.

Key Words maximal strength, periodization, resisted sprinting, speed

Introduction

Maximal running speed is a critical component to success in many sports. Maximal running, or sprinting, can be divided into 3 distinct phases–acceleration, constant velocity (or maximum speed), and deceleration–all of which can be improved via specific training (22). The acceleration phase may be subdivided into 2 phases: the initial phase characterized by changes in stride length (0–10 m) and a transition phase (11–36 m) characterized by greater stride frequency (9). This acceleration phase is highly dependent on reaction time and the athlete's ability to generate force during propulsion (22). There is a linear increase in both stride length and frequency up until approximately 7 $m{\cdot}s^{-1}$, after which there is a smaller increase in stride length and a greater increase in stride frequency (22). The constant velocity (maximum speed) phase is characterized by reaching peak stride length, rate, and velocity. When the sprint is of sufficient length and duration, a deceleration phase occurs in which the athlete can no longer maintain his or her maximum velocity.

Athletic training programs are designed to enhance performance of all phases of sprinting and include a combination of plyometric training, sprint training (nonresisted, uphill and downhill running, resisted [chutes, sleds, weighted vests] and assisted towing), and resistance training (1,6,11, 17,20,23,25,28,31). Studies have shown that nonresisted sprint training (6,20,28,31), uphill and downhill sprint training (23), and resisted sprint training (17,28,31) significantly increased acceleration and sprinting speed. In addition, the combination of sprint and resistance training has been shown to be effective for enhancing maximal speed, speed endurance, power, and strength of the lower body

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(16,24). Maximal strength, particularly for the squat and power clean exercise, has been shown to be significantly correlated with sprint performance (8,29). Resistance training increases muscular strength and power and, in combination with sprint training, enables the athlete to exert greater force with each foot contact, thereby increasing running acceleration and velocity (4,16,24). Thus, an integrated training approach seems most effective for maximizing sprinting speed.

The addition of resistance to sprint running (i.e., via weighted vests, towing weighted sleds, or other athletes) has been shown to enhance sprinting speed (5,17). Resisted sprint training seems to produce some kinematic alterations in technique compared with unloaded sprint training (1,7,19,28). Lockie et al. (19) have shown that sled towing decreased stride length (up to 24% depending on the magnitude of loading) and stride frequency and increased ground contact time, trunk lean, and hip flexion. Cronin et al. (7) have shown that weighted vests and sled towing reduced sprint times, decreased stride length and frequency, and increased foot contact duration and trunk angle. Although some research has shown that resisted and nonresisted sprint training led to similar increases in maximal sprinting performance (28), other research has shown that resisted sprint training was more effective for increasing acceleration and that nonresisted sprint training was more effective for enhancing the maximum velocity phase of sprinting (31). Thus, it seems that resisted sprint training may be beneficial for at least enhancing the acceleration phase of sprinting.

The majority of resisted and nonresisted sprint training studies have been performed on indoor and/or outdoor tracks or fields. Although treadmills are a popular piece of equipment for training and performance assessment, less is known concerning the impact of treadmill sprint running on maximal sprinting performance. Recently, a new model of treadmill (Woodway Force 3.0, Woodway, Inc., Waukesha, Wisc) has been designed that enables nonresisted and resisted sprint running. The belt is user driven and contains an electromagnetic braking system that provides up to 68.2 kg of resistance to the treadmill belt. In addition, 4 vertical load cells are located under the running surface that are interfaced with a computer and a specific software program that calculates time, velocity (peak and average), work, power, and distance. Thus, critical kinetic and kinematic information is readily available to the user and may serve as a useful training tool on multiple levels. However, there are no data investigating the efficacy of training on a treadmill of this caliber. Therefore, the purpose of the present study was to examine the efficacy of 7 weeks of resisted and nonresisted sprint training on the Woodway 3.0 treadmill, administered alone and in conjunction with resistance training on maximal running speed and power. A secondary purpose was to examine the potential transfer of training effects from treadmill sprint training to nontreadmill 30-m sprint times.

Methods

Experimental Approach to the Problem

To address the primary hypothesis of this investigation, subjects were matched for 30-m sprint times and randomly assigned to 1 of 3 training groups: 1) a treadmill sprint-only training group (ST), 2) a resistance training–only group (RT), or 3) a combination heavy-resistance plus treadmill sprint training group (SRT). This design enabled us to examine both the independent and combined effects of treadmill sprint and resistance training on maximal sprinting speed, power, and strength. This design also enabled us to examine the potential transfer of training effects from treadmill sprint training to land-based maximal sprint speed and to investigate the potential for resistance training to augment sprint training. Sprint speed, power, and muscular strength assessments were performed before and after 7 weeks of training to evaluate the effects of all training programs.

Subjects

Twenty-five men who were current or former competitive athletes (age = 19.8 ± 1.5 years, height = 181.2 ± 7.9 cm, body mass = 88.9 ± 10.9 kg) who participated in sports such as American football, soccer, and track and field participated in this study. All subjects had substantial experience with nonresisted sprint training because sprinting speed was an integral component to all of their respective sports. None of the subjects were taking any medications or anabolic steroids known to affect sprint and resistance exercise performance. Subjects were matched for maximal sprint performance and randomly assigned to 1 of 3 training groups: 1) ST ($N = 6$, age = 19.8 ± 1.8 years, height = 179.3 ± 12.6 cm, body mass = 80.0 ± 8.4 kg), 2) RT ($N = 9$, age 19.9 ± 1.4 years, height 181.7 ± 6.2 cm, body mass 93.5 ± 12.6 kg), and 3) SRT ($N = 10$, age 19.8 ± 1.2 years, height 182.5 ± 5.0 cm, body mass 93.3 ± 11.6 kg). After initiating the study, 2 subjects in the ST group were unable to complete training because of illness and withdrew from the study; therefore, a smaller N size in the ST group was observed compared with the RT and SRT groups. This study was approved by the college's institutional review board, and each subject signed a written informed consent document before participation. None of the subjects had any physiological or orthopedic limitations that could have affected performance as determined by completion of a health history questionnaire before initiating the study.

Testing Procedures

Maximal sprint and strength testing was performed before and after the 7-week training period. Testing occurred on 2 days separated by 48–72 hours. Maximal strength testing occurred on day 1, and all maximal sprint tests occurred on day 2. Pre and post testing occurred at the same time of day. Because a nonexercising control group was not employed in the present study, test-retest reliability data were calculated for each assessment. Test-retest reliability coefficients were

$R = 0.99$ for strength testing and $R > 0.90$ for all sprint testing measures. Before testing, all subjects participated in 2 familiarization sessions in which they practiced and were critiqued on their barbell squat technique (with light and moderately heavy loading) and completed submaximal 30-m sprints at varying resistances that ranged from 0 to 20% of their body mass.

Maximal Strength Testing

Maximal strength testing took place on 2 separate occasions, before and after 7 weeks of training. The 1-repetition maximum (1RM) squat was used to assess maximal lower-body strength using standardized procedures (14). A warm-up set of 5–10 repetitions was performed using 40–60% of the perceived 1RM. After a 1-minute rest period, a set of 2–3 repetitions was performed at 60–80% of the perceived 1RM. Subsequently, 3–4 maximal trials (1-repetition sets) were performed to determine 1RM. Each subject descended to the "parallel" position in which the greater trochanter of the femur was aligned with the knee and ascended until full knee and hip extension. A research assistant was located lateral to the subject and gave a verbal signal "up" to ensure proper range of motion. Rest intervals between trials were 2–3 minutes. A complete range of motion and proper technique was required for each successful 1RM trial.

Maximal Sprint Testing

Maximal sprint testing was conducted 48–72 hours after 1RM squat testing. Two sprint tests were used: an indoor (to control temperature and wind resistance) 30-m land-based sprint test, and a treadmill sprint test. The 30-m sprint trials were performed indoors on a wooden gym floor. For the 30-m sprint test, subjects warmed up on a stationary cycle for 3–5 minutes followed by low-intensity dynamic stretching and 3 low- to moderate-intensity sprints. Each subject performed 3 maximal sprint trials with 3–4 minutes of rest between trials. The fastest time of the 3 trials was recorded for statistical analysis. All timing was performed with a stopwatch that measured time to the nearest 1/100th of a second. The same technician conducted all sprint trials during pre and post testing. Standardized sprint starts (3-point stance) and footwear were used for all testing sessions. All subjects had extensive sprint training experiences and were current or former athletes quite familiar with sprint testing.

After a 10-minute rest period, subjects completed the treadmill sprint test. The treadmill sprint test consisted of 5 sprints of 20 m; the first 2 trials were nonresisted, and the last 3 trials required the subjects to sprint against a resistance equivalent to 10, 20, and 30% of their body mass, respectively. The order in which the subjects completed the sprint trials was randomized. The treadmill used was a Woodway Force 3.0. The belt was made of vulcanized rubber, was user driven, had a drive system consisting of 114 ball bearings with 12 guide rollers, and contained an electromagnetic braking system that provided up to 68.2 kg of resistance to the treadmill belt. In addition, 4 vertical load cells were located under the running surface, and 1 horizontal load cell was attached to a vertical strut; these were interfaced with a computer and a specific software program that calculated time, velocity (peak and average), work, power, and distance (see Figure 1). Each subject was harnessed around the abdomen to the vertical strut located at the rear of the treadmill to enhance stability and assist in overcoming the inertia of the treadmill belt encountered when starting from a 2-point stance. All subjects were given 3–4 minutes of rest between trials. Sprint trials 1 and 2 (unloaded) were used to measure average velocity data, and sprint trials 3–5 were used to measure peak power outputs (because loaded sprints yielded higher-power data). The subjects' best trials from sprints 1 and 2 and from 3–5 were recorded for statistical analyses.

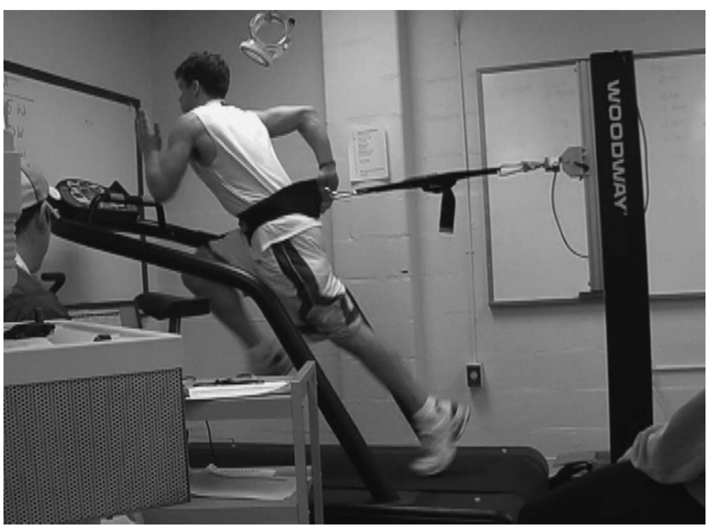

Figure 1. Illustration of subject training on treadmill.

Sprint Training

The ST and SRT groups performed all sprint training on the Woodway Force 3.0 treadmill for 2 workouts per week for 7 weeks. The sprint training program is shown in Table 1. On arrival at the human performance laboratory, subjects performed a 5-minute warm-up on a stationary cycle and then proceeded to a short, submaximal

TABLE 1. Sprint training program.

	Repetitions	Distance (m)	Resistance (% BM)	Rest interval (min)
Week 1				
Day 1	8	60	0	2
Day 2	8	60	0	2
Week 2				
Day 1	4	60	0	3
	2	40	10	3
	2	60	0	2
Total	8			
Day 2	4	60	0	3
	2	40	15	3
	2	60	0	2
Total	8			
Week 3				
Day 1	3	60	0	3
	4	40	15	3
	3	60	0	2
Total	10			
Day 2	3	60	0	3
	4	40	20	3
	3	60	0	2
Total	10			
Week 4				
Day 1	3	60	0	3
	4	40	20	3
	3	60	0	2
Total	10			
Day 2	3	60	0	3
	4	40	20	3
	3	60	0	2
Total	10			
Week 5				
Day 1	2	60	0	3
	8	40	15-0-15-0-20-0-20-0	3
	2	60	0	2
Total	12			
Day 2	2	60	0	3
	8	40	15-0-15-0-20-0-20-0	3
	2	60	0	2
Total	12			
Week 6				
Day 1	2	60	0	3
	8	40	20-0-20-0-25-0-25-0	3
	2	60	0	2
Total	12			
Day 2	2	60	0	3
	8	40	20-0-20-0-25-0-25-0	3
	2	60	0	2
Total	12			
Week 7				
Day 1	8	40	0	3
Day 2	8	40	0	3

BM = body mass.

warm-up on the treadmill. Workouts varied from 8 to 12 maximal sprints for 40–60 m at 0–25% of each subject's body mass, with rest intervals ranging from 2 to 3 minutes. The rationale was to gradually introduce subjects to nonresisted sprints and to progress to resisted sets by the second week. Thus, 25% of the trials were resisted in week 2, 40% in weeks 3 and 4, and 33% in weeks 5 and 6. Sets were alternated between loaded and unloaded sprints during weeks 5 and 6. Week 7 was a tapering period during which volume was decreased and only unloaded sprints were included. Subjects in the SRT group performed their sprint training before resistance training to avoid residual fatigue negatively affecting sprint performance. Peak and average velocity, power, and work were recorded for every set of every workout. Values were averaged for each workout, and percent changes were analyzed from the first to the last workout for the ST and SRT groups.

Resistance Training

The RT and SRT groups performed the same periodized resistance training program for 7 weeks; this program had been shown previously to enhance maximal strength (13). Subjects trained 4 $d \cdot wk^{-1}$ with 2 predominantly lower-body workouts (Tuesday and Friday) and 2 predominantly upper-body workouts (Monday and Thursday). Subjects performed 8–9 exercises of 6–10 repetitions with 2- to 3-minute rest intervals between sets (Table 2). A core circuit consisting of 3 consecutive abdominal exercises was performed at the end of each workout. Subjects in all training groups refrained

TABLE 2. Periodized resistance training program.

	Sets × repetitions	
	Weeks 1–3	Weeks 4–7
Days 1 and 3		
Power clean	–	4 × 4–6
Bench press	4 × 8–10	4 × 6–8
Incline bench press	3 × 8–10	3 × 6–8
Incline fly	3 × 8–10	3 × 6–8
Push press	–	4 × 4–6
Seated shoulder press	4 × 8–10	–
Dumbbell shrugs	3 × 8–10	–
Dumbbell front raise	3 × 8–10	3 × 6–8
Triceps push-down	3 × 8–10	3 × 6–8
Triceps dumbbell extension	3 × 8–10	3 × 6–8
Core circuit	2 × 10	3 × 10
Days 2 and 4		
Squat	4 × 8–10	4 × 6–8
Dead lift	4 × 8–10	3 × 6–8
Leg extension	3 × 8–10	–
Leg curl	3 × 8–10	3 × 6–8
Standing calf raise	3 × 8–10	3 × 6–8
Lat pull-down	4 × 8–10	4 × 6–8
Seated row	4 × 8–10	4 × 6–8
Dumbbell hammer curl	3 × 8–10	3 × 6–8
Dumbbell biceps curl	3 × 8–10	3 × 6–8
Core circuit	2 × 10	3 × 10

from participating in any type of exercise outside the domain of the study.

Statistical Analyses

Descriptive statistics (mean ± *SD*) were calculated for all dependent variables. A 3 (group) × 2 (time) analysis of variance with repeated measures was used to analyze all sprint performance data. Because there was a significant pretraining difference observed between groups in maximal strength, 1RM squat data were analyzed via a 3 (group) × 2 (time) analysis of covariance. Subsequent Tukey post hoc tests were used to determine pairwise differences when significant *F* ratios were obtained. Independent *t*-tests were used to analyze sprint training data between the ST and SRT groups. Pearson product-moment correlations were calculated between 1RM squat and various sprint parameters. For all statistical tests, a probability level of $p \le 0.05$ was established to denote statistical significance.

RESULTS

The 30-m sprint results are shown in Figure 2. A significant main effect was observed ($p = 0.02$), but there was no interaction ($p = 0.40$). The SRT group significantly reduced 30-m sprint time (by 0.10 seconds), and a trend ($p = 0.06$) was observed for reduced sprint time in the ST group (by 0.08 seconds). No significant difference was observed in RT.

The 20-m treadmill sprint average velocity and peak power data are presented in Figures 3 and 4. For sprint average velocity, a significant main effect ($p < 0.0001$) and interaction ($p = 0.001$) were observed. The SRT (~8%), ST (~5%), and RT (~1.6%) groups all significantly increased sprint average velocity from pre to post training. However, the increases in the SRT and ST groups were significantly greater than those in the RT group. For sprint peak power, only a significant main effect ($p = 0.002$) was observed. The SRT group was the only group to significantly increase sprint peak power from pre to post training.

Changes in 1RM squat are shown in Figure 5. Pre training, the ST group had a significantly lower 1RM squat than SRT and RT, and 1RM also was significantly lower post training in ST. A significant main effect ($p = 0.018$) was observed, but there was no interaction. The SRT (+8.4 kg), RT (+6.8 kg), and ST (+6.6 kg) groups all made similar significant increases in 1RM squat strength. The 1RM squat was significantly correlated to treadmill sprint peak power ($r = 0.46$ and 0.65

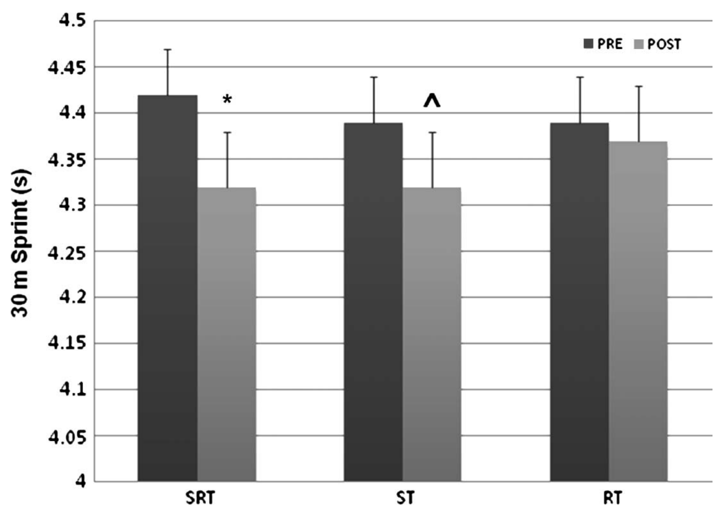

Figure 2. Thirty-meter sprint time changes. SRT = sprint and resistance training; ST = sprint training only; RT = resistance training only. *Significant difference ($p < 0.05$) from pre to post training; ^$p = 0.06$ from pre to post training. Data are mean ± *SEM*.

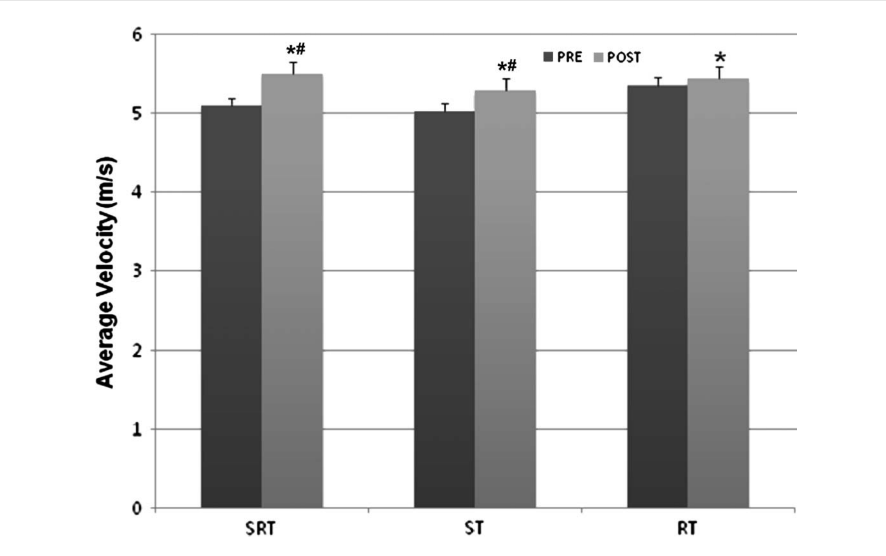

Figure 3. Twenty-meter treadmill sprint average velocity changes. SRT = sprint and resistance training; ST = sprint training only; RT = resistance training only. *Significant difference ($p < 0.05$) from pre to post training; #significant difference ($p < 0.05$) compared with the RT group. Data are mean ± *SD*.

force output. Treadmill sprint average velocity increased 18.5% (range = 6–54%) in SRT and 22.3% (range = 17–26%) in ST. Treadmill sprint peak power increased 39.8% (range = 12–69%) in SRT and 35.6% (range = 20–88%) in ST. However, treadmill sprint average power increased significantly more ($p < 0.001$) for ST (56.2%) than for SRT (35.6%).

pre and post training, respectively). No other significant correlations were observed.

Analysis of individual sprint workout data revealed significant improvements in the SRT and ST groups. Figure 6 depicts the total work performed during each workout for the SRT and ST groups. The patterns reflect program variation, although total work performed for SRT was significantly higher than for ST ($p < 0.001$) because of greater

Discussion

Unique to this study was the examination of sprint training on a user-driven treadmill that enabled resisted sprint training via loading to the belt vs. external loading to the skeletal system. The results of the present study indicate that treadmill sprint training significantly increased sprint velocity and power. Most important, treadmill sprint training increased land-based sprinting speed as evidenced by enhanced 30-m sprint times. The addition of resistance training to treadmill sprint training seemed mostly to augment gains in sprinting power; it had limited effects on velocity. Resistance training alone improved treadmill sprinting velocity, but it did not enhance 30-m land-based sprint performance. Sprint training alone in the ST group significantly increased maximal lower-body strength.

The results of the present study show that treadmill sprint training and sprint training in conjunction with resistance training produced similar improvements in 30-m sprint times. These data support previous studies demonstrating speed enhancement with resisted (17,28,31) and nonresisted (6,20,28,31) sprint training. Maximal sprint speed is the product of stride length and frequency (22), and resisted and nonresisted sprint training has been shown to increase both stride length and frequency (31). Thus, it is likely that an increase in stride length or a combination of increased stride length and frequency

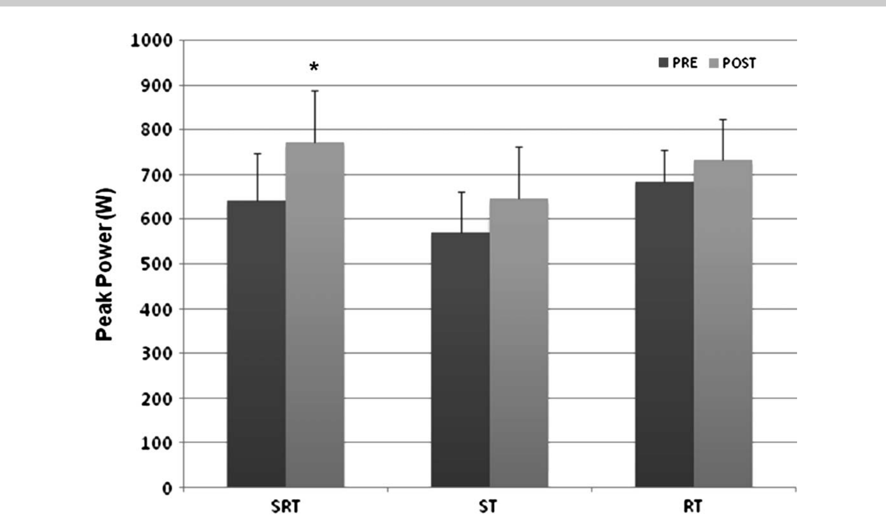

Figure 4. Twenty-meter treadmill sprint peak power changes. SRT = sprint and resistance training; ST = sprint training only; RT = resistance training only. *Significant difference ($p < 0.05$) from pre to post training. Data are mean ± *SD*.

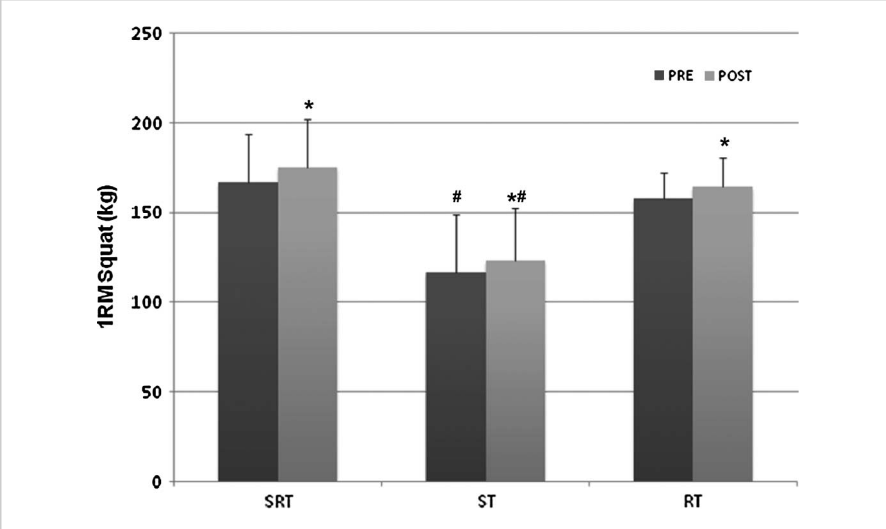

Figure 5. One-repetition maximum (1RM) squat changes. SRT = sprint and resistance training; ST = sprint training only; RT = resistance training only. *Significant difference ($p < 0.05$) from pre to post training; #significant difference ($p < 0.05$) pre and post training between groups. Data are mean ± *SD*.

stimulus for speed enhancement in our subjects who had substantial nonresisted sprint training experience but limited resisted sprint training experience.

Of great significance to the practitioner is the potential for transferred training effects from treadmill sprint training to land-based speed. The principle of training specificity states that performance gains are most specific to the modality used, and training specificity has been observed in the muscle actions involved, speed of movement, range of motion, muscle groups trained, and energy systems involved (15). Thus, the ability of treadmill sprint training to enhance land-based speed may be questioned primarily because of the design of most treadmills, which might limit maximal sprint ability. Treadmill belt speed is manually controlled in many models, and there may be a limitation to acceleration when sprinting on a treadmill because of the lag time observed between programming a high speed and the belt actually reaching that speed in a timely manner. That is, the maximal acceleration ability of athletes may supersede the ability of the treadmill to reach the desired speed in a timely manner. However, a transfer of training effects was observed in the present study in that our results showed significant reductions in 30-m sprint times (0.08–0.10 seconds). The most critical factor leading to the high transfer of training effects to land-based sprint speed may have been the advanced technology of the treadmill. The treadmill used in the present study was user driven (i.e., reacted to each foot contact made by the subject), was capable of reaching velocities higher than most individuals can attain, and provided subjects the ability to rapidly accelerate without hesitation. In addition, the belt provided a wide range of loading that enabled resisted sprint training in a familiar environment. It

occurred. The sprint training program used in the present study combined resisted and nonresisted sprint sets. Resisted sprint training has been used to increase strength and power in the hip, knee, and ankle musculature with the aim of increasing stride length and reducing foot contact time with the ground (28); it also has been shown to significantly enhance acceleration ability (31). Thus, the combination of resisted and nonresisted sprint training seemed to be a potent

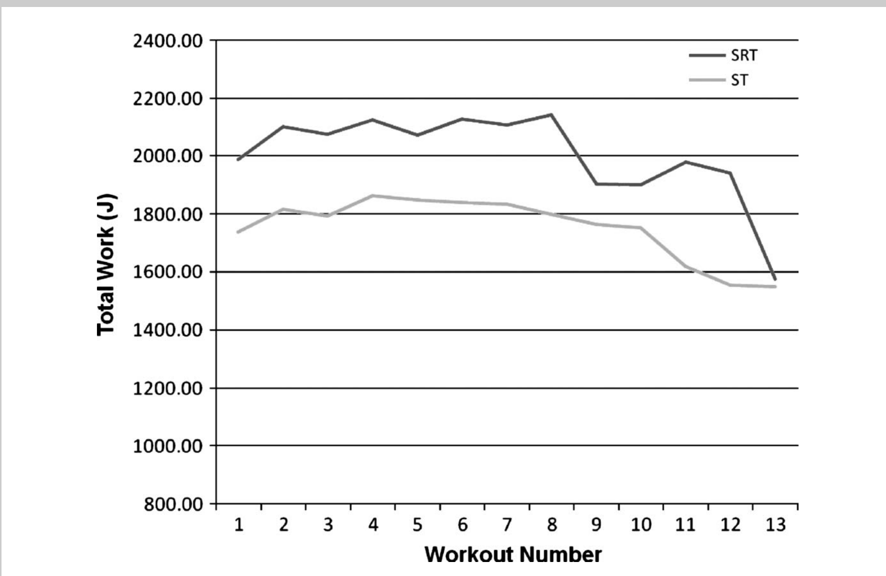

Figure 6. Total work completed during each workout in the sprint and resistance training (SRT) and sprint training–only (ST) groups.

seems plausible that these treadmill attributes mimicked land-based sprinting enough to attain a substantial magnitude of specificity.

The results of the present study also indicated increased sprint velocity and power enhancement assessed via a 20-m maximal treadmill sprint test. The ST and SRT groups increased sprint average velocity by approximately 5–8% from pre to post training, and only the SRT group increased sprint peak power. Analysis of workout training data revealed that treadmill sprint average velocity increased 18.5–22.3%, and sprint peak power increased 39.8 and 35.6% in the SRT and ST groups, respectively. These data indicate that resisted and nonresisted sprint training can significantly improve kinetic and kinematics parameters associated with sprinting.

The addition of resistance training to sprint training (e.g., the SRT group) only augmented 20-m peak treadmill sprinting power. Although the SRT group was the only group to significantly increase sprint average velocity (the ST group showed a trend $p = 0.06$), the addition of resistance training to sprint training only seemed to augment the kinetics of sprinting rather than the kinematics. In support of these data, 1RM squat was significantly correlated with sprint power performance and not 30-m sprint times or treadmill sprint velocity in our subject pool. Thus, the combination of sprint and resistance training provided no additional kinematic enhancement than sprint training alone in the present study. Resistance training has been shown to be a valuable component to a program targeting enhanced sprint performance. Several studies have reported significant correlations between lower-body muscular strength and sprinting speed (2,3,30). Young et al. (30) have reported significant correlations between strength and starting ability ($r = 0.86$), acceleration out of the block ($r = 0.64$), and maximum sprinting speed ($r = 0.80$). Delecluse et al. (10) have reported that heavy resistance training improved sprint ability by increasing acceleration. Absolute maximal strength can improve the force component of the power equation (power = force × velocity). When resistance and sprint training are combined, significant improvements in sprinting speed have been observed (10). In contrast, a few studies have shown limited efficacy of resistance training in reducing sprint times (9,12). In the present study, resistance training alone improved treadmill average velocity but did not enhance 30-m sprint times or any other kinetic parameters (peak or average power) associated with maximal sprint speed. These data demonstrate the need for specific sprint and plyometric training (in addition to resistance training) when the goal is to maximize sprint speed.

Interestingly, analysis of sprint training data revealed similar improvements in most variables in the SRT and ST groups. However, treadmill sprint average power increased to a greater extent in ST than in SRT. Average power was calculated as the mean power attained for each sprint set, and then each workout was averaged according to values attained for each set. The percent increase from the first to last workout was subsequently calculated and analyzed. These data may be interpreted as greater enhancement of high-intensity muscular endurance in the ST group than in the SRT group. Although the addition of resistance training in SRT produced greater gains in peak power, the ST group seemed able to maintain higher power output throughout each workout (i.e., there were fewer reductions in average power during the last few sets per workout). It is important to note that we did not include any assessments of high-intensity sprint endurance pre and post training. However, these data may be reflective of enhanced high-intensity muscle endurance.

One-repetition maximum squat increased significantly in the SRT and RT groups. Interestingly, 1RM squat increased significantly in the ST group as well. Thus, the results of the present study show that sprint training alone can enhance 1RM squat strength in the absence of resistance training. Sprint training is a ballistic modality of exercise that maximizes stretch-shortening cycle activity (22). Electromyographic activity has been shown to increase with increases in running speed (21), and sprint training has been thought to enhance neural function by producing greater recruitment and firing rate of fast-twitch motor units (26). In addition, sprint training is thought to increase reflex potentiation (22), and sprint cycle ergometry training has been shown to increase type II muscle fiber cross-sectional area (18). These adaptations to sprint training have been shown to occur during resistance training (27). It may be hypothesized that sprint and resistance training enhance performance via several common mechanisms and that this could have led to the transfer of training effect to 1RM squat performance observed in the present study. In addition, 1RM strength was lower in the ST group. Thus, training status could have played a role in that these subjects in the ST group could have had a greater window of adaptation. However, the combination of sprint and resistance training in the SRT group did not result in greater gains in 1RM strength compared with the RT group. Thus, the role that sprint training plays in maximal muscular strength increases remains unclear.

In conclusion, this study has shown that treadmill sprint training significantly increased sprint velocity and power. Most important, treadmill sprint training increased land-based sprinting speed as evidenced by enhanced 30-m sprint times. The addition of resistance training to treadmill sprint training seemed mostly to augment gains in sprinting power; it had limited effects on velocity. Resistance training alone did not enhance 30-m land-based sprint performance. These data provide support to the utility of sprint training on a treadmill with advanced technology for enhancing land-based speed.

Practical Applications

The major finding of the present study is that 7 weeks of resisted and nonresisted sprint training on a newly designed treadmill increased land-based maximal speed in addition to velocity and power improvements during sprinting on the treadmill. Coaches, practitioners, and athletes are constantly seeking new and innovative ways to increase maximal speed. Resisted sprint training is commonly used and is effective for enhancing speed development. The development of treadmills that can supply loading to athletes (via the belt as opposed to the trunk, which is common among other methods of resisted sprinting) is unique and may provide functional value to a sprint training program. In comparison with the existing land-based resisted running training procedures, another advantage of using this new technique is that it will allow coaches and athletes to design and monitor training programs more precisely. Our study confirms the utility of training with such a treadmill for enhancing maximal speed. We have shown that a small group of subjects can easily be trained within a short period of time using the sprint program developed in this study. However, one potential limitation is that several treadmills may be needed to sprint train large groups of athletes at the same time.

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References

1. Alcaraz, PE, Palao, JM, Elvira, JL, and Linthorne, NP. Effects of three types of resisted sprint training devices on the kinematics of sprinting at maximum velocity. *J Strength Cond Res* 22: 890–897, 2008.
2. Alexander, MJL. The relationship between muscle strength and sprint kinematics in elite sprinters. *Can J Sport Sci* 14: 148–157, 1989.
3. Anderson, MA, Gieck, JB, Perrin, D, Weltman, A, Rutt, R, and Denegar, C. The relationships among isometric, isotonic, and isokinetic quadriceps and hamstring force and three components of athletic performance. *J Orthop Sports Phys Ther* 14: 114–120, 1991.
4. Blazevich, J. Optimizing hip musculature for greater sprint running speed. *Strength Cond J* 22(2): 22–27, 2000.
5. Bosco, C, Rosko, H, and Hirvonen, J. The effect of extra-load conditioning on muscle performance in athletes. *Med Sci Sports Exerc* 18: 415–419, 1986.
6. Callister, R, Shealy, MJ, Fleck, SJ, and Dudley, GA. Performance adaptations to sprint, endurance, and both modes of training. *J Appl Sports Sci Res* 2: 46–51, 1988.
7. Cronin, J, Hansen, K, Kawamori, N, and McNair, P. Effects of weighted vests and sled towing on sprint kinematics. *Sports Biomech* 7: 160–172, 2008.
8. Davis, DS, Barnette, BJ, Kiger, JT, Mirasola, JJ, and Young, SM. Physical characteristics that predict functional performance in division I college football players. *J Strength Cond Res* 18: 115–120, 2004.
9. Delecluse, C. Influence of strength training on sprint running performance. *Sports Med* 24: 147–156, 1997.
10. Delecluse, C, Coppenolle, HV, Willems, E, Leemputte, MV, Diels, R, and Goris, M. Influence of high-resistance and high velocity training on sprint performance. *Med Sci Sports Exerc* 27: 1203–1209, 1995.
11. De Villarreal, ES, Gonzalez-Badillo, JJ, and Izquierdo, M. Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency. *J Strength Cond Res* 22: 715–725, 2008.
12. Fry, AC, Kraemer, WJ, Weseman, CA, Conroy, BP, Gordon, SE, Hoffman, JR, and Maresh, CM. The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *J Appl Sport Sci Res* 5: 174–181, 1991.
13. Hoffman, JR, Ratamess, NA, Kang, J, Falvo, MJ, and Faigenbaum, AD. Effect of protein intake on strength, body composition and endocrine changes in strength/power changes. *J Int Soc Sports Nutr* 3: 12–18, 2006.
14. Kraemer, WJ, Fry, AC, Ratamess, NA, and French, DN. Strength testing: development and evaluation of methodology. In: *Physiological Assessment of Human Fitness* (2nd ed.). P. Maud and C. Foster, eds. Champaign: Human Kinetics, 2006.
15. Kraemer, WJ and Ratamess, NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sport Exerc* 36: 674–678, 2004.
16. Kraemer, WJ, Ratamess, NA, Volek, JS, Mazzetti, SA, and Gómez, AL. The effects of the Meridian shoe on vertical jump and sprint performances following short-term combined plyometric/sprint and resistance training. *J Strength Cond Res* 14: 228–238, 2000.
17. Kristensen, GO, Van Den Tillaar, R, and Ettema, GJC. Velocity specificity in early-phase sprint training. *J Strength Cond Res* 20: 833–837, 2006.
18. Linossier, MT, Dormois, D, Geyssant, A, and Denis, C. Performance and fibre characteristics of human skeletal muscle during short sprint training and detraining on a cycle ergometer. *Eur J Appl Physiol Occup Physiol* 75: 491–498, 1997.
19. Lockie, RG, Murphy, AJ, and Spinks, CD. Effects of resisted sled towing on sprint kinematics in field-sport athletes. *J Strength Cond Res* 17: 760–767, 2003.
20. Marcovic, G, Jukic, I, Milanovic, D, and Metikos, D. Effects of sprint and plyometric training on muscle function and athletic performance. *J Strength Cond Res* 21: 543–549, 2007.
21. Mero, A and Komi, PV. Force-, EMG-, and elasticity-velocity relationships at submaximal, maximal and supramaximal running speeds in sprinters. *Eur J Appl Physiol* 55: 553–561, 1986.
22. Mero, A, Komi, PV, and Gregor, RJ. Biomechanics of sprint running: a review. *Sports Med* 13: 376–392, 1992.
23. Paradisis, G and Cooke, C. The effects of sprint running training on sloping surfaces. *J Strength Cond Res* 20: 767–777, 2006.
24. Ratamess, NA, Kraemer, WJ, Volek, JS, French, DN, Rubin, MR, Gomez, AL, Newton, RU, and Maresh, CM. The effects of ten weeks of resistance and combined plyometric/sprint training with the Meridian Elyte athletic shoe on muscular performance in women. *J Strength Cond Res* 21: 882–887, 2007.
25. Rimmer, E and Sleivert, G. Effects of a plyometric intervention program on sprint performance. *J Strength Cond Res* 14: 295–301, 2000.
26. Ross, A, Leveritt, M, and Riek, S. Neural influences on sprint running: training adaptations and acute responses. *Sports Med* 31: 409–425, 2001.

27. Sale, DG. Neural adaptations to strength training. In: *Strength and Power in Sport* (2nd ed.). P.V. Komi, ed. Malden, Mass: Blackwell Science, 2003. pp. 281–314.

28. Spinks, CD, Murphy, AJ, Spinks, WL, and Lockie, RG. The effects of resisted sprint training on acceleration performance and kinematics in soccer, rugby union, and Australian football players. *J Strength Cond Res* 21: 77–85, 2007.

29. Wisloff, U, Castagna, C, Helgerud, J, Jones, R, and Hoff, J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med* 38: 285–288, 2004.

30. Young, W, McLean, B, and Ardagna, J. Relationship between strength qualities and sprinting performance. *J Sports Med Phys Fitness* 35: 13–19, 1995.

31. Zafeiridis, A, Saraslanidis, P, Manou, V, Ioakimidis, P, Dipla, K, and Kellis, S. The effects of resisted sled-pulling sprint training on acceleration and maximum speed performance. *J Sports Med Phys Fitness* 45: 284–290, 2005.