Sprint Training on a Treadmill vs. Overground Results in Modality-Specific Impact on Sprint Performance but Similar Positive Improvement in Body Composition in Young Adults

Sandor Dorgo,[1] Jeremy J. Perales,[1] Jason B. Boyle,[1] Jerome Hausselle,[2] and Samuel Montalvo[1]

[1]Department of Kinesiology, University of Texas at El Paso, El Paso, Texas; and [2]School of Mechanical and Aerospace Engineering, Oklahoma State University, Stillwater, Oklahoma

Abstract

Dorgo, S, Perales, JJ, Boyle, JB, Hausselle, J, and Montalvo, S. Sprint training on a treadmill vs. overground results in modality-specific impact on sprint performance but similar positive improvement in body composition in young adults. *J Strength Cond Res* XX(X): 000–000, 2018—The effects of different sprint training modalities on body composition are not yet known, and the effectiveness of using motorized treadmills for sprint training is yet to be assessed accurately. The following study investigated the effects of motorized treadmill and overground training on sprint performance and body composition. Sixty-four young adults (33 men and 31 women) completed 12 sprint training sessions over a 6-week period either on a treadmill (TM) or overground (TR), or followed their normal exercise routine (CONTROL). Fifty-yard sprint time, 20-yard maximal sprint speed split time, and maximal treadmill speed were used as sprint performance indicators. Body composition and sprint performance assessments were completed before and after the 6-week intervention. On completion of the 6-week training program, maximal treadmill speed significantly increased for all 3 groups, while split sprint time significantly decreased for the TR group. The CONTROL group's 50-yd sprint time and split sprint time significantly worsened after 6 weeks. Improvements in sprint time and speed were significantly greater for the TR and TM groups compared with the CONTROL group for 50-yd sprint time, 20-yard maximal sprint speed split time, and maximal treadmill sprint speed. The change in maximal treadmill sprint speed for the TM group was significantly greater than that of the TR group. TR and TM subjects also showed significant decrease in total body fat and increase in leg lean muscle mass. These findings indicate that although overground sprint training resulted in the greatest performance improvements within overground sprint tests, sprint training on a motorized treadmill may be a beneficial alternative modality to overground sprint training and may also positively impact subjects' body composition.

Key Words running, sprint training modalities, high-speed treadmill, overground sprinting

Address correspondence to Sandor Dorgo, sdorgo@utep.edu.

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Introduction

The ability to sprint fast is a key element of success for many sports. Sprint performance is defined by the speed-time and distance-time relationships (14) and is often assessed to determine an athlete's fitness or to monitor general training adaptations (19). Sprint performance in linear running is a multidimensional movement skill that consists of the initial and late acceleration phases, as well as the ability to maintain maximal sprint velocity (11).

Sprint training outdoors often has environmental limitations, while indoor track facilities are not widespread. To circumvent these limitations, treadmills are used as alternative training modalities. To identify effective alternative methods to traditional overground (on the track) sprint training, recent studies focused on high-speed treadmill and nonmotorized treadmill training modalities (3,11). Several studies investigated the kinematic and kinetic differences between overground and treadmill sprint modalities (1,6,11,12,14). Conventional motor-driven treadmills allow an athlete to attain the same velocity as overground sprinting during the maximal velocity phase, but kinematic differences exist particularly during the acceleration phases (12). Because the belt controls the acceleration, a motorized treadmill does not allow the subject to have control over sprint acceleration (12), and on most treadmills, rapid acceleration is not possible (6). Furthermore, researchers found

TABLE 1. Mean ± *SD* of anthropometric measurements of subjects in the overground (TR), treadmill (TM), and control groups.*

Group	*N*	Age (y)	Height (cm)	Body mass (kg)	BMI ($kg\cdot m^{-2}$)
TR	21	23.08 ± 2.94	166.79 ± 5.49	66.95 ± 10.38	24.08 ± 3.81
TM	20	23.04 ± 2.32	168.11 ± 9.42	70.24 ± 12.35	24.77 ± 3.46
CONTROL	23	22.41 ± 1.70	171.65 ± 7.82	79.78 ± 17.23	27.07 ± 5.99

*BMI = body mass index.

that sprinting on a motorized treadmill does not reproduce sprinting biomechanics measured overground (14). During overground sprinting, sprint speed constantly changes as a function of the force applied to the ground throughout the duration of the sprint, which is not the case in treadmill sprinting (14). Sprint performance variables can be 20% lower on a treadmill compared with overground after performing a single 100-m sprint, mainly due to force production differences between the 2 conditions (14). Although these initial findings provide some insight into the biomechanical differences, there is a lack of knowledge regarding the effects of short-term sprint training on sprint performance. Specifically, no study has compared the training effects elicited by overground and treadmill sprint training modalities.

In addition, the current scientific literature has limited experimental data on the effects of sprint training on body composition. Most studies investigating the effects of sprint training on body composition used a cycle ergometer protocol. Running sprint modality was used in 2 studies where subjects completed 30-second sprint intervals 3 times per week on self-propelled treadmill and after a 6-week intervention showed decreased body fat mass and minimally increased fat-free mass (7,9). However, both of these studies used a small sample size and provided no insight as to whether body composition is affected by different sprint training modalities. Furthermore, the body composition assessment method used in these studies allowed no information on regional fat mass and fat-free mass changes. Moreover, our current knowledge is limited whether men and women respond differently to running-based sprint training programs. Therefore, the purpose of the current study was to investigate changes in sprint performance and body composition in young men and women after a 6-week sprint training intervention, training either overground or on a high-speed motorized treadmill. Our study hypothesis was that overground sprint training is superior in both sprint performance and body composition improvements after a 6-week sprint training intervention.

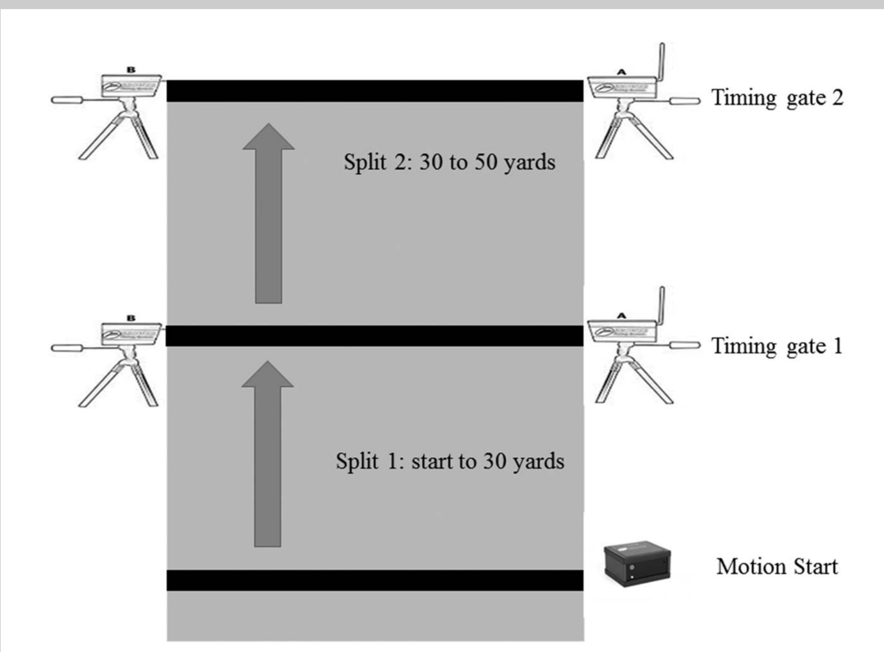

Figure 1. Testing set-up for the 50-yard maximal sprint time test.

METHODS

Experimental Approach to the Problem

This study used a 3-group randomized pre-test to post-test design in which all subjects were considered amateur sprinters. They were first assessed on body

Figure 2. Maximal treadmill sprint speed testing session.

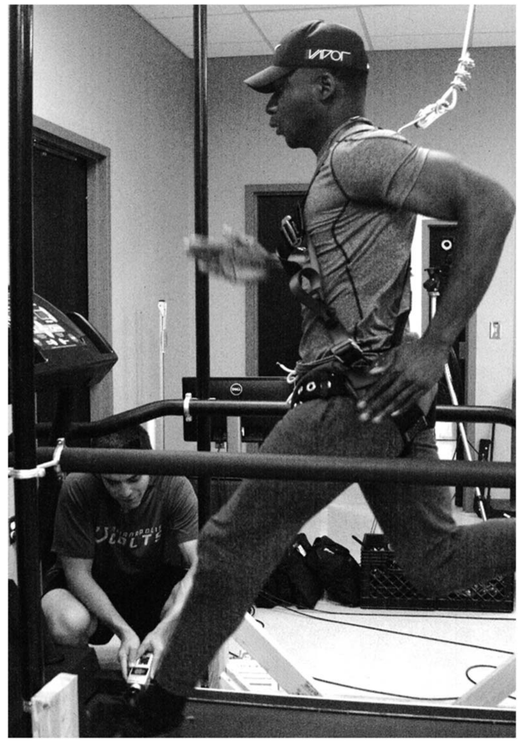

Figure 3. Assessment of belt speed during a maximal sprint speed testing session.

composition and then performed an initial overground 50-yard familiarization sprint test session. On the following week, based on relevant recommendations (15), all subjects underwent a 1-week sprint technique familiarization period. Sessions focused on sprint drills, start/acceleration drills, and maximum sprint intervals. After the 1-week familiarization period, a second overground sprint test (pre-test) and a maximal sprint speed treadmill pre-test were conducted. To allow full recovery between the overground and treadmill tests, a minimum of 48 hours of rest between sessions was required. The faster times of each subject's familiarization test and pre-test sprint times were used as baseline data for statistical analyses.

Subjects were randomly assigned to 1 of the following 3 groups: (a) overground (track) sprint training (TR) group, (b) treadmill sprint training (TM) group, or (c) nontraining control (CONTROL) group. TR group performed sprint training exclusively outdoors on a National Collegiate Athletic Association–certified track while the TM group exclusively on a high-speed motorized indoor treadmill. Subjects in both training groups were asked to attend 2 sprint training sessions weekly for 6 weeks and limit any additional sprint training outside the study. Control group subjects were asked not to engage in any form of sprint training. All sprint and body composition tests were repeated immediately after the 6-week training period.

Subjects

One hundred two recreationally active men ($n = 59$) and women ($n = 43$) with mean ± *SD* age: 23.6 ± 2.85 years; age range: 19 to 30 years, were randomly assigned to either the TR, TM, or CONTROL group. All subjects were informed of the risks and benefits of the study, provided a signed institutionally approved informed consent document, and completed a training history survey. Inclusion criteria for the subjects were as follows: (a) between the ages of 18 and 30 years, (b) free from any underlying diagnosed health conditions (spine deformities, impaired gait, restricted range of motion, heart conditions, musculoskeletal deformations, etc.), (c) free from any serious injuries, and (d) recreationally active with at least 2 sessions weekly involving vigorous running. Specifically, only subjects who reported regularly attending activities such as running-based recreational sports or fitness sessions were accepted. Descriptive data are reported in Table 1. The study was approved by the University of Texas at El Paso's institutional review board before subject recruitment and data collection.

Procedures

50-Yard Sprint Time Test. The overground sprint time test was conducted over a 50-yard distance performed under nonrainy and low wind speed ($<3\ m\cdot s^{-1}$) conditions. Sprint time tests used a Motion Start Timing System (TC-System; Brower Timing Systems, Draper, UT, USA) with 2 sets of timing gates. The first gate was placed at the 30-yard mark and the second gate at the 50-yard finish line (Figure 1) to capture 2 split times (split 1: start to 30-yard mark; split 2: 30- to 50-yard mark) and the cumulative 50-yard sprint time. Amateur sprinters have been

Figure 4. Gradual progression of speed during a TR training session.

shown to attain their maximal sprint speed by 32 yards and maintain maximal sprinting speed through a 55-yard distance (1). We concluded that our subjects would reach their maximum velocity before gate 1; yet, the overall distance was not too long to observe a fatigue related slow down before gate 2. This distance was also used in previous studies (10,11) for the same reasons. The 20-yard distance between the 2 timing gates represented the maximal speed maintenance phase.

Subjects conducted a general warm-up followed by a series of standardized dynamic stretching and running drills, as well as 3 practice sprints at approximately 50, 75, and 90% maximal effort. Subjects were then asked to complete 3 maximal effort sprint trials with up to 5 minutes of rest between trials. During rest times, subjects were informed of their sprint times as motivation for subsequent trials.

Subjects self-selected when they would start each trial. Subjects started from a semi-crouched standing position with the motion start box placed at the mid heel of their rear foot. The motion start box started the timer once subjects lifted off their rear foot from the original starting position. Subjects were instructed to run as fast as they could and maintain their maximal speed between the timing gates. Split and cumulative times were read on the handheld display of the timing system and recorded on a clipboard.

Maximal Treadmill Sprint Speed Test. The treadmill speed tests were conducted in a laboratory setting using a motorized Track Master Treadmill (Full Vision, Inc., Newton, KS, USA) with a maximum belt speed capacity of 13.5 $m \cdot s^{-1}$. Subjects performed a warm-up protocol similar to the overground sprint testing. Subjects wore a safety harness with a D-ring on the upper back of the harness that was attached to a steel frame (Figure 2). The safety harness prevented subjects from falling and allowed subjects to reach maximal sprint speeds without the fear of falling.

As the motorized treadmill took approximately 30 seconds to accelerate from zero to sprint speeds, an alternative starting method was used to ensure that subjects reached their top running speed without any fatigue. Subjects first stood with their feet on the sides of the treadmill and hands on the handrails. The treadmill belt was accelerated to

TABLE 2. Mean ± *SD*, mean difference, 95% confidence interval (CI) of difference, and effect size of sprint performance changes from pre-test to post-test for the overground (TR), treadmill (TM), and control groups.

Groups	SP measure	Pre-test	Post-test	Mean difference	95% CI	Effect size
TR	50-yard sprint time (s)	6.89 ± 0.70	6.82 ± 0.69	−0.07	−0.51 to 0.36	0.11
	Split 2 sprint time (s)	2.46 ± 0.30	2.41 ± 0.29*	−0.06	−0.24 to 0.13	0.19
	Max TM speed ($m \cdot s^{-1}$)	7.46 ± 0.98	8.09 ± 0.96*	0.64	0.03 to 1.24	0.66
TM	50-yard sprint time (s)	6.73 ± 0.68	6.68 ± 0.65	−0.05	−0.47 to 0.38	0.07
	Split 2 sprint time (s)	2.39 ± 0.29†	2.35 ± 0.27	−0.04	−0.22 to 0.14	0.14
	Max TM speed ($m \cdot s^{-1}$)	7.73 ± 0.94	8.56 ± 0.90*	0.84	0.25 to 1.43	0.91
CONTROL	50-yard sprint time (s)	7.36 ± 1.12	7.52 ± 1.17*	0.17	−0.51 to 0.85	0.15
	Split 2 sprint time (s)	2.67 ± 0.49	2.77 ± 0.51*	0.09	−0.20 to 0.39	0.19
	Max TM speed ($m \cdot s^{-1}$)	7.18 ± 1.25	7.33 ± 1.19*	0.14	−0.58 to 0.87	0.12

*Significantly different from pre-test.
†Significantly different from CONTROL.

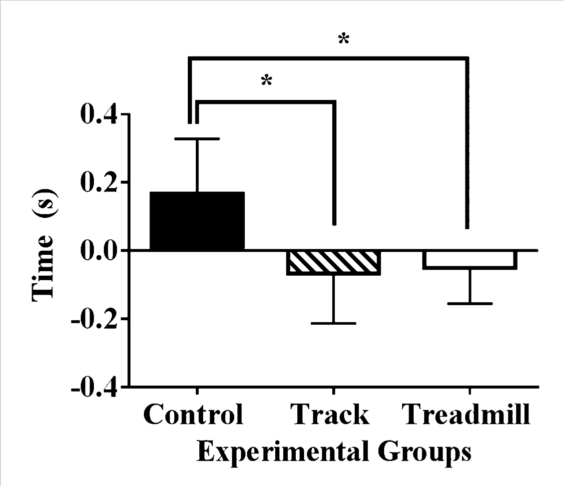

Figure 5. Pre-test to post-test change in cumulative 50-yard sprint times for TR, TM, and CONTROL groups. *Significantly differences between groups.

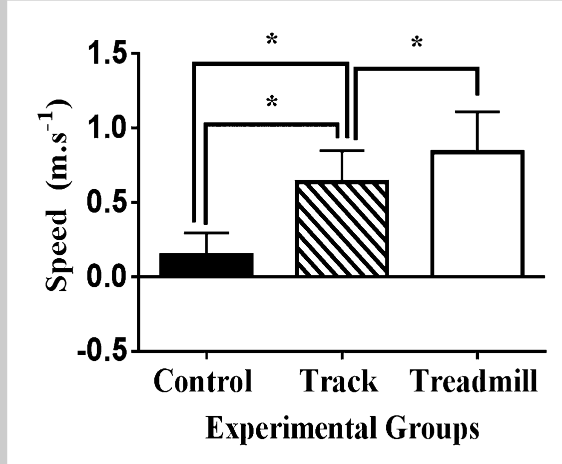

Figure 7. Pre-test to post-test change in maximal treadmill sprint speeds for TR, TM, and CONTROL groups. *Significantly differences between groups.

a speed 0.25–0.5 $m \cdot s^{-1}$ below their maximum sprint speed. Once the target belt speed was attained and verified, subjects gradually transferred their bodyweight onto the moving belt while holding onto the handrails. Once they fully controlled their running motion, they released the handrails. Similar treadmill sprint protocols were used in previous studies (8,20). After achieving proper running position, the treadmill belt speed was raised in increments of 0.25 $m \cdot s^{-1}$. As the belt continuously accelerated, subjects were verbally encouraged to run until failure or until instructed to stop. At the maximum belt speed, subjects were asked to maintain their sprint for 3 seconds. If successful, treadmill belt speed was increased by 0.25 $m \cdot s^{-1}$ for the subsequent trial. The top speed recorded was the measured belt speed that subjects were able to maintain for a minimum of 3 seconds before losing their footing. Altogether, each speed trial lasted approximately 10 seconds from the subject stepping onto the belt until stopping the trial. To overcome the inaccuracy of the belt speed displayed by the treadmill console, accurate belt speed was assessed by a Model DT-107A Handheld Contact LED Digital Tachometer (NIDEC-SHIMPO; American Corp., Itasca, IL, USA) placed directly on the belt (Figure 3).

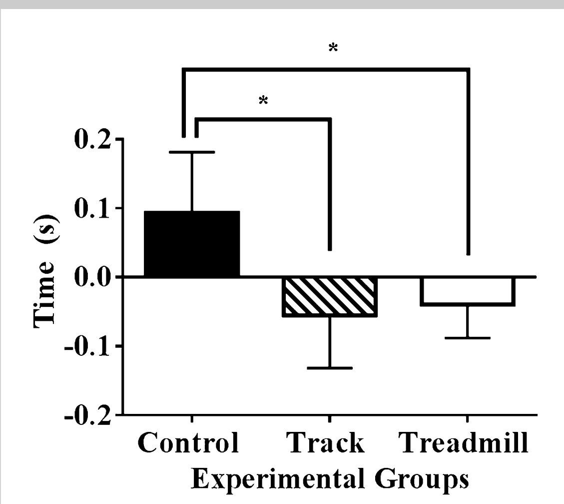

Figure 6. Pre-test to post-test change in split 2 sprint times for TR, TM, and C groups. *Significantly differences between groups.

Body Composition Tests. Body composition was assessed using dual-energy X-ray absorptiometry (DEXA) (Lunar DPX-NT; GE Lunar Corp., Madison, WI, USA) using the default software for the system. All subjects were assessed before any sprint testing or familiarization training and tested again after the 6-week training program. Subjects were instructed to refrain from eating and physical activity for at least 6 hours before testing. Subjects were asked to wear light clothing and remove any metal and plastic materials that would interfere with scanning. Subjects were first tested for height and body mass, followed by a whole-body x-ray scan in a supine position on a padded table. A quality assurance test calibrating and verifying the correct operation of the densitometer was performed at the start of each testing day to examine the accuracy of the system.

Experimental Training Protocol. Experimental group subjects were instructed to attend 2 supervised training sessions weekly, each session including 4 maximum effort sprints with up to 5 minutes of rest between attempts. To balance training volume, procedures were similar for both experimental groups, including a slow acceleration to maximum

Table 3. Mean ± *SD*, mean difference, 95% confidence interval (CI) of difference, and effect size body composition changes from pre-test to post-test for the overground (TR), treadmill (TM), and control groups.

Groups	Body composition measure	Pre-test	Post-test	Mean difference	95% CI	Effect size
TR	Total body mass (kg)	65.47 ± 12.19	65.31 ± 11.82	−0.15	−0.56 to 0.87	0.01
	Total body tissue (kg)	62.64 ± 11.76	62.50 ± 11.43	−0.14	−0.57 to 0.85	0.01
	Total body fat (kg)	15.63 ± 8.07	14.91 ± 7.48*	−0.72	0.06 to 1.39	0.09
	Total body lean mass (kg)	47.01 ± 10.58	47.45 ± 10.14	0.44	−1.32 to 0.44	0.04
	Legs lean mass (kg)	15.54 ± 3.66	16.50 ± 3.59*	0.96†	−1.55 to −0.37	0.26
TM	Total body mass (kg)	69.48 ± 12.56	69.09 ± 12.55	−0.39	−0.16 to 0.95	0.03
	Total body tissue (kg)	66.36 ± 12.10	65.87 ± 12.07*	−0.49	−0.07 to 1.07	0.04
	Total body fat (kg)	17.04 ± 7.02	16.25 ± 7.42*	−0.78	0.07 to 1.49	0.11
	Total body lean Mass (kg)	49.33 ± 12.94	49.62 ± 13.03	0.29	−0.79 to 0.21	0.02
	Legs lean mass (kg)	16.37 ± 4.36	17.05 ± 5.03*	0.68†	−1.27 to −0.09	0.14
CONTROL	Total body mass (kg)	71.65 ± 13.53	70.73 ± 13.67	−0.92	−0.59 to 2.44	0.06
	Total body tissue (kg)	67.96 ± 12.32	67.18 ± 12.31	−0.78	−0.74 to 2.30	0.06
	Total body fat (kg)	19.02 ± 4.56	18.74 ± 4.44	−0.28	−0.60 to 1.17	0.06
	Total body lean mass (kg)	48.94 ± 12.71	48.69 ± 12.79	−0.25	−0.54 to 1.03	0.02
	Legs lean mass (kg)	16.46 ± 4.39	16.59 ± 4.45	0.13	−0.52 to 0.25	0.03

*Significantly different from pre-test.
†Significantly different from CONTROL.

sprint speed and maintaining maximum speed for about 5–7 seconds.

TR group subjects completed 4 repetitions of 50-yard maximum sprints, each preceded by a slow acceleration start to simulate the slow speed progression of the treadmill condition. Specifically, subjects started from 60 yards behind the 50-yard sprint zone and progressed from slow jog to maximal sprint speed by reaching the 50-yard sprint zone. Subjects' effort was assessed by using timing gates and recording their 50-yard run-through times for each trial, which was then shared with them (Figure 4). Subjects walked back to the starting line before resting for 5 minutes. Overall, each sprint trial lasted approximately 15–20 seconds, with typically 10–13 seconds of slow acceleration and 5–7 seconds of maximum effort sprint in the 50-yard zone.

The TM group also completed 4 sets of maximum effort sprints in each training session, following the same safety protocols with the use of the fall protection safety harness as described for testing. Treadmill belt speed was set at 2.2 $m \cdot s^{-1}$ below the subject's maximal treadmill sprint speed assessed at pre-test. Subjects were instructed to gradually transfer their bodyweight onto the moving treadmill belt. Once subjects fully controlled their treadmill running, the belt speed was increased to the subject's predicted maximal treadmill sprint speed. Typically, it took about 10–12 seconds for the belt speed to reach the programmed level, and subjects were instructed to maintain their maximum effort speed for an additional 5–6 seconds (15–17 seconds total per trial). Time was counted out loud to encourage subjects to stay on the belt for the full duration of the trial (Figure 2). For subsequent trials, belt speed was adjusted in 0.2 $m \cdot s^{-1}$ increments as needed. At the conclusion of each TM and TR training session, subjects completed a 5-minute cool down jog and a set of lower-body static stretches.

Statistical Analyses

Sprint data were analyzed using GraphPad Prism Software, v6.0 (GraphPad Software, La Jolla, CA, USA), while SPSS for Windows (version 24.0; SPSS, Inc., Chicago, IL, USA) was used for body composition data analysis. Data are expressed as mean ± *SD* of mean. Pre-test data among groups were compared using a 1-way analysis of variance (ANOVA). Differences in training-induced sprint performance and body composition changes were assessed using 2-way repeated-measures ANOVA, with repeated-measures Tukey's *post hoc* tests. Significance level was set at $p \leq 0.05$ for all analyses.

Results

Pre-test sprint performance data were collected on 102 subjects who were then randomly divided into TR ($N = 32$), TM ($N = 30$) and CONTROL ($N = 40$) groups. Because of subjects' withdrawal or removal from the study due to noncompliance, pre-test to post-test comparisons were completed for 64 subjects (Table 1): 21 TR subjects (11 men and 10 women), 20 TM subjects (10 men and 10 women), and 23 control subjects (12 men and 11 women). The groups, therefore, were balanced for nearly equal male-to-female ratio, and data analysis of pre-test group comparisons revealed no significant between-group differences for age ($p = 0.60$), height ($p = 0.58$), body mass ($p = 0.37$), or body mass index ($p = 0.55$).

Table 4. Mean ± *SD*, mean difference, 95% confidence interval (CI) of difference, and effect size lean leg mass changes from pre-test to post-test for the overground (TR), treadmill (TM), and control males and females.

Group	Sex	Pre-test (kg)	Post-test (kg)	Mean difference	95% CI	Effect size
TR	Males	17.86 ± 3.04	19.23 ± 2.04	1.36*	0.26 to 2.46	0.53
	Females	13.00 ± 2.38	13.51 ± 2.25	0.51	0.09 to 0.94	0.22
TM	Males	19.96 ± 2.53	21.15 ± 3.26	1.19*	0.17 to 2.21	0.41
	Females	12.78 ± 2.27	12.96 ± 2.33	0.18	−0.43 to 0.79	0.08
CONTROL	Males	19.13 ± 2.59	19.43 ± 2.42	0.29	−0.19 to 0.78	0.12
	Females	12.00 ± 2.49	11.87 ± 1.97	−0.13	−1.44 to 1.18	0.06

*Significantly different from females.

Pre-test group comparisons for sprint performance data included cumulative 50-yard sprint time, split 2 sprint time, and maximum treadmill sprint speed data. The TM group was significantly faster at pre-test on the split 2 sprint time performance than the CONTROL group ($p = 0.04$), but no significant differences were observed between the TM and TR groups ($p = 0.823$) and the TR and CONTROL groups ($p = 0.152$) (Table 2). For the 50-yard sprint time performance pre-test, the differences observed between the groups were not significant; however, a trend was observed to a greater sprint performance of the TM and TR group subjects compared with the CONTROL group ($p \geq 0.0523$). No significant differences were observed at pre-test in the maximal treadmill sprint speed test between any of the groups ($p \geq 0.2291$) (Table 2).

Sprint Performance Changes

From pre-test to post-test, the TR group significantly improved split 2 sprint time ($p = 0.003$) and significantly increased maximal treadmill running speed ($p < 0.001$), but only tended to improve the cumulative 50-yard sprint time ($p = 0.054$). The TM group showed significant improvement on the maximal treadmill sprint speed ($p < 0.001$) and also a tendency to improve the split 2 sprint time ($p = 0.060$) but showed no significant improvement on the cumulative 50-yard sprint time ($p = 0.348$). The CONTROL group showed a significant worsening in the cumulative 50-yard sprint time ($p < 0.001$) and the split 2 sprint time ($p < 0.001$). Table 2 displays pre-test and post-test sprint performance measurements for TR, TM, and CONTROL groups.

Comparison of Sprint Performance Changes Between Groups

Analysis of calculated pre-test to post-test changes data on sprint performance showed significant between-group differences. The change for the CONTROL group's cumulative 50-yard sprint time (0.167 ± 0.161 seconds) was significantly greater than that of the TR (−0.067 ± 0.146 seconds) or TM (−0.050 ± 0.105 seconds) groups ($p < 0.0001$), as the CONTROL group showed a diminished sprint performance compared with the improvements by the TR and TM groups (Figure 5). The change for the CONTROL group's split 2 sprint time (0.093 ± 0.088 seconds) was also significantly greater than that of the TR (−0.055 ± 0.077 seconds) or TM (−0.040 ± 0.049 seconds) groups ($p < 0.0001$) (Figure 6). Although all 3 groups showed significant improvements in maximal treadmill sprint speed from pre-test to post-test, improvement for the TM (0.840 ± 0.272 $m \cdot s^{-1}$) group was significantly greater than the TR (0.640 ± 0.209 $m \cdot s^{-1}$) group ($p = 0.011$) or the CONTROL (0.140 ± 0.152 $m \cdot s^{-1}$) group ($p < 0.0001$), while the TR group also showed a significantly better improvement than the CONTROL group ($p < 0.0001$) (Figure 7).

Body Composition Changes

Body composition post-test data were collected on all 21 TR and 20 TM group subjects, but only on a subset of 8 control subjects (5 men and 3 women). DXA data were analyzed for total body tissue, fat mass, lean mass, and leg lean mass. There were no significant between-group differences at pre-test for any of the DXA measures ($p \geq 0.499$). Analysis showed a significant time effect for total tissue, total fat, and lean leg mass ($p \leq 0.016$) and a significant group-by-time interaction for lean leg mass ($p = 0.032$). Post hoc analysis revealed that the TR subjects showed significant decrease in total body fat ($p = 0.017$) and increase in leg lean mass ($p = 0.002$). For TM subjects, significant decrease was observed for total body tissue ($p = 0.043$) and total body fat ($p = 0.016$) and significant increase for leg lean mass ($p = 0.012$). Control subjects showed nonsignificant changes in all body composition measures ($p > 0.131$). Table 3 displays pre-test and post-test body composition measurements for all groups. Analyzing sex differences in body composition adaptations, we observed significant differences between men and women for changes in total body lean mass for the TR and TM groups ($p < 0.001$). Similar trends were observed for leg lean mass with significant sex differences in the TR and TM groups ($p < 0.001$) (Table 4).

Discussion

To the best of our knowledge, this study was the first to investigate and compare the training effects of overground and motorized treadmill sprint training programs. To comprehensively assess possible improvements in sprint performance, subjects were tested in both overground and treadmill sprint conditions. Our findings highlight that 6 weeks of overground sprint training significantly improved sprint time at the maximal speed maintenance phase and maximal treadmill sprint speed. The 6-week treadmill sprint training program elicited some but nonsignificant improvement in overground maximal speed, while improvements on the treadmill sprint speed were significantly higher than that of the overground training program. In comparison with the nonexercising CONTROL group, changes in maximal sprint speed for the overground and treadmill conditions seem to be modality specific.

Both of the overground and treadmill sprint training programs also resulted in significant changes in body composition. We observed 0.72 and 0.78 kg (4.57 and 4.61%) decrease in total body fat mass and 0.96 and 0.68 kg (6.18 and 4.15%) increase in lean leg mass in the TR and TM groups, respectively. Comparing body composition changes between men and women, we observed a significant difference in lean leg mass changes, as men experienced 1.19–1.36 kg (5.96–7.61%) of lean leg mass increase compared with the 0.18–0.51 (1.41–3.92%) increase seen in women. These findings are unique and show the potential of either sprint training modality to impact body composition in healthy young adults.

Only 2 previous studies have investigated the effects of running-based sprint training on body composition (7,9), and our results are comparable with the findings reported in these studies. Macpherson et al. (9) reported 1.7 kg decrease in total body fat with a mixed group of male and female subjects. Hazell et al. (7) observed 1.2 kg decrease in total body fat mass (8.0%) and 0.6 kg increase in fat-free mass (1.3%) in female only subjects as a result of a 6-week sprint training program on self-propelled treadmills. In this study, we observed 1.0 kg decrease in total fat mass (5.3%) and 0.61 kg increase in fat-free mass (1.6%) in the TR group female subjects, and 0.7 kg decrease (3.4%) fat mass and 0.26 kg increase in fat-free mass (0.7%) in TM group female subjects. Although the values for total fat loss and fat-free mass increase are slightly more modest for our female subjects, the intervention protocol was different in these studies (7,9) than in ours. These authors used self-propelled treadmills and applied a greater volume of experimental sprint training program with 3 training sessions weekly and with 4–6 sets of longer (30-second) sprint intervals (7,9). Subjects in our study were exposed to more than 50% lower training volume because they attended only 2 sessions weekly and completed only 4 sets per session, but exerted maximum effort through 15- to 20-second sprints.

Hazell et al. (7) hypothesized that the observed increase in fat-free mass in their subjects was likely due to the self-propelled treadmill's external resistance and speculated that such muscle mass increase might not occur with overground sprinting. Our results contradict this theory and show that similar body composition changes can be achieved even with a lower volume of overground sprint training program over a 6-week period. Furthermore, our study is the first to indicate that sprint training both overground or on a motorized treadmill have the capacity to reduce fat mass and increase fat-free mass in both men and women. In addition, our findings also indicate that men respond better to either sprint training modality and can experience greater increases in fat-free mass than women.

The reasons for these changes in body composition are not fully known. The decrease in fat mass observed in both previous studies, and our study is likely due to changes in energy expenditure. Hazell et al. (7) hypothesized that lipids may have a role in the energy metabolism during high-intensity sprint training. Although total energy expenditure may be small during the sprint training sessions, increased post-training energy expenditure can result in fat loss over a 6-week training program (7). Sprint interval training results in greater negative postexercise energy balance than traditional endurance training, and this may be due to high quantities of lactic acid accumulations during sprint training (9). Increases in lean mass, specifically in leg lean mass, are likely due to the intensive recruitment of fast-twitch fibers during the sprint protocol. We speculate that even in the motorized treadmill sprint protocol, where the moving best assists the leg movement, an increase motor unit recruitment pattern allowed subjects to recruit a greater number of fast-twitch fibers, with an increased response to hypertrophy stimuli resulting in leg lean mass increase. Altogether with data from these previous studies, it appears that fat loss can be achieved through different sprint training modalities, including self-propelled and motorized treadmills, as well as overground sprinting.

In terms of sprint performance, our subjects were consistently able to reach higher maximal sprint speeds on the treadmill compared with overground. Subjects in the treadmill training group, for example, were able to reach 8.6 $m \cdot s^{-1}$ average speed on the treadmill at post-test, while their calculated average maximum speed on the 50-yard overground sprint was only 7.8 $m \cdot s^{-1}$. This indicates that subjects in the treadmill training group were training at supramaximal sprint speeds, which likely elicited neural adaptations related to that condition. Previous studies also found that treadmill sprint training significantly increased maximal treadmill sprint speed (4,16). However, our study is the first to show that these treadmill-specific sprint performance improvements only modestly transfer to overground sprinting, and that a similarly designed overground sprint training program elicits greater sprint performance responses when assessed overground.

Frishberg (6) suggested that treadmill sprinting can enable an athlete to attain similar running velocities as overground sprinting during the maximal velocity phase, but results in different sprinting kinematics. Significant biomechanical differences were also observed by other researchers between overground and treadmill sprinting (8,12,14). McKenna and Riches (12) reported that conventional motor-driven treadmills allowed athletes to attain similar maximal velocities as overground sprinting but with altered treadmill sprinting kinematics. These authors suggested that such modifications in sprinting kinematics would result in a reduced sprint performance overground. Investigating specific kinematic differences by performing high-speed treadmill sprinting over a range of velocities, Kivi et al. (8) found that stride frequency increased as a result of decreased stance and flight phases seen with increased treadmill speeds. These authors further suggested that training near maximal velocity on a treadmill results in an increased hip extension angular velocity (8). Performing treadmill sprinting at increased velocities causes sprinters to become less consistent in the angular positioning of their hips at high speeds. In comparison, overground sprinting has been associated with increased hip extension and hip flexion compared with treadmill sprinting (17). According to Kivi et al. (8), maximizing hip flexion angle results in an increased upper-leg angular velocity before and during ground contact. This is supported by Markovic et al. (11) who found that the maintenance of maximal velocity is highly dependent on forward propulsion created by the hip and ankle extensor muscles.

Forward propulsion is strongly related to the amount of force exerted with each foot strike, which is altered when sprinting on a conventional motor-driven treadmill (14). Moreover, sprint speed constantly changes during overground sprinting because of the force being applied to the ground throughout the duration of the sprint, which is not seen in treadmill sprinting. Also, peak horizontal ground reaction forces are greater in overground sprinting than in treadmill sprinting (14), and these ground reaction forces significantly increase at higher speeds (3). Weyand et al. (20) suggested that faster running speeds are achieved by the application of greater ground reaction forces but not by a higher stride frequency. The relevant literature appears to be consistent, suggesting that maximal treadmill sprinting results in a higher stride frequency than overground sprinting. Early research found that treadmill sprinting increased stride frequency at higher speeds because of a decreased nonsupport phase (5). Stride frequency training adaptations have been seen in response to both incline and level treadmill high-speed running (18). Mero et al. (13) suggested that sprinting at maximum speed results in an increased stride frequency restricting the hip range of motion to maintain cadence and belt speed.

Our current findings align with those of previous studies. Overground sprint training (TR group) showed to be effective in eliciting significant improvements in overground maximal sprint speed. Although high-speed treadmill sprint training modestly improved overground sprint performance, it did not elicit the same sprint performance improvements as overground sprint training. The main benefit of maximal treadmill sprints seem to be related to an improvement in stride frequency, but our findings indicate that such improvement does not lead to improved overground sprint performance.

Another aspect of comparison of these 2 sprint training modalities is the metabolic demands of the 2 conditions. Bowtell et al. (1) suggested that greater sprint speeds are attained on a high-speed treadmill compared with overground sprinting due to a lesser metabolic demand. Accordingly, treadmill sprinting enables an athlete to perform more successive trials without a noticeable decline in speed, while overground sprinting results in a significant decrease in speed after as few as 5 trials (1). Brown (2) hypothesized that athletes performing treadmill sprinting do not show a noticeable decrease in speed because the treadmill would not stop, suggesting the athletes are forced to perform maximally or supramaximally while maintaining power output requirements. Moreover, as motorized treadmills accelerate slowly to the desired speed, such training is not appropriate for sprint acceleration performance. The lack of acceleration seen in free sprinting is another factor for the lower metabolic demands of treadmill sprinting (1).

Practical Applications

Sprint training on a motorized high-speed treadmill may be used as an alternative modality to traditional overground sprint training because outdoor sprint training may be frequently affected by environmental factors and indoor track facilities are not usually available. Sprinting on a high-speed treadmill typically allows an athlete to achieve higher sprint speeds than overground free sprinting. Therefore, such supramaximal speed training may carry some benefits, particularly an increase in stride frequency. However, as the sprint kinetics and kinematics between treadmill and overground sprinting are different, particularly in relation to the hip flexion-extension pattern, improved stride frequency may only modestly improve overground sprint performance. It seems that sprint improvements may be modality-specific; thus, high-speed treadmill sprint training would predominantly improve treadmill sprint performance. Although both modalities seem to be effective in decreasing total body fat and increasing leg lean mass, our results suggest that traditional overground sprint training is superior if the goal is to improve overground sprint performance. As the goal for sprint training in most sports is to achieve better overground sprint performance, motorized high-speed treadmill sprint training should be limited to be used as a supplemental training modality and should not entirely replace overground sprint training.

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References

1. Bowtell, MV, Tan, H, and Wilson, AM. The consistency of maximum running speed measurements in humans using a feedback-controlled treadmill, and a comparison with maximum attainable speed during overground locomotion. *J Biomech* 42: 2569–2574, 2009.
2. Brown, LE. Treadmill running to improve speed. *Strength Cond J* 24: 27–29, 2002.
3. Brughelli, M, Cronin, J, and Chaouachi, A. Effects of running velocity on running kinetics and kinematics. *J Strength Cond Res* 25: 933–939, 2011.
4. Cheetham, ME and Williams, C. High intensity training and treadmill sprint performance. *Br J Sports Med* 21: 14–17, 1987.
5. Elliott, BC and Blanksby, BA. A cinematographic analysis of overground and treadmill running by males and females. *Med Sci Sports* 8: 84–87, 1976.
6. Frishberg, BA. An analysis of overground and treadmill sprinting. *Med Sci Sports Exerc* 15: 478–485, 1983.
7. Hazell, T, Hamilton, C, Olver, T, and Lemon, P. Running sprint interval training induces fat loss in women. *Appl Physiol Nutr Metab* 39: 944–950, 2014.
8. Kivi, DM, Maraj, BK, and Gervais, P. A kinematic analysis of high-speed treadmill sprinting over a range of velocities. *Med Sci Sports Exerc* 34: 662–666, 2002.
9. Macpherson, R, Hazell, T, Olver, T, Paterson, D, and Lemon, P. Run sprint interval training improves aerobic performance but not maximal cardiac output. *Med Sci Sports Exerc* 43: 115–122, 2011.
10. Mangine, GT, Hoffman, JR, Gonzalez, AM, Wells, AJ, Townsend, JR, Jajtner, AR, et al. Speed, force, and power values produced from nonmotorized treadmill test are related to sprinting performance. *J Strength Cond Res* 28: 1812–1819, 2014.
11. Markovic, 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.
12. McKenna, M and Riches, PE. A comparison of sprinting kinematics on two types of treadmill and over-ground. *Scand J Med Sci Sports* 17: 649–655, 2007.
13. Mero, A, Komi, PV, and Gregor, RJ. Biomechanics of sprint running. *Sports Med* 13: 376–392, 1992.
14. Morin, JB and Seve, P. Sprint running performance: Comparison between treadmill and field conditions. *Euro J Appl Physiol* 111: 1695–1703, 2011.
15. Palmieri, J. Sport-specific: Speed training for football. *Strength Cond J* 15: 12–17, 1993.
16. 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: 385–394, 2009.
17. Sinclair, J, Richards, J, Taylor, PJ, Edmundson, CJ, Brooks, D, and Hobbs, SJ. Three-dimensional kinematic comparison of treadmill and overground running. *Sports Biomech* 12: 272–282, 2013.
18. Swanson, SC and Caldwell, GE. An integrated biomechanical analysis of high speed incline and level treadmill running. *Med Sci Sports Exerc* 32: 1146–1155, 2000.
19. Vescovi, JD and McGuigan, MR. Relationship between sprinting, agility, and jump ability in female athletes. *J Sports Sci* 26: 97–107, 2008.
20. Weyand, PG, Sternlight, DB, Bellizzi, MJ, and Wright, S. Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol* 89: 1991–1999, 2000.