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Effect of Elastic-Cord Towing on the Kinematics of the Acceleration Phase of Sprinting

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ABSTRACT

We studied the specificity of elastic-cord towing by measuring selected kinematics of the acceleration phase of sprinting. Nine collegiate sprinters ran two 20-m maximal sprints (MSs) and towed sprints (TSs) that were recorded on high-speed video (180 Hz). Sagittal plane kinematics of a 4-segment model of the right side of the body were digitized for a complete stride at the 15-m point for the fastest trial. Significant ($p < 0.001$) differences were observed for horizontal velocity of the center of mass (CoM), stride length (SL), and horizontal distance from the CoM of the foot to the CoM of the body. There was no significant difference in stride rate between the MS and TS conditions. Omega-squared analysis showed that elastic-cord towing accounted for most of the variance in acute changes in horizontal velocity (73%), SL (68%), and horizontal position of the CoM at foot contact (64%). Elastic-cord tow training resulted in significant acute changes in sprint kinematics in the acceleration phase of an MS that do not appear to be sprint specific. More research is needed on the specificity of TS training and long-term effects on sprinting performance.

Key Words: running, overspeed training, tow training, velocity

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Introduction

Running speed is an essential component of most major sports. Often, it is the determining factor in the outcome of a sporting event. Thus, the ability to enhance running speed is of prime importance to coaches and athletes alike. Mechanically, running speed can be defined as the product of stride rate (SR) and stride length (SL) (7). To increase the running speed of an athlete, one or both components (SR and SL) must be improved without adversely affecting the other. Although some researchers have suggested that any improvement in SR beyond the age of 13 or 14 years is virtually impossible (5), it is generally accepted that running speed can be improved through various training techniques affecting SL or SR (3, 10, 11, 16).

Various training techniques have been used for the development of running speed (3). Delecluse (3) summarized the research on sprint training and concluded that weight training, plyometrics, and sprint resistance training were all implicated in the improvement of SL, with plyometrics having a possible added effect on decreasing contact time of the foot. However, none of these methods have been shown to increase SR.

One method of creating a training stimulus that is hypothesized to increase SR may be sprint-assisted training. Sprint-assisted training involves towing runners to greater speeds than they can usually sprint. This kind of training has also been referred to as tow training, overspeed training, or supramaximal sprinting (3, 11). This study will refer to this training method as a towed sprint (TS). Several forms of TS training have been used: downhill running (6) and horizontal ''towing'' with a motorcycle (2), a truck (17), a motor (1, 8, 15), a computer-guided towing system (4), and an elastic band (11, 12). It is hypothesized that TS training might have adaptive effects on the neuromuscular system (3, 11).

In recent years, the production of various speed-enhancement devices has increased. One such product is an elastic towing device that uses the effort of a lead runner to stretch an elastic band, thus creating a pull to tow a sprinter to supramaximal speed. Companies that produce this training device claim that it will increase both SR and SL; however, research has demonstrated inconsistencies in the effects of towing on sprinting variables. A significant increase in SL has been noted in some studies (11), whereas in others, significant differences in SL have not been observed for any of the subjects (12). Mero and Komi (11) reported a significant increase in SR for elite men only, whereas a later study (12) showed a significant increase in SR in all subjects except elite men. A third study by Mero et al. (14) showed no significant differences in SR with TS training.

Table 1. Sprinter demographic data.

	Men	Women
Variable	Mean ± *SD*	Mean ± *SD*
Age (y)	21.0 ± 1.2	21.5 ± 3.4
Height (cm)	179.6 ± 5.0	165.4 ± 4.0
Mass (kg)	75.5 ± 9.3	59.7 ± 3.9
Best 100-m (s)	11.05 ± 0.4	12.98 ± 0.2

The conflicting results may be attributable to variation in towing forces produced by different towing methods and the different points in a sprint race that have been studied. Currently, there is no research validating the appropriate amount of force to be used with towing systems and thus no standard means for comparison to evaluate the levels of force used. With respect to video data collection, most researchers captured data at the 35-m point in a sprint (11, 12, 15), and others used the 30-m point (8) and a point between 50 and 60 m (1). Bosco and Vittori (1) suggested that TS training might initially produce a higher-than-normal SR. Majdell and Alexander (8) also hypothesized that speed improvements might take place before the 30-m point in TS. The acceleration phase of a 100-m sprint occurs in the first 30 m of the sprint (14).

In response to the conflicting research on TS training and the lack of data captured before the 30-m point, the present study measured selected kinematics in normal sprinting and TS to document the acute effects of towing on the acceleration phase (15-m point) of sprinting. It was hypothesized that the acute effects of this TS training would not be sprint specific. The study focused on 4 key biomechanical variables related to sprinting performance (7, 9): SR, SL, the horizontal distance from the center of mass (CoM) of the foot to the CoM of the body (D_h), and horizontal velocity of the CoM (V_h).

Methods

Subjects

Five male and 4 female collegiate sprinters gave informed consent to participate in the study. All subjects were familiar with the elastic-cord TS training device from team practices. All subjects were competitive sprinters at the collegiate level with a minimum of 3 practice sessions using the towing device. Demographic data for the subjects are provided in Table 1. Subjects were briefed on procedures and encouraged to run with a maximal effort. No instructions were given concerning their technique or running form during practice or data collection.

Subjects followed their normal warm-up routine and participated in a light preseason practice before testing. The practice lasted approximately 45 minutes and consisted of form running and technique drills, with no maximal sprinting. The subjects gave informed consent and had 1.27- × 1.27-cm reflective markers taped to the right fifth metatarsal, lateral malleolus, lateral condyle of the femur, greater trochanter, and the point on the shoulder representing the head of the humerus.

Test sprints were performed on a 20-m running lane that was marked off on a 50-m stretch of an indoor hardwood gymnasium floor. All sprints were initiated from a standing start. Recovery time between each sprint trial was approximately 5 minutes. Times for each sprint were determined by averaging the readings from 2 experienced timers using handheld digital stopwatches at the 20-m point. Sprinting technique in the sagittal plane was captured on high-speed video (180 Hz). The fastest sprint of each condition was selected for kinematic analysis.

After 2 maximal sprint (MS) trials, the subjects were paired with one another according to height and weight for two 20-m TSs. Because of the odd number of subjects, 1 man was paired with a member of the track team who chose to not participate in the study but was familiar with the procedure. The paired subjects alternated running the TS trials with 5 minutes' rest between trials. This was repeated until both subjects in each pair had performed two 20-m TS trials.

The TS was performed with a Power Systems (Knoxville, TN) Speed Harness (medium tubing 10100 and heavy tubing 10110) elastic-band towing device. The tubing had a manufacture's suggested body weight parameter. The medium tubing was designed for persons 180 lb and under, whereas the heavy tubing was designed for those above 180 lb. Eight of the subjects were towed with the medium tubing. The subject who was towed with the heavy tubing was the one paired with the nonparticipant of similar height and weight. Before each TS trial, the lead runner stretched the elastic band to approximately 14 m in length, then both runners began to sprint until the experimental runner had passed the 20-m point. This resulted in an approximate 40–50 N of horizontal towing force from the band that decreases as the band shortens.

Statistical Analyses

Kinematic data of a 4-segment model (foot, leg, thigh, trunk) of the right side of the body were digitized with Peak Performance Technologies *Motus* software beginning 2 frames before and after 1 running stride at the 15-m point. Marker position data could be located to within 4 mm of accuracy and were smoothed with a digital filter with automatic cutoff frequency (3–9 Hz) selection. The biomechanical variables calculated from smoothed data for each sprinting condition were SR, SL, the horizontal distance from the CoM of the foot to the CoM of the model (D_h), and horizontal velocity

Table 2. Biomechanical variables of the acceleration phase of sprinting.†

Variable	MS	TS
	Mean ± *SD*	Mean ± *SD*
SL (m)	1.90 ± 0.11	2.03* ± 0.15
SR (Hz)	4.26 ± 0.09	4.25 ± 0.08
D_h (m)	0.15 ± 0.02	0.22* ± 0.04
V_h ($m \cdot s^{-1}$)	8.06 ± 0.49	8.63* ± 0.60

† MS = maximal sprint; TS = towed sprint; SL = stride length; CoM = center of mass; SR = stride rate; D_h = horizontal distance from the CoM of the foot to the CoM of the body; V_h = horizontal velocity of the CoM.

* Significant ($p < 0.001$) differences between MS and TS.

of the CoM (V_h). A variety of definitions have been used for step and SL, but this study defined SL as half the horizontal displacement of the fifth metatarsal from right footstrike to the next right footstrike. Pilot studies had shown that the CoM of the model was within 0.6 cm of the CoM of a sprinter calculated using a whole-body model, and all data had good reliability (coefficient of variance < 7%). Data were analyzed with 4 dependent *t*-tests. Statistical significance was accepted at $p < 0.0125$ to keep the experimentwise error rate significant at $p \leq 0.05$.

Results

Mean horizontal velocity (V_h) was significantly ($t_8 = 7.07$, $p < 0.001$) higher (7.1%) in the TS condition than in the MS condition. Stride length was also significantly ($t_8 = 6.26$, $p < 0.001$) higher (6.8%) in the TS condition than in the MS condition. Stride rate was not significantly different ($t_8 = 0.80$, $p < 0.445$) between MS and TS conditions. The D_h was significantly ($t_8 = 5.87$, $p < 0.001$) larger (46.7%) in the TS condition than in the MS condition. The means ± *SD*s for all variables in each condition are presented in Table 2. Omega-squared analysis showed that towing had a major effect on acceleration-phase sprinting technique, accounting for 68% of the variance in SL, 64% of the variance in D_h, and 73% of the variance in V_h.

Discussion

The V_h in the acceleration phase increased in the TS condition by 7.1% compared with MS as a result of 40- to 50-N force from the elastic band. This is within the range of the 4–15% increases in V_h observed in previous TS (35–150 N) studies (1, 4, 11, 12, 15). The effect size (ES) for this difference was large (ES = 1.2). Significant increases in SL and D_h, not in SR, primarily created this large change in V_h in these subjects. These acute responses in sprinting technique, however, may not be consistent with the principle of specificity of training.

Stride length significantly increased in the TS condition by approximately 7%, and this ES was also large (ES = 1.2). The significant increase in SL was consistent with the findings of most TS studies (1, 4, 11, 15). The values for SL from the present study (1.90–2.03 m) were slightly lower than those reported (2.0–2.45 m) in previous studies of TS training (1, 11, 12, 15), but this is likely because the acceleration phase was studied.

The SR values of the present study (4.24–4.26 Hz) were also slightly lower than the reported values (4.49–5.1 Hz) of other studies (1, 11, 12, 15, 18). This might be attributed to data being captured during the acceleration phase because it is noted that SR increases as velocity increases (7, 17). Seven of the 9 subjects showed a decreased SR, whereas two, 1 man and 1 woman, showed an increase. The man whose SR increased demonstrated a theoretically ideal training response with the use of the elastic-band towing device. Interestingly, this subject had the fastest 100-m time of all the subjects in the present study. For this subject, horizontal velocity increased from MS to TS (from 8.2 to 8.8 $m \cdot s^{-1}$, respectively), SL increased from 1.97 to 2.07 m in TS, SR increased from 4.24 to 4.39 Hz in TS, and D_h decreased from 0.17 to 0.16 m in TS. This was similar to the observation of Mero and Komi (11) that elite male sprinters significantly increased their SR, whereas others did not. More research is needed on the individual response of sprint athletes to elastic tow training. The lack of a consistent group response to increase SR, however, does not support the use of this mode of training in these collegiate sprinters.

Foot placement relative to the center of gravity (D_h) showed the most dramatic increases (46%, ES = 3.5) in TS relative to MS. Mero et al. (14) also observed an increased D_h in towed sprinting compared with regular sprinting, which they attributed to the sprinter being pulled over a greater distance per stride. These elongated strides showed greater braking forces (21.9%) during footstrike. The further the foot lands in front of the CoM, the greater the braking forces at footstrike, which tends to slow the sprinter (9). This longer SL and poor positioning of the body relative to the CoM in TS training supports the contention of poor specificity and possibly negative training effects of this form of conditioning (1, 18).

The inability of the elastic-band towing device to produce any increase in mean SR, along with potentially detrimental increases in SL and D_h, suggests that TS training using the elastic cord may not be a sprint-specific training method. The subjects in the present study represented a small, homogenous group of skilled collegiate sprinters. The data in the present study represent the first kinematic data calculated during the acceleration phase (15-m point) of TS training.

Previous studies of TS training used intervals in the constant-velocity phase of sprinting (1, 11, 12, 15). More research is needed to examine the individual short-term and long-term responses of athletes using TS training during the acceleration phase and the constant-speed phase of sprinting as defined by Mero et al. (13).

Practical Applications

We concluded that the elastic-band towing device pulled the participating sprinters into an exaggerated stride (increased SL and D_h) and did not increase the SR in the acceleration phase of sprint-training runs. These acute changes in sprinting technique were not consistent with the principle of specificity of training. Only 1 of 9 subjects showed a trend of desirable changes in key sprinting variables in the elastic towing trial. These data combined with the data from previous studies on several methods of TS training do not support the use of elastic-band tow training for increasing sprinting speed in collegiate sprinters.

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