Effects of Three Types of Resisted Sprint Training Devices on the Kinematics of Sprinting at Maximum Velocity

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Abstract

Resisted sprint running is a common training method for improving sprint-specific strength. For maximum specificity of training, the athlete's movement patterns during the training exercise should closely resemble those used when performing the sport. The purpose of this study was to compare the kinematics of sprinting at maximum velocity to the kinematics of sprinting when using three of types of resisted sprint training devices (sled, parachute, and weight belt). Eleven men and 7 women participated in the study. Flying sprints greater than 30 m were recorded by video and digitized with the use of biomechanical analysis software. The test conditions were compared using a 2-way analysis of variance with a post-hoc Tukey test of honestly significant differences. We found that the 3 types of resisted sprint training devices are appropriate devices for training the maximum velocity phase in sprinting. These devices exerted a substantial overload on the athlete, as indicated by reductions in stride length and running velocity, but induced only minor changes in the athlete's running technique. When training with resisted sprint training devices, the coach should use a high resistance so that the athlete experiences a large training stimulus, but not so high that the device induces substantial changes in sprinting technique. We recommend using a video overlay system to visually compare the movement patterns of the athlete in unloaded sprinting to sprinting with the training device. In particular, the coach should look for changes in the athlete's forward lean and changes in the angles of the support leg during the ground contact phase of the stride.

Key Words athletics, biomechanics, specificity, sled towing, parachute, weight belt.

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Introduction

The ability to achieve a high maximum sprinting velocity is an important determinant of success in sports such as athletics, soccer, rugby, and American football (1,11,19). High-intensity strength training exercises with free weights and machines can improve the strength of the musculature of the hips, quadriceps, and hamstrings (23,28) and so increase an athlete's acceleration and maximum sprint velocity (4,7,8). However, many coaches believe that a sprint training program should also include strength-specific exercises, where the athlete uses the sport movement with an added resistance as the training exercise (3,4,5,21). For sprint training, such strength-specific exercises include towing a tire or weighted sled, towing a parachute, wearing a weighted belt or vest, sprinting on a sand surface, and uphill sprinting (9,14,25,27,31). To achieve the greatest exercise specificity, the athlete's movement patterns should remain similar to those observed in unloaded sprinting.

Several studies have looked for changes in sprint kinematics produced by sled towing devices during the acceleration phase of sprinting (15,17,22). The studies found that towing a weighted sled reduces the athlete's stride length and stride frequency, increases the ground contact time, increases the forward lean of the trunk, and produces some changes in the configuration of the athlete's lower limbs during the ground contact phase of the stride. The magnitudes of the effects were dependent on the weight added to the sled, and recommendations were proposed for a load that provides a training stimulus without inducing detrimental changes in sprinting technique.

Although the acceleration phase is particularly relevant to field sports which involve short bursts of speed, acceleration performance and maximum sprint velocity are separate and specific qualities. Young et al. (31) presented a concise summary highlighting the different muscle groups used, types of strength required and differences in running mechanics. With respect to the use of resisted sprint devices to train the maximum velocity phase of sprinting, we currently do not know if the movements during resisted sprint exercises are similar to those in unloaded sprinting.

There is a concern among coaches that inappropriate use of these exercises will induce detrimental changes in technique that will be transferred to normal sprinting.

In the present study, we compared the kinematics of unloaded sprinting at maximum velocity to sprinting when towing a weighted sled, towing a parachute, and wearing a weight belt. The aim was to establish whether these devices are appropriate for training the maximum velocity phase of sprinting in that they can produce an overload on the athlete without inducing detrimental changes to sprinting technique.

METHODS

Experimental Approach to the Problem

A quasi-experimental intrasubject cross-sectional design was used. The independent variables were the four running conditions: unloaded sprinting, towing a weighted sled, towing a parachute, and wearing a weight belt (Figure 1). The dependent variables were the horizontal velocity of the center of mass (COM), stride length, stride frequency, joint and segment angles (Figure 2), joint angular velocities, and the landing and takeoff distances (Figure 3). Studies on sprinting at maximum velocity have shown that these variables can be used to discriminate between good and poor sprinting technique (20).

We used running velocity as an indirect measure of the overload on the athlete arising from the training device. The greater the decrease in running velocity, the greater the overload on the athlete. In this study, the direction of the resistance applied to the athlete was different for each device, and so each device was expected to have different effects on the athlete's velocity and sprinting mechanics. In sprinting with a weight belt, the additional resistance on the athlete arises from the weight of the device (which is directed vertically downwards), whereas in sprinting with a parachute the device trails directly behind the athlete and so the resistance force is directed horizontally backwards (Figure 1). A weighted sled is also trailed behind the athlete, but here the resistance force on the athlete is directed slightly downwards as well as backwards because the attachment point to the sled is lower than the attachment point to the athlete (Figure 1).

We also expected changes in running velocity and sprint kinematics to depend on the magnitude of the resistance applied to the athlete by the training device. For each resisted sprint training device we deliberately selected a relatively high resistance so that training with the device would to induce a substantial physical adaptation in the athlete, but not so great as to induce large detrimental changes in the athlete's sprint kinematics. Previous studies of the acceleration phase when towing a sled indicated that a resistance that reduces the

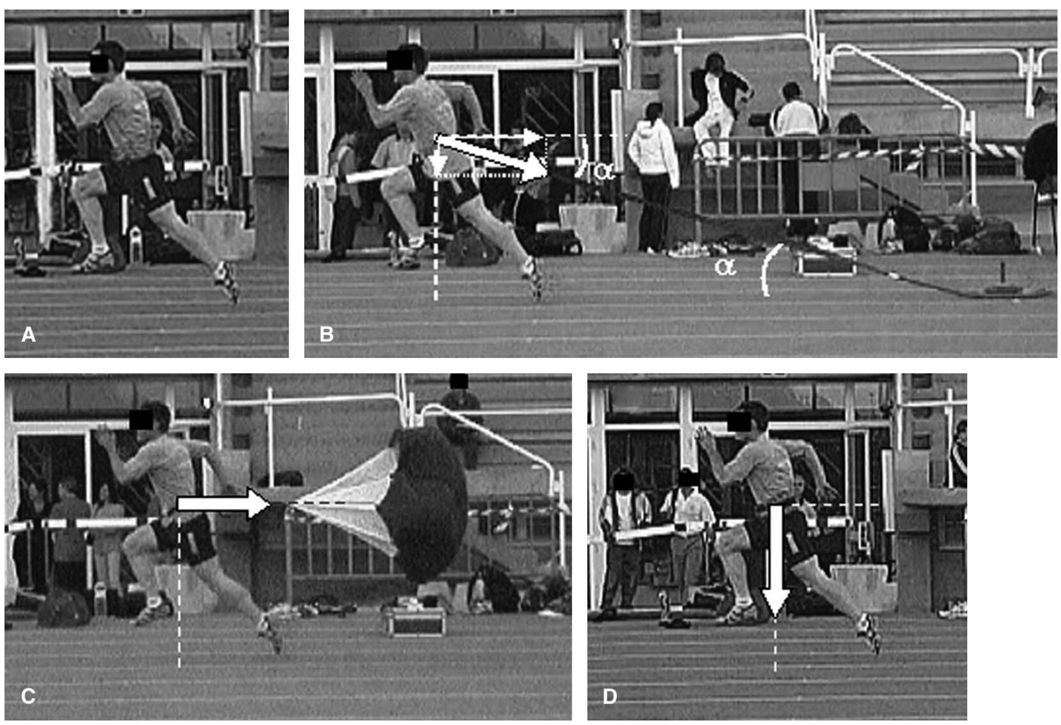

Figure 1. Comparison of (a) unloaded sprinting with sprinting when using 3 types of resisted sprint training devices; (b) weighted sled, (c) parachute, and (d) weight belt. The arrows show the direction of the force applied to the athlete by the training device.

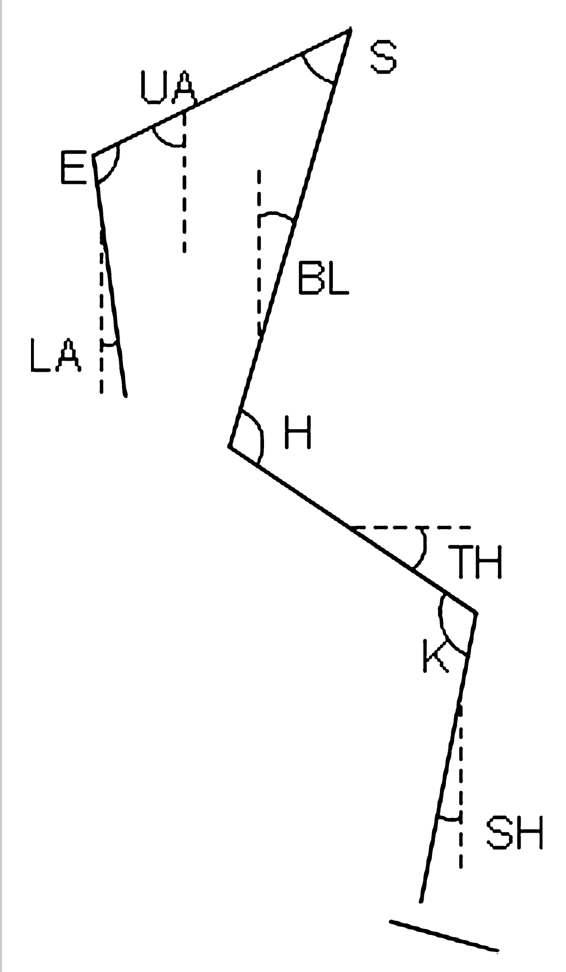

Figure 2. Definitions of joint angles and segment angles (LA = lower arm; E = elbow; UA = upper arm; S = shoulder; BL = body lean; H = hip; TH = thigh; K = knee; SH = shank).

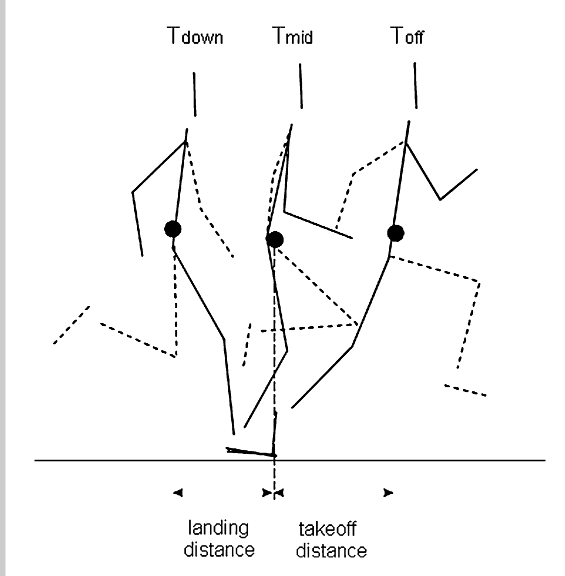

Figure 3. Typical body configurations and the location of the center of mass at 3 key times during the stance phase (T_{down} = touchdown; T_{mid} = midstance; T_{off} = takeoff).

athlete's velocity by more than 10% from unloaded sprinting results in substantial changes to the athlete's sprinting mechanics (17). Therefore, in the present study we attempted to limit the reduction in velocity arising from the training device to less than about 10%.

Subjects

Eleven men and seven women were recruited to the study (Table 1). The participants were active competitive athletes who specialized in either the sprints or long jump and all had previously used resisted sprint devices in their training. All participants were currently engaged in a periodized strength training program using explosive free weight exercises. The study was approved by the Human Subjects Ethics Committee of the Universidad Católica San Antonio de Murcia, the participants were informed of the protocol and procedures prior to their involvement, and written consent to participate was obtained.

Procedures

A weighted sled (Power Systems Inc., Knoxville, TN) was attached to the athlete by a 3.6-m cord and waist harness (Figure 1). When sprinting at maximum velocity the angle of the cord to the horizontal was between 12.5 and 15.5°, depending on the athlete's body dimensions. The sled traveled on two parallel metal tubes approximately 400 mm long and 30 mm in diameter. The sliding surfaces of the base of the sled were smooth and bare. The sled was loaded to 16% of body mass so as to produce a reduction in velocity of about 10% from unloaded sprinting. Lockie et al. (17) found that a load of 13% of body mass produced a velocity reduction of 10% in the acceleration phase of a sprint, but pilot testing by some of our participants in the maximum velocity phase of sprinting indicated that a load of 16% could be used.

The parachute (Power Systems Inc.) was of "medium" size (about 1.2 × 1.2 m) and was attached to the athlete by a waist harness (Figure 1). The size of the parachute was chosen according to the guidelines of Tabachnick (27), who recommends a medium-sized parachute when training to improve maximum sprint speed. The weight belt (Power Systems Inc.) was loaded to 9% of body mass and was placed around the athlete's waist (Figure 1). Bosco et al. (2) used a load of 7–8% of body mass when training to improve power output in sprinters, but pilot testing by our participants in the maximum velocity phase of sprinting indicated a greater load could be used without reducing the velocity by more than 10% from unloaded sprinting.

The sprint trials were conducted on a synthetic running track (Rekortan M99, Advanced Polymer Technology Inc., Brick, NJ) in an outdoor athletics stadium. Participants wore

TABLE 1. General characteristics of the participants (mean ± *SD*).

Variable	Men (n = 11)	Women (n = 7)
Age, years	22 ± 4	19 ± 2
Body mass, kg	75 ± 7	59 ± 5
Height, cm	180 ± 8	167 ± 7
Best 100-m sprint performance, s	11.2 ± 0.3	12.6 ± 0.2
Training experience, years	8 ± 2	6 ± 3

their own athletic training clothes and spiked sprint shoes. Before commencing the trials the participants performed a sprint-specific warm-up consisting of 8 minutes of running with a heart rate of 140 bpm, 8 minutes of active stretching, 10 minutes of running technique exercises, and 2–4 submaximal and maximal short sprints. The sprint trials were 30-m flying sprints at maximum intensity using a run-in distance of 20 m from a standing start. The order of the trials was randomized for each participant and an unlimited rest period was given between trials to minimize the effects of fatigue on sprint performance. The rest period typically lasted about 6 minutes, which is sufficient for full recovery from repeated maximal sprints of short duration (10). The wind velocity for all trials was measured using a wind gauge (Standar, Cantabrian, Cambridge, UK), and trials in which the wind was not between -2 m·s^{-1} and 2 m·s^{-1} were repeated. For wind velocities within this range, the wind produces a change in 30-m sprint time of less than ±1% from a zero-wind result (16).

Kinematic Analysis

The sprints were recorded with a Canon XM-1 digital miniDV video camera (Canon Inc., Tokyo, Japan) operating at 50 Hz. The camera was mounted on a rigid tripod at a height of 1.3 m and placed at a distance of 20 m from the middle of the athlete's lane. The optical axis of the camera was perpendicular to the direction of running, and the field of view of the camera was zoomed so that the athlete was visible in a 10-m wide region about the 20-m mark of the 30-m flying sprint. This field of view ensured that a complete running cycle (2 steps) would be recorded. The movement space was calibrated with two 2-m high poles that were placed along the midline of the athlete's lane and 5 m apart. Photoelectric cells (BioMedic, Barcelona, Spain) were placed at the start and finish of the 30-m flying sprint to record the sprint times.

Kwon3D biomechanical analysis software (Visol, Cheolsan-dong, Korea) was used to analyze the video images of the trials. Twenty-two body landmarks that defined a 14-segment model of the athlete were digitized in each image. The segmental data used were those proposed by de Leva (6) for male adults. The digitized images were interpolated to 100 Hz using fifth-order splines, and the two-dimensional coordinates of the body landmarks and the athlete's centre of mass were calculated using the direct linear transform algorithm. Coordinate data were smoothed using a second-order Butterworth digital filter with a cut-off frequency of 6 Hz, and the velocity of the athlete's center of mass and joint angular velocities were calculated from the coordinate data using the finite differences method (30). The kinematic variables were measured at three instants during the stride: touchdown (T_{down}), midstance (T_{mid}), and takeoff (T_{off}) (26). The instant of touchdown was the first frame in which the athlete's foot was in contact with the ground; the midstance was the frame nearest to when the athlete's center of mass passed directly over the toe of the foot; and the instant of takeoff was the first frame in which athlete's foot was no longer in contact with the ground (Figure 3).

All digitizing was performed by the same operator to maximize the consistency of the dependent variables. The reliability of intra-participant digitizing and inter-participant digitizing was very high. An intraclass correlation coefficient value of 0.999 was obtained when three instants of the same video sequence were digitized 5 times, and an intraclass correlation coefficient value of 0.998 was obtained when 2 researchers digitized three instants of the same sequence.

Statistical Analyses

One trial by each participant for each sprint condition was analyzed. Data for men and women were grouped separately, and a two-way analysis of variance with a post-hoc Tukey test of honestly significant differences (SPSS 12.0, SPSS Inc., Chicago, IL) was used to compare the four running conditions (unloaded, sled, parachute, and weight belt). Significance was set at $p \leq 0.05$.

TABLE 2. Average velocity, stride length, and stride frequency in the 30-m flying sprint for the men (n = 11, mean ± *SD*).

Variable	Unloaded	Sled	Parachute	Weight belt
Velocity, m·s^{-1}	9.3 ± 0.4	8.2 ± 0.3*	8.8 ± 0.4*	9.0 ± 0.3
Velocity decrease, %	–	12 ± 3*	5 ± 2*	3 ± 1
Stride length, m	2.13 ± 0.09	1.95 ± 0.12*	2.04 ± 0.13	2.08 ± 0.12
Stride frequency, Hz	4.5 ± 0.3	4.3 ± 0.3	4.5 ± 0.3	4.3 ± 0.4

*Statistically significant difference ($p \leq 0.05$) from unloaded sprinting.

TABLE 3. Average velocity, stride length, and stride frequency in the 30-m flying sprint for the women (n = 7, mean ± *SD*).

Variable	Unloaded	Sled	Parachute	Weight belt
Velocity ($m \cdot s^{-1}$)	7.9 ± 0.4	6.7 ± 0.3*	7.4 ± 0.4	7.6 ± 0.3
Velocity decrease (%)	–	14 ± 2*	6 ± 4	3 ± 3
Stride length (m)	1.88 ± 0.10	1.72 ± 0.11*	1.85 ± 0.13	1.87 ± 0.09
Stride frequency (Hz)	4.2 ± 0.3	4.0. ± 0.4	4.1 ± 0.3	4.1 ± 0.3

*Statistically significant difference ($p \leq 0.05$) from unloaded sprinting.

RESULTS

The effects of the 3 resisted sprint devices on the athlete's sprint kinematics were similar for men and women. As expected, all 3 devices reduced the average running velocity to less than that in unloaded sprinting (Tables 2 and 3). The decrease in running velocity arose through decreases in both stride length and stride frequency. For the loads used in this study, the three resisted sprint devices did not produce significant changes to the joint and segment angles and joint angular velocities in the upper limbs or the free leg. Only minor changes in joint angles and joint angular velocities were observed in the lower limbs and trunk (Tables 4 and 5).

The most substantial changes were observed when using the weighted sled and parachute. The sled and parachute tended to increase the angle of trunk lean, but only the sled produced a statistically significant increase. With the weighted sled and parachute, the athlete's shank tended to be less upright at touchdown and so the athlete had a slightly shorter landing distance. No significant differences were observed in any parameter when using the weight belt. However, the athletes tended to have a shorter take-off distance, which indicates that they did not use a full extension of the leg at take-off.

In the unloaded trials, the body configurations and joint angular velocities were similar for men and women, and the observed values were similar to those in other studies of experienced sprinters (20). The women had a slower average running speed, a shorter stride length, and a slightly lower stride frequency than the men (Tables 2 and 3). However, these differences were expected as they are believed to arise from the lesser muscular strength of the women relative to

TABLE 4. Kinematic variables in the stance phase of sprinting for the men (n = 11, mean ± *SD*).

Variable	Time	Unloaded	Sled	Parachute	Weight belt
COM velocity ($m \cdot s^{-1}$)	T_{down}	9.3 ± 0.4	8.4 ± 0.4*	9.0 ± 0.4	9.2 ± 0.5
	T_{mid}	9.3 ± 0.5	8.2 ± 0.5*	8.8 ± 0.4	9.0 ± 0.4
	T_{off}	9.7 ± 0.5	8.8 ± 0.7*	9.3 ± 0.7	9.5 ± 0.6
Body lean (°)	T_{down}	11 ± 3	16 ± 5*	14 ± 3	11 ± 3
	T_{mid}	11 ± 3	16 ± 6*	13 ± 2	11 ± 4
	T_{off}	9 ± 4	15 ± 5*	12 ± 3	11 ± 5
Thigh angle (°)	T_{down}	61 ± 5	60 ± 5	62 ± 6	61 ± 5
	T_{mid}	81 ± 3	79 ± 5	81 ± 6	82 ± 5
	T_{off}	113 ± 7	113 ± 4	114 ± 5	112 ± 8
Shank angle (°)	T_{down}	0 ± 5	7 ± 7*	4 ± 5	0 ± 7
	T_{mid}	25 ± 6	26 ± 5	25 ± 6	26 ± 5
	T_{off}	51 ± 6	48 ± 5	48 ± 4	48 ± 6
Hip angle velocity ($° \cdot s^{-1}$)	T_{down}	390 ± 110	480 ± 100	430 ± 90	450 ± 110
	T_{mid}	560 ± 80	570 ± 100	580 ± 110	610 ± 70
	T_{off}	260 ± 110	320 ± 140	310 ± 190	320 ± 200
Knee angle velocity ($° \cdot s^{-1}$)	T_{down}	190 ± 110	−6 ± 90	40 ± 140	40 ± 200
	T_{mid}	−20 ± 110	−90 ± 110	−110 ± 130	−100 ± 110
	T_{off}	160 ± 170	5 ± 210	90 ± 350	120 ± 310
COM distance (cm)	T_{down}	−37 ± 7	−29 ± 6	−31 ± 9	−37 ± 10
	off	54 ± 9	53 ± 7	53 ± 7	50 ± 12

T_{down}, instant of touchdown; T_{mid}, instant of midstance; T_{off}, instant of takeoff.
For angular velocity measures: +ve = extension; −ve = flexion.
*Statistically significant difference ($p \leq 0.05$) from unloaded sprinting.

Table 5. Kinematic variables in the stance phase of sprinting for the women (n = 7, mean ± *SD*).

Variable	Time	Unloaded	Sled	Parachute	Weight belt
COM vel ($m \cdot s^{-1}$)	T_{down}	8.1 ± 0.6	6.9 ± 0.4*	7.4 ± 0.4	7.8 ± 0.4
	T_{mid}	7.8 ± 0.4	6.7 ± 0.3*	7.2 ± 0.5*	7.6 ± 0.3
	T_{off}	8.2 ± 0.5	7.1 ± 0.4*	7.5 ± 0.4	7.9 ± 0.5
Body lean (°)	T_{down}	12 ± 3	17 ± 3	12 ± 5	10 ± 5
	T_{mid}	12 ± 4	16 ± 3	13 ± 3	9 ± 5
	T_{off}	10 ± 4	14 ± 3	13 ± 4	9 ± 4
Thigh angle (°)	T_{down}	56 ± 3	58 ± 5	56 ± 6	56 ± 2
	T_{mid}	77 ± 4	76 ± 7	78 ± 6	79 ± 4
	T_{off}	112 ± 3	118 ± 4*	112 ± 3	112 ± 4
Shank angle (°)	T_{down}	3 ± 3	7 ± 5	4 ± 4	0 ± 3
	T_{mid}	29 ± 4	29 ± 4	29 ± 5	27 ± 4
	T_{off}	48 ± 5	50 ± 3	47 ± 5	47 ± 3
Hip angle velocity ($° \cdot s^{-1}$)	T_{down}	360 ± 60	370 ± 100	400 ± 90	360 ± 100
	T_{mid}	600 ± 90	560 ± 110	570 ± 70	590 ± 60
	T_{off}	380 ± 70	240 ± 60*	360 ± 30	450 ± 130
Knee angle velocity ($° \cdot s^{-1}$)	T_{down}	180 ± 80	110 ± 130	60 ± 70	150 ± 170
	T_{mid}	−120 ± 90	−210 ± 110	−120 ± 110	−100 ± 50
	T_{off}	90 ± 80	80 ± 140	70 ± 40	130 ± 110
COM distance (cm)	T_{down}	−34 ± 3	−29 ± 6	−35 ± 6	−37 ± 3
	T_{off}	47 ± 5	53 ± 4	46 ± 3	43 ± 5

T_{down}, instant of touchdown; T_{mid}, instant of midstance; T_{off}, instant of takeoff.
For angular velocity measures: +ve = extension; −ve = flexion.
*Statistically significant difference ($p \leq 0.05$) from unloaded sprinting.

the men (12). The slightly lesser COM distances at touchdown and takeoff for the women are mostly a reflection of their shorter stature, rather than differences in body configuration (Tables 4 and 5).

Discussion

The desired outcome when performing a resisted sprint training exercise is a reduction in running velocity without inducing substantial changes in the athlete's sprinting technique. In our study, all 3 devices produced a reduction in running velocity and so these devices are appropriate for training the maximum velocity phase of sprinting. However, the reduction in running velocity was different for each device (Tables 2 and 3), which makes it difficult to compare the effects of the devices on sprint kinematics.

In our study, some minor changes to sprinting technique were observed for all 3 devices, which suggests that our choices of load were probably close to the maximum acceptable for effective training of the maximum velocity phase. The reduction in velocity was greatest for the weighted sled, and suggests that this device may be the most effective in improving maximum sprint speed. However, this conjecture needs to be confirmed with a training study using different types of resisted sprint training devices. We must stress here that although there is strong anecdotal evidence that resisted sprint training exercises can improve acceleration and maximum sprint speed, their efficacy has not been scientifically confirmed (5,24).

A major limitation of our study was the use of only one load for each training device. Previous investigations of the acceleration phase in sled towing have shown that changes in running velocity and sprint kinematics depend on the load applied to the athlete by the device (15,17). A further study on the use of resisted training devices for training the maximum velocity phase should measure the changes in sprint kinematics when using a range of loads. The aim would be to identify the optimum load that gives the greatest training stimulus (i.e., reduction in running velocity) without inducing undesirable changes in sprinting technique.

Our study suggests that an important detrimental change in sprinting technique that is induced by a weighted sled or parachute is a greater forward lean of the trunk. Mann and Herman (20) noted that elite sprinters run in a more upright position than good sprinters, and therefore we suspect that trunk lean must be carefully monitored when training with resisted sprint devices so that an inappropriate angle is not induced and reinforced. When using a weighted sled or parachute the load applied to the athlete is directed backwards. The trunk pivots about the hips, and so the higher the harness attachment point is above the hips, the greater the forward lean required to counteract the applied load. A shoulder harness is therefore expected to induce a greater forward lean than a waist harness. We also suspect that changes in forward lean can be minimized by placing the harness around the hips so that the line of action of the applied load passes through the pivot point of the trunk (and therefore produces no torque).

When using a weight belt, the applied load is directed downwards rather than backwards. In this study, the weight belt did not induce a substantial change in the athlete's forward lean. The load due to the weight belt was close to the hips and evenly distributed around the waist, and therefore the total torque on the trunk was relatively small. If the athlete were to use a weighted vest instead of a weight belt, the applied load would be shifted up and farther away from the hips. However, we suspect that a substantial change in forward lean can be avoided if the weights are positioned appropriately on the chest and back so as to balance the torques about the hips.

Running velocity is determined by the product of the athlete's stride length and stride frequency. The mechanism by which faster sprinters achieve a higher running velocity is by exerting a larger force on the ground and hence producing a longer stride length (29). Resisted sprint training exercises aim to increase the athlete's running velocity by overloading the muscles that are used in sprinting, causing the athlete to elicit greater neural activation and recruit more fast-twitch muscle fibers. In unloaded sprinting the athlete exerts a horizontal force on the ground to accelerate the body forward and overcome air resistance, and a vertical force to propel the body upwards and produce a flight phase. Resisted sprint training exercises are expected to increase the athlete's ability to generate horizontal and vertical sprinting forces, depending on the direction of the applied resistance arising from the training exercise.

In the 3 resisted sprinting training exercises examined here, the additional loads on the athlete were expected to produce decreases in running velocity, stride length, and stride frequency (Tables 2 and 3). The horizontal force on the athlete arising from a parachute or sled reduces the distance the athlete travels forward during the flight phase of the stride and hence reduces the athlete's stride length. If the athlete is able to maintain the same movement patterns and ranges of motion during the ground contact phase of the stride, the horizontal force from the device increases the time taken to perform these movements and hence gives a longer ground contact time. In contrast, a horizontal force from the device does not affect the time taken for the athlete to perform leg movements during the flight phase of the stride. The net result of a longer ground contact time and unchanged flight time is a reduced stride frequency. As sprinting velocity is the product of stride length and stride frequency, the athlete's running velocity when using a resisted training device is correspondingly reduced.

The vertical force on the athlete arising from the weight belt was also expected to produce decreases in running velocity, stride length, and stride frequency. The athlete's response to a greater vertical load will be a greater vertical force during the ground contact phase so as to propel the body upwards and produce the necessary flight phase of the stride. However, this greater vertical force will probably come at the expense of a reduction in the horizontal force exerted by the athlete, and so the running velocity, stride length, and stride frequency will be reduced in a way similar to that described above for the horizontal force on the athlete arising from a training device.

During the ground contact phase of the stride, the athletes in this study increased the velocity of their center of mass by about 0.1–0.4 $m \cdot s^{-1}$ (Tables 4 and 5). At first glance this suggests that the athletes were still accelerating at the time they were recorded by the video camera (at about 40 m from the start of the sprint). However, when sprinting at constant speed the athlete's velocity must increase during the ground contact phase of the stride to compensate for the velocity lost due to air resistance in the flight phase of the stride. When sprinting at 7–10 $m \cdot s^{-1}$ the expected loss in velocity due to air resistance in each stride is approximately 0.2 $m \cdot s^{-1}$. Therefore, the magnitude of the velocity increase during the contact phase that was observed in this study is consistent with running at constant velocity, and suggests that the athletes were sprinting at close to their maximum speed.

In a study of the effect of a weighted sled on sprinting technique in the acceleration phase, Lockie et al. (17) presented an equation that relates the reduction in running velocity to the weight of the sled. However, the load applied to the athlete by a weighted sled depends on the coefficient of friction between the sled and the running surface, as well as on the weight of the sled. Therefore, the proposed equation is specific to the combination of sled and running surface used in the study. In our experience, the coefficient of friction for running surfaces can vary by a factor of two, and hence the weight of the sled required to produce a given reduction in velocity can vary by a corresponding amount.

Practical Applications

Many coaches attempt to improve their athlete's maximum sprint velocity by applying a resistance during sprinting so as to overload the athlete. When using a resisted sprint training device the coach can use the athlete's running velocity as an indirect measure of the overload on the athlete. The greater the decrease in running velocity, the greater the overload on the athlete. Successful adaptation by the athlete to an overload is believed to allow the athlete to produce a greater force during the ground contact phase of the stride, resulting in a longer stride length and hence a greater running velocity (13,18,29). The three types of resisted sprint training devices examined here (sled, parachute, and weight belt) are appropriate devices for training the maximum velocity phase in sprinting. These devices were shown to induce a substantial reduction in running velocity compared to unloaded sprinting. The athlete should use a high load so as to experience a large training stimulus, but not so high that the device induces substantial changes in sprinting technique.

With devices that exert a horizontal force on the athlete (such as a sled or parachute), the coach should pay particular attention to the forward lean of the trunk. We recommend using a waist or hip harness rather than a shoulder harness, as this should minimize the torque about the hips and hence minimize any change in trunk angle. The coach should also look at the angles of the support leg during the ground contact phase of the stride, and adjust the load so as to minimize any changes from unloaded sprinting. We recommend using a video overlay system such as Quintic Coaching (Quintic Consultancy, Coventry, UK) to visually compare the movement patterns of the athlete in unloaded sprinting to sprinting with the training device.

With devices that exert a vertical force on the athlete (such as a weight belt or weight vest), the weights should be distributed at the front and rear of the body so as to balance the torques about the hips and hence minimize the change in the angle of the trunk. Again, the coach should pay particular attention to the angles of the support leg during the ground contact phase of the stride, and adjust the load as necessary.

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