# THE EFFECTS OF RESISTED SLED LOADING ON SPRINT START KINEMATICS

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Alterations in sprint start kinematics during resisted sled sprinting with loads of 10% and 20% body mass (BM) of ten track sprinters was assessed. High-speed video footage was collected at 250 Hz for the start action with sagittal kinematic measures subsequently obtained using APAS motion analysis software. A repeated measure ANOVA determined if there was a significant ($p < 0.01$) interaction between the kinematics under the various loaded conditions. Resisted sled loading did not change sprint start performance (mean horizontal block acceleration) but it did stimulate some key technical aspects such as start time and block push-off angle. Stimulating these two aspects of sprint start performance may lead to an enhanced sprint start, through a larger generation of force within the starting blocks and a more horizontal leaving position from the blocks.

**INTRODUCTION:** Superior execution of the block start phase is critical for achieving a performance edge over the competition in the short sprint events of Track and Field (Coh, Jost, Skof, Tomazin, & Dolenec, 1998; Harland & Steele, 1997). Specifically, a successful sprint start requires the development of large horizontal forces at a high rate whilst in the blocks (Harland & Steele, 1997), resulting in a swift movement that leads to the generation of a rapid sprint running velocity. Identifying training strategies that are appropriate for improving horizontal force production in the starting blocks may assist coaches and physical conditioners in the task of training sprinters.

Resisted sled towing is widely considered the most appropriate training technique to improve the strength of the muscles that are fundamental to sprint performance (Saraslanidis, 2000). The suggested benefits from using resisted sled towing are a faster start performance (Mouchbahani, Gollhofer, & Dickhuth, 2004; Sheppard, 2004), an increase in muscular force output of the lower body (Saraslanidis, 2000), and the development of specific recruitment patterns that target the fast-twitch muscle fibers (Lockie, Murphy, & Spinks, 2003).

Research has revealed that resisted sled towing causes acute alterations in sprint kinematics of the early acceleration phase (Letzelter, Sauerwein, & Burger, 1995; Lockie et al., 2003). Kinematics such as stride frequency and stride length have been reported to decrease, whereas stance time, trunk and hip angles have been reported to increase as a consequence of this training method (Letzelter et al., 1995; Lockie et al., 2003; Mouchbahani et al., 2004). Despite the fact that resisted sled towing has been promoted as a useful tool for improving sprint start performance (Mouchbahani et al., 2004; Sheppard, 2004), no studies have examined the effects of this training modality on sprint start kinematics. The identification of the kinematic alterations to sprint start technique that result from resisted sled loading, if any, would provide valuable information on whether or not this training tool is beneficial for attempting to improve sprint start performance.

The purpose of this study was, therefore, to examine the changes to block start sprint kinematics with resisted sled loading and, secondly, to identify the most appropriate loads to prescribe as a resistance when training.

**METHODS:** Ten male (mean ± SD: age 20 ± 3 years; height 1.82 ± 0.06 m; weight 76.7 ± 7.9 kg; 100 m personal best: 10.87 ± 0.36 s {10.37–11.42 s}) track sprinters at a national and regional competitive level participated in the current study. Each participant gave written informed consent to participate in this study prior to testing. Ethics approval was obtained for all testing procedures from the Auckland University of Technology Ethics Committee.

Athletes performed twelve 10 m sprints from a block start in total, four trials each under three experimental conditions. The conditions used were unresisted sprinting and resisted sprinting with two different loads (10% BM and 20% BM). A metal sled weighing 7 kg was employed in this study. A nylon rope 30 m in length was used to connect the athlete to the sled via a waist

harness. The placement of the starting blocks was individually set according to the preference of the individual athlete.
Swift timing lights (80 Hz) were utilized to record the time from the start signal to the 10 m line. A microphone attached to a wooden start clapper was connected to the timing light handset. Timing was initiated when the appropriate sound threshold was broken. As sprint running from a block start involves body movements that occur predominately in the sagittal plane, a two-dimensional protocol was considered satisfactory for the present study. The set position, starting action (leaving the starting blocks) and initial acceleration (first few steps from the starting blocks) were filmed with two Fastcam PCI1000 cameras operating at 250 Hz with a shutter speed of 1/500 s. The cameras were placed perpendicular to the running direction, with overlapping fields, giving a sagittal view of the athlete for approximately three full running steps. The first camera registered the set position, starting action and one full step, whilst the second camera captured the movement of the athlete during the remaining two steps. Both cameras were positioned 13 m from the athlete and elevated to the athlete's approximate hip height of 1.1 m. Three marker strips were placed in the field of view so that one was visible in the overlapping view and towards the outer edge of each camera. These three markers ran across the lane with a strip placed parallel to the lane's long axis in the lane centre. These markers were used to calculate the measures of horizontal displacement. A 1.7 m tall rod fitted with a spirit level was filmed pre and post testing session at each of the three marker strips to enable the calculation of vertical displacement measures.
High speed video footage collected from both cameras was analysed frame-by-frame to identify the x and y co-ordinates of the athlete's joints using a kinematic analysis system (Ariel Performance Analysis System, U.S.A.). Eighteen points of the body were digitized: apex of the head, $7^{th}$ cervical vertebra, glenohumeral joints, elbows, wrists, third metacarpophalangeal joints, hips, knees, ankles, and distal ends of the feet (Johnson & Buckley, 2001). From these 18 points, human body segments were modeled. The segments included: trunk (shoulder to hip), head, upper arms, forearms, hands, thighs, shanks, and feet. The data was smoothed using a digital filter with a cutoff frequency of 8 Hz. While the overall study looked at the whole 10 m, this paper is just about the block start. The kinematic variables derived from the block start were mean horizontal block acceleration, reaction time, time to remove hands off ground, time to remove back leg off blocks, start time, total block time, flight time, mean horizontal block velocity, joint angles at takeoff from the blocks (angles from the ankle, knee, hip, front shoulder, back shoulder, front elbow, and back elbow joints), block push-off angle, segment angles at takeoff from the blocks (angles from the shank, thigh, trunk, front upper arm, back upper arm, front forearm, and back forearm segments). All absolute angles were measured from the distal end (e.g. wrist for the lower arm segment) of a segment going in a counterclockwise direction from the horizontal plane.
Means and standard deviations were calculated for each of the kinematic measures of the two fastest trials of each condition. A repeated measures ANOVA was used to determine if there was a significant interaction between the kinematics under the various loaded conditions. Statistical significance was set at $p < 0.01$ for all analyses. All statistical procedures were performed using SPSS for Windows 12.0.

**RESULTS:** Sprint times for the unresisted 10 m sprint from a block start ranged from 1.94 s to 2.14 s ($\overline{X} = 2.04 \pm 0.06$ s). The sprint times became slower when the athletes were connected to the sled towing device (main effect: $p = 0.001$; 0% vs. 10%; $p = 0.001$; 0% vs. 20%: $p = 0.001$). A resistance load of 10% or 20% BM reduced 10 m sprint time by approximately 8% (0.16 s) and 14% (0.28 s) respectively. Mean sprint time with a 20% BM load was approximately 6% slower (0.12 s) then mean sprint time with a load of 10% BM.
A small number of sprint start kinematics were significantly ($p < 0.01$) affected by a resisted sled load of 10% and 20% BM. The sprint start kinematic variables of total block time, start time, and flight time from the blocks are presented in Table 1. Generally the introduction of the resisted sled towing tool decreased these measures by 5%-20%. Total block time, for example, was 29 ms (7%) slower with a 10% BM resistance, and 40 ms (10%) slower with a 20% BM. Whereas, flight time from the blocks with no resistance was approximately 16%

(11ms) and 21% (13 ms) longer than with a 10% BM load and 20% BM load respectively. The 10% BM load conditions start time was approximately 6% (18 ms) longer than the condition with no resistance. Start time with a 20% BM load was also longer by approximately 10% (30 ms) compared with sprinting with no resistance.

**Table 1 Alterations in sprint performance and sprint start kinematics with added resistance.**

| | No Resistance | 10% BM Resistance | 20% BM Resistance |
|---|---|---|---|
| 10 m sprint time (s) | 2.04 ± 0.06 | 2.20 ± 0.04* | 2.32 ± 0.05*,** |
| Total block time (ms) | 430 ± 38 | 459 ± 25* | 470 ± 36*,** |
| Start time (ms) | 314 ± 28 | 332 ± 24* | 344 ± 29* |
| Flight time from blocks (ms) | 67 ± 14 | 56 ± 16* | 54 ± 20* |
| Block push-off angle (°) | 47.3 ± 1.7 | 45.9 ± 2.3* | 45.2 ± 1.8* |
| Block takeoff shank angle (°) | 37.9 ± 4.2 | 34.9 ± 3.4* | 33.7 ± 3.4* |

All results are reported as means ± standard deviations (SD)"
* Significantly ($p < 0.01$) different from no resistance
** Significant differences between 10% BM and 20% BM loads

**DISCUSSION:** Resisted sled towing is a sprint specific training method promoted as a useful tool for improving sprint start performance (Mouchbahani et al., 2004; Sheppard, 2004). However, the block start in the short sprint events is highly technical (Harland & Steele, 1997), and no studies have examined the effects resisted sled towing has on sprint start kinematics. Sprint start performance (mean horizontal block acceleration) was unaffected by added resistance. Further, many of the kinematics during the sprint start were unaltered as a result of resisted sled towing. Loading did not effect, for example, mean horizontal block velocity, reaction time, and the total time taken to remove both hands off the ground. However, kinematic measures such as start time and block push-off angle identified to change when the athlete was attached to the sled device, may benefit from resisted sled tow training and lead to an enhancement in sprint start performance.

The aim of the block start is to activate the correct sequence of muscular activity so that maximal force production occurs (Harland & Steele, 1997), whilst leaving the blocks in the shortest possible time (Helmick, 2003). Resisted sled towing led to increased start time, which possibly suggests that greater motor activity is occurring within the hip and lower limb musculature. Intuitively, a greater load would require the production of a greater force to overcome the inertia of the object. This greater force requirement will result in a greater recruitment of additional motor units available within the muscle, or possibly increase the rate of neural impulses to the already recruited motor units (Deschenes, 1989). These neural activation qualities are considered important for a superior sprint performance (Ross, Leveritt, & Riek, 2001). The results of the current study suggest that resisted sled towing may be a useful tactic to increase force production and the muscle activity during the time from reacting to the start signal to leaving the starting blocks (start time), which in turn may improve start performance. The increase in start time was less than 10% for both loads, indicating that either load would be appropriate to use for improving start time. Therefore, if a successful block start requires the production of large horizontal forces in the blocks (Harland & Steele, 1997), resisted sled towing with a load of 20% BM would be an excellent training tool to use to improve sprint start performance as the greater mass would result in a greater force production.

When coaching the sprint start, technical emphasis is placed on leaving the starting blocks in a more horizontal position. Resisted sled towing with either a 10% or 20% load resulted in the athletes adopting a more horizontal push-off or drive angle out of the starting blocks. This was more than likely due to the greater inertia restricting the ability of the athlete to move vertically. Hoster and May (1979) stated that the drive angle during block take-off should be as low (horizontal) as possible. If the angle of takeoff is shifted closer to the horizontal it is likely that an increase in step length would occur providing the takeoff velocity remains the same. Increases in the length of the first steps out of the starting blocks has been advocated as part of an optimal start (Korchemny, 1992). The findings of the current study indicated that either training load would be appropriate to use during resisted sled tow training in order to increase the horizontal drive out of the blocks, however, the heavier load did put the athlete in a slightly more horizontal position. Hence, resisted sled towing with a load of 20% BM may be useful for athletes who propel themselves in a more vertical direction as opposed to a horizontal direction out of the starting blocks.

**CONCLUSION:** If the training goal of the track and field sprints coach or athlete is to improve sprint start performance the results of this study suggest resisted sled towing to be an excellent training tool to employ in an individuals training regime to aid this training goal. This was due to increased force output within the starting blocks without a significantly detrimental affect on sprint start kinematics. Although sprint start performance was not directly altered as a result of resisted sled towing, two vital sprint start kinematics, start time and block push-off angle, may benefit from the added resistance which would lead to an enhancement in sprint start performance. It is recommended that a resisted sled load of 20% BM be employed to induce an adaptation for the key sprint start technical coaching aspects start time and block push-off angle. Specifically, a load of 20% BM, will allow for a large generation of force within the starting blocks, and cause a more horizontal leaving position from the starting blocks, whilst causing minimal disruption to technique.

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