ACUTE SPATIOTEMPORAL AND MUSCLE EXCITATION REPONSES TO WEARABLE LOWER LIMB LOADING DURING MAXIMAL VELOCITY SPRINTING

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This study quantified the mechanical effects of adding light wearable loads to the thigh or shank segments during maximal velocity sprinting. Eight university level sprinters performed two 40 m sprints under each condition (unloaded, thigh loaded, shank loaded) in a randomised order, and effects were analysed using magnitude based inferences. In both loaded conditions, there was a possibly small decrease in step velocity which was associated with a likely small decrease in step rate and no clear difference in step length. There was a likely small increase in contact time in the thigh-loaded condition, and possibly small increases in both flight and contact time in the shank-loaded condition. There were no clear differences in biceps femoris or semitendinosus excitation between any conditions. These results provide information which can be used to objectively implement wearable resistance in to periodised training programmes.

KEY WORDS: EMG, hamstring, injury, kinematics, muscle, performance.

INTRODUCTION: Track and field sprinting is a pure athletic endeavour, where the world record holder in the 100 m event is titled the 'fastest person on the planet'. Given the popularity of this event, much research intended to inform the enhancement of sprint performance has focussed on strength and conditioning practices. One such focus has been on the effects of resistance training during physical preparation for the purposes of injury prevention and performance enhancement. Resistance training practice in sprinters is typically periodised, which is thought to be the most suitable way to appropriately peak for competition (Bompa & Buzzichelli, 1999). The style of periodisation used typically transfers from less specific, basic and pre-competition phase training to specific, competition phase training and maintenance. However, a common issue with this method of periodisation is managing the transition between phases, as increases in the volume and/or intensity of maximum velocity running may be problematic, particularly for the hamstrings given their importance in producing force during maximum velocity sprinting (Morin et al., 2015).
Training methods which help to bridge the transition between phases are therefore of interest to sprint coaches and practitioners, and sprinting with wearable resistance may offer one such highly-specific training method. In the few studies that have investigated wearable resistance, significant changes to sprint kinematics have been identified in response to both trunk and limb-based loading. When loading the trunk during sprinting, greater loads have to be used to produce similar changes in velocity and spatiotemporal variables, compared with lower limb loading (Simperingham & Cronin, 2014). Consequently, for the purposes of highly-specific training intended to bridge the gap between the pre-competition and competition phases of periodised resistance training programmes, lower limb loading enables lighter loads to be used. However, it is not known how placing loads at different locations on the lower limbs affects sprint kinematics, and in particular how it might affect the demands placed on the hamstrings. The aim of this research was therefore to quantify the acute changes in spatiotemporal characteristics, hamstring muscle excitation and performance levels when light wearable loads are added to either the thigh or shank segments during maximum velocity sprinting, in comparison to unloaded maximum velocity sprinting.

METHODS: Six male and two female university-level sprinters (Mean ± SD: age = 21 ± 1 years; height = 1.72 ± 0.09 m; mass = 70.4 ± 6.4 kg, season's best sprint time, male = 11.61 ± 0.39 s, female = 12.63 ± 0.33 s) provided written informed consent to participate in this study which

was approved by the local Research Ethics Committee. Data collection took place at an indoor track and participants wore tight-fitting shorts, a vest top and spikes. Participants completed their typical warm-up for a maximum velocity training session, after which they performed a series of six 40 m sprints from a two-point start, with at least two minutes of recovery between each sprint within a condition and at least five minutes between conditions. These consisted of two unloaded sprints, two thigh loaded sprints (+0.6 kg per leg) and two shank loaded sprints (+0.2 kg per leg) with conditions in a randomised order between participants. These specific loads were chosen because the wearable equipment used ascended in 0.2 kg increments (Exogen suit, Lila, Malaysia). Therefore, to normalise the rotational demands between conditions the loads were situated on the anterior portion of the given segment at a specific location based on each participant's measured segment lengths. This ensured that the moment of inertia of the whole leg about the hip was theoretically matched (at +4.5%) between the two loaded conditions based on typical lower limb angular kinematics during a maximum velocity stride cycle (Zhong, Fu, Wei, Li, & Liu, 2017).
A high speed video camera (PXW-Z150, Sony, Japan) with a frame rate of 120 Hz was set up perpendicular to the sprint lane at the 35 m mark. The video camera was 16 m from the centre of the lane, and an 8 × 2 m area was calibrated within the view to ensure that one complete stride cycle of the left leg could be captured. An optical measurement system with infra-red light barriers (Optojump, Microgate, Italy) was placed either side of the sprint lane between 30 and 40 m to obtain spatiotemporal characteristics (step length, step rate, contact time and flight time). A wireless electromyography (EMG) system (Trigno™, Delsys USA) was used to obtain raw muscular excitation data at 2000 Hz from the biceps femoris long head and semitendinosus of the left leg of each participant, in accordance with the SENIAM 5 guidelines for electrode placement (Hermens & Freriks, 1999). The EMG data and video data were synchronised to the nearest half a video frame using a Trigger Module (PM-U02, Delsys, USA) which activated an LED in the view of the camera at the instant EMG data collection commenced.
All raw data was analysed for one complete left leg stride cycle (starting at left foot touchdown) which occurred closest to the 35 m mark as identified from the video footage. The EMG data were processed by removing DC bias, high-pass filtering (30 Hz), full wave rectifying, and creation of a linear envelope via low-pass filtering (10 Hz). Peak processed EMG values for each muscle in both of the loaded conditions were then extracted and expressed as a percentage of the respective values obtained during the unloaded sprints. From the optical measurement system outputs, velocity was calculated as the function of step length and step rate. The spatiotemporal step characteristics and step velocity for the two steps which combined to form the analysed stride cycle were averaged. The raw spatiotemporal and EMG data were then averaged across the two trials for each condition to obtain the dependent variables used for statistical analysis.
All dependent variables were analysed using a magnitude based inference (MBI) approach (Batterham & Hopkins, 2006). Group-wide means and standard deviations (SDs) were first calculated for each variable. Effect sizes (Cohen's *d*) and their 95% confidence intervals were then calculated between each of the loaded conditions and the unloaded condition, with thresholds of 0.2, 0.6, 1.2 and 2.0 used to define small, moderate, large and very large mean effects, respectively. Based on a smallest worthwhile effect size of 0.2 (Winter, Abt, & Nevill, 2014), meaningful differences were identified where the 95% confidence interval did not overlap an effect size of both +0.2 and -0.2. The percentage likelihoods of a negative | trivial | positive effect were also calculated and described qualitatively (Batterham & Hopkins, 2006).

RESULTS: For both of the loaded conditions, there was a possibly small decrease in step velocity compared with the unloaded conditions (Table 1; Figure 1). This occurred due to likely decreased step rates in both loaded conditions, with only trivial or unclear differences in step length between the loaded conditions and the unloaded condition. Contact times were likely greater during the thigh loaded condition compared with the unloaded condition, and possibly greater during the shank loaded condition compared with the unloaded condition. There was also a possible increase in flight time during the shank loaded condition compared with the unloaded condition, but there was no clear difference in flight time between the thigh loaded condition and unloaded condition. There were no clear differences in peak muscle excitation of the biceps femoris or semitendinosus between conditions (Table 1).

Table 1. Group mean ± SD values for all dependent variables for each condition.

	Unloaded	Thigh Loaded	Shank Loaded
Step Velocity (m/s)	8.95 ± 0.68	8.79 ± 0.73*	8.83 ± 0.69*
Step Length (m)	2.01 ± 0.17	2.04 ± 0.11	2.03 ± 0.16†
Step Rate (steps/s)	4.47 ± 0.28	4.30 ± 0.33**	4.37 ± 0.30**
Flight Time (s)	0.108 ± 0.012	0.113 ± 0.008	0.111 ± 0.011*
Contact Time (s)	0.117 ± 0.011	0.120 ± 0.012**	0.119 ± 0.012*
Peak BFlh EMG (%)		98 ± 16	106 ± 17
Peak ST EMG (%)		100 ± 16	96 ± 16

*** clear difference versus the unloaded condition (* = possible difference, ** = likely difference). † trivial difference versus the unloaded condition († = possibly trivial difference, †† = likely trivial difference). Peak EMG values are expressed as a percentage of the unloaded condition, BFlh = biceps femoris long head, ST = semitendinosus.**

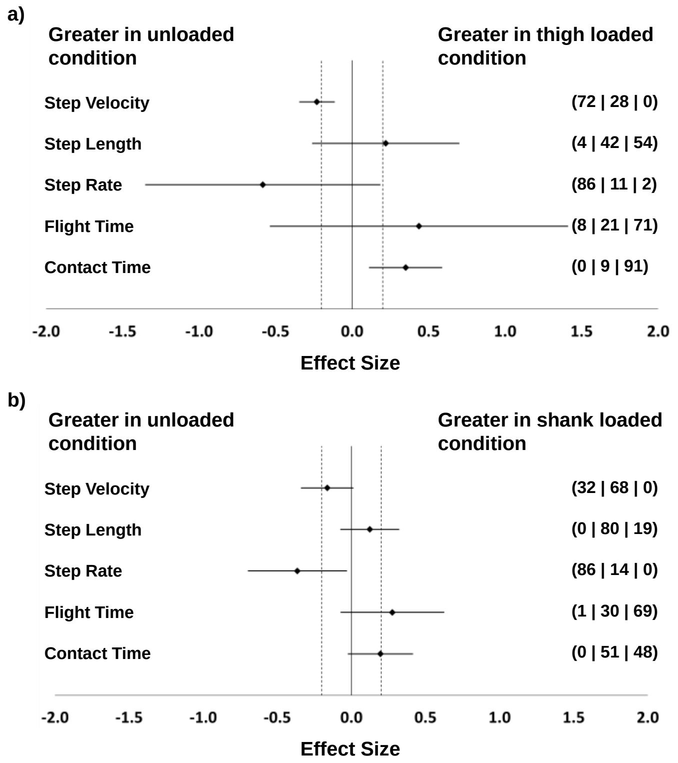

Figure 1. Effect size (Cohen's *d*, ± 95% CIs) for all spatiotemporal variables for the a) thigh-loaded condition and b) shank-loaded condition, compared with the unloaded condition. The right-hand side of each figure quantifies the percentage likelihood of a negative | trivial | positive effect.

DISCUSSION: This study aimed to quantify the acute changes in spatiotemporal characteristics, hamstring muscle excitation and performance levels associated with the addition of light wearable loads to either the thigh or shank segments during maximum velocity sprinting. In both loading conditions, step velocity exhibited a possibly small decrease compared with the unloaded condition, highlighting that a small overload effect on performance was evident in both loading conditions. Step velocity is the product of step length and step rate, and the observed decreases in step velocity were due to a likely small decrease in step rate in both conditions as there were no clear differences (thigh loaded condition) or likely trivial differences (shank loaded condition) in step length. The decreases in step rate occurred due to increases in contact time in both loaded conditions, and also due to possible increases in flight time in the shank loaded condition. As any changes in performance (step velocity) and the measured spatiotemporal variables between the unloaded and loaded conditions were small, this supports the high degree of specificity between the loaded sprinting conditions and the unloaded condition, providing evidence to support the idea that loading the lower limbs with loads on either the thigh or shank segments could be an effective training tool to bridge the gap between pre-competition and competition phases of a periodised training programme. Furthermore, there were no clear differences in biceps femoris or semitendinosus muscle EMG between the conditions. This demonstrates that the light wearable resistance does not increase the excitation demand placed on the hamstrings. However, further research is required to investigate whether the strain placed on the hamstrings changes with the addition of light wearable resistance.

Of note is that the 95% confidence intervals associated with the effect sizes (Figure 1) were narrower for the shank loaded condition than the thigh loaded condition. This suggests that there were more consistent group-wide responses to the shank loading, whereas there was greater variation in the individual responses to the thigh loading. This may be in part due to the greater loads which had to be applied to the thigh to create the same moment of inertia demand about the hip. Loading the shank with light wearable resistance may provide a more consistent response during maximum velocity sprinting, whereas loading the thigh may lead to more varied, and potentially greater, responses between individuals. Further analysis and research is therefore warranted to explore the individual responses to these wearable resistance conditions.

CONCLUSION: The addition of light wearable resistance to either the shank or thigh segment during maximal velocity sprinting leads to a possible, small reduction in step velocity, caused by likely small decreases in step rate. These reduced step rates are due to possible or likely greater contact times in both of the thigh and shank loading conditions, and also possibly greater flight times in the shank loaded condition. This study provides objective information which can be used by coaches and medical staff to help prepare sprinters for the competition phase of their periodised training programmes.

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