The effect of lower-limb wearable resistance on anterior pelvic tilt during high-speed running: A pilot study

Erin H Feser and Derek Sabin

Belmont University, Nashville, Tennessee, United States

This study determined the effect of two different lower-limb (i.e. thigh and calf) wearable resistance loads on anterior pelvic tilt during self-selected, high-speed (4.72 – 6.71 m/s) treadmill running. Nine athletes completed a series of 10-second intervals at a self-selected speed for each experimental condition. Compared to unloaded running, the heaviest wearable resistance load (0.91 – 1.24 kg) significantly ($p < 0.05$) reduced anterior pelvic tilt at the instants of maximal hip extension and maximal hip flexion by -3.54º (ES = 0.80) and -3.30º (ES = 0.55), respectively. Individual responses showed a primary trend towards a reduction in anterior pelvic tilt when running with wearable resistance (6/9 athletes). This study provides initial evidence for the use of lower-limb wearable resistance as a training stimulus to induce pelvic kinematic changes over time.

KEYWORDS: microload, limb loading, resistance training, sprint running, specificity

INTRODUCTION: Hamstring injury and reinjury are prevalent in sports that require sprint running. Although much attention has been directed towards prevention and rehabilitation efforts, incidence rates remain high (Ekstrand et al., 2016). This has resulted in researchers shifting focus to different factors that may influence the mechanism of hamstring injury, such as anterior pelvic tilt (Mendiguchia et al., 2021; Schuermans et al., 2017b). Excessive sagittal plane motion of the pelvis and low neuromuscular control of the lumbo-pelvic region during sprint running have been shown to be related to hamstring injury susceptibility in sporting samples (Schuermans et al., 2017b; Schuermans et al., 2017a). Thus, training protocols that can successfully reduce anterior pelvic tilt while sprint running are thought to reduce risk for hamstring injury and have been shown to concomitantly improve sprint performance (Mendiguchia et al., 2021). An emerging method of training for sprint running involves the use of light wearable resistance (e.g. 1% of body mass) attached to the lower-limbs (Feser et al., 2021). It has been shown that increasing the inertia of a lower-limb segment via wearable resistance increases the mechanical work at the proximal joint (Martin and Cavanagh, 1990). For example, wearable resistance placed on the thigh segment increased the mechanical work at the hip joint. This provides a targeted and velocity specific method to overload the important muscle groups for sprint running performance. However, it has yet to be investigated if athletes alter lumbo-pelvic kinematics during the increased mechanical work demands of sprint running with lower-limb wearable resistance. Therefore, the purpose of this study was to determine the effect of two different wearable resistance loads on anterior pelvic tilt during high-speed treadmill running. Given the additional proximal (i.e. “core”) stability needs that come with moving a greater limb load at high-speeds, it was hypothesized that athletes would shift to a less anteriorly tilted pelvis position when running with lower-limb wearable resistance.

METHODS: Nine competitive collegiate athletes (Male: n = 4, female: n = 5) (mean ± standard deviation; age: 19.7 ± 1.22 years, height: 172 ± 0.08 cm, mass: 65.7 ± 6.56 kg) volunteered to participate in this study. The sample included five track athletes and four field-based team sport athletes. The testing session began with a standardized dynamic warm-up with time allocated for self-selected warm-up activities. Following, a barefoot, standing pelvis position measure was

taken using the anterior superior iliac spine and the posterior superior iliac spine as reference points (Suits, 2021). Athletes were then asked to select a treadmill speed that represents an effort level equivalent to an 8 on a 10-point Borg Rating of Perceived Exertion Scale. This speed was then used for all experimental conditions. Athletes completed three 10-second intervals at their selected treadmill speed after getting the treadmill up to speed and reaching a normal running gait. A 20-second rest period between intervals and a 2-minute rest between experimental conditions were provided. The three experimental conditions - unloaded (UN), single load (SL), and double load (DL) - were completed in a randomized order. Athletes wore one or two pairs of the Omorpho G-Tight (Omorpho, Portland, USA) for the SL and DL conditions, respectively. For the SL condition, the added weight of the tight totaled 0.45 kg (0.69% of mean body mass (BM)) for the females and 0.62 kg (0.96% BM) for the males with the weight distributed across the thighs and shanks. For the DL condition, the added weight equaled 0.91 kg (1.39% BM) for the females and 1.25 kg (1.92% BM) for the males.
An inertial measurement unit (sampling rate = 100 Hz; Myomotion, Noraxon, Scottsdale, USA) was attached to the pelvis, thighs, left shank, and left foot in accordance with manufacturer's instructions to measure joint and segment kinematics during the treadmill intervals. To represent each athlete's technique, the kinematic data points of interest were extracted from the MyoMotion software and averaged from strides 10, 11, and 12 of the second interval of each experimental condition. Specifically, sagittal plane pelvic tilt at touchdown, maximal hip extension, and maximal hip flexion were identified along with the hip joint angle at maximal hip extension and maximal hip flexion for the left limb. A one-way repeated measures ANOVA with pair-wise post hoc comparisons (Fisher's LSD) were conducted. An outlier was defined as a value greater than 1.5 box-length from the edge of the box and was removed from the analysis (see Table 1 for final analysis sample size). The differences between measures were normally distributed as assessed by Shapiro-Wilk's test ($p > 0.05$). Analyses were performed using SPSS Statistics (Version 28, IBM, Armonk, NY, USA). Significance was set at $p \leq 0.05$. Effect size statistics (Cohen's *d*) were calculated as the mean of the within-subjects difference scores divided by the average standard deviation of both repeated measures. The effect size statistics were described as trivial (<0.20), small (0.20 – 0.49), moderate (0.50 – 0.79), and large (>0.80) (Cohen, 1988). To describe individual responses in pelvic tilt to each loaded condition, the smallest worthwhile change (SWC) was calculated as 0.2 × unloaded between-subject standard deviation and classified as an increase (> + SWC) or decrease (< - SWC) if the absolute change in pelvic tilt from the unloaded condition was outside of the SWC.

RESULTS: Standing pelvic tilt measures ranged from 4º to 17º and are reported next to the athlete number in Figure 1. The average treadmill speed used by the athletes was 5.66 m/s (range = 4.72 – 6.71 m/s). Stride frequency was reduced by 0.02 Hz with the DL ($p = 0.05$; ES = 0.12, trivial) compared to the SL condition. All other comparisons for stride frequency were not significant. The DL significantly reduced anterior pelvic tilt at maximal hip extension and maximal hip flexion compared to the unloaded condition by -3.54º (ES = 0.80, large) and -3.30º (ES = 0.55, moderate), respectively (Table 1). All other comparisons for pelvic tilt were not significant. No significant differences ($p > 0.05$) were identified in maximal hip extension or maximal hip flexion between any of experimental conditions (Table 1). Inspection of individual responses largely revealed consistency in an athlete's directional response to running with weighted tights for the pelvic tilt measures at touch down, maximal hip extension, and maximal hip flexion. Four athletes shifted to a more neutral pelvic tilt position (> - SWC) in every measure, while two athletes were either more neutral or unchanged. One athlete shifted to a greater anterior pelvic tilt position (> + SWC) in every measure, while two athletes were either in greater anterior pelvic tilt or unchanged. Individual responses for pelvic tilt at maximal hip flexion are presented in Figure 1.

Table 1. Mean and standard deviation for sagittal plane pelvic tilt, maximal hip extension, and maximal hip flexion for the unloaded (UN), single load (SL), and double load (DL) experimental conditions.

		UN	SL	DL	SL – UN	DL – UN	DL – SL
	n	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$; ES	$\bar{x}$; ES	$\bar{x}$; ES
APT_{TD} (°)	9	4.40 (4.92)	3.48 (6.20)	2.23 (6.46)	-0.93; 0.17	-2.17; 0.38	-1.24; 0.20
APT_{HE} (°)	8	9.44 (3.73)	7.11 (4.14)	5.90 (3.92)	-2.33; 0.52	-3.54*; 0.80	-1.20; 0.23
APT_{HF} (°)	8	9.55 (4.72)	7.25 (3.89)	6.25 (4.01)	-2.30; 0.43	-3.30*; 0.55	-1.00; 0.17
MHE (°)	7	-19.3 (4.70)	-20.5 (3.70)	-21.4 (6.97)	-1.25; 0.18	-2.12; 0.29	0.87; 0.11
MHF (°)	9	64.4 (8.57)	63.0 (8.15)	59.9 (10.8)	-1.43; 0.17	-4.46; 0.46	-3.04; 0.32

APT = anterior pelvic tilt; TD = touchdown; MHE = maximal hip extension; MHF = maximal hip flexion; * = $p \leq 0.05$; ES = effect size.

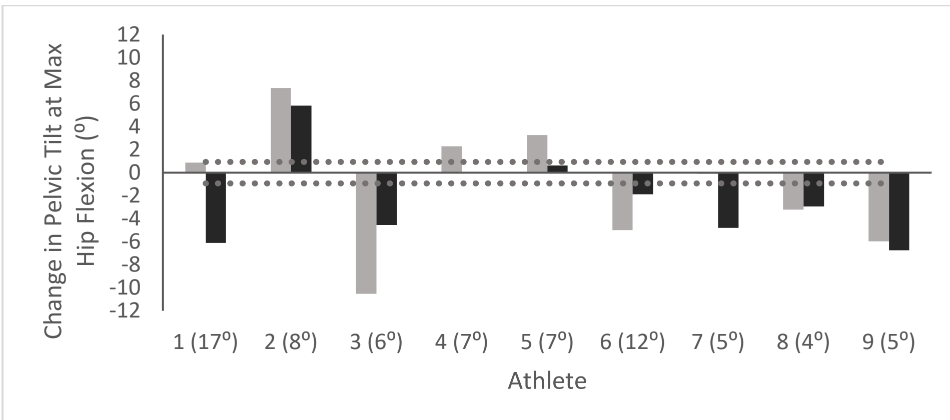

Figure 1. Absolute change in pelvic tilt from the unloaded condition with single load (grey) and double load (black) wearable resistance for each athlete. Dashed lines indicate the smallest worthwhile change threshold. Each athlete's standing pelvic measure is in parentheses.

DISCUSSION: The purpose of this study was to determine the effect of two different lower-limb wearable resistance loads on anterior pelvic tilt during high-speed treadmill running. The main findings were: 1) the DL condition significantly reduced anterior pelvic tilt at maximal hip extension and maximal hip flexion without significant coinciding changes to hip joint position; and 2) the primary trend in individual response was towards a reduction in anterior pelvic tilt when running with lower-limb wearable resistance (6/9 athletes).

Lower-limb wearable resistance is a training methodology that provides an overload specific to the movement speed, movement pattern, and muscle actions used during high-speed running and sprinting. Given this, lower-limb wearable resistance would also overload the dynamic coordination and stability requirements. This led to the hypothesis that athletes would shift to a more neutral pelvis position when running with lower-limb wearable resistance considering greater proximal (i.e. "core") stability would be needed to successfully move a greater limb load at a high-speed. It was shown that athletes significantly reduced anterior pelvic tilt during the DL wearable resistance condition compared to the unloaded condition [at maximal hip extension (-3.54º; ES = 0.80, large) and maximal hip flexion (-3.30º; ES = 0.55, moderate)]. Maximal hip flexion and extension were also reduced (small, non-significant). However, with a more neutral pelvis an athlete needs less hip flexion to reach a similar knee drive position relative to the ground, same for hip extension. Considering the relationship between excessive anterior pelvic tilt and hamstring injury susceptibility (Schuermans et al., 2017b), a training method that encourages athletes to be in a more neutral position without negatively altering stride mechanics could serve as a useful tool to produce beneficial long-term adaptations. It is important to note that not all athletes utilized a more neutral pelvis position when running with lower-limb wearable resistance. Some athletes (3/9) shifted further into anterior tilt when running with the wearable resistance, representing both the team sport (athletes 4 and 5, both females) and track (athlete 2, male) samples. Also, the response to the DL was not always a greater change than that from the SL even though the load magnitude was greater (e.g. Figure 1). This reiterates the value of considering individual responses to potential training interventions before prescribing based on general whole group trends. It is also likely some athletes would benefit from verbal coaching cues to focus on goal movement technique when training with wearable resistance.

CONCLUSION: This study is the first to investigate pelvic kinematics during high-speed running with lower-limb wearable resistance. The results of this study provide initial evidence for the use of lower-limb wearable resistance as a stimulus to induce pelvic kinematic changes over time. Ultimately, practitioners are encouraged to use multifactorial approaches in hamstring injury rehabilitation and prevention efforts (Mendiguchia et al. 2021). It is possible lower-limb wearable resistance could be a useful tool within these efforts to address individual athlete needs.

REFERENCES:

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Lawrence Erlbaum Associates.

Ekstrand, J., Walden, M., and Hagglund, M. (2016). Hamstring injuries have increased by 4% annually in men's professional football, since 2001: A 13-year longitudinal analysis of the UEFA Elite Club injury study. *British Journal of Sports Medicine*, *50*(12), 731-737.

Feser, E.H., Neville, J., Bezodis, N., Macadam, P., Uthoff, A.M., Nagahara, R., Tinwala, F., and Cronin, J.B. (2021). Waveform analysis of shank loaded wearable resistance during sprint running acceleration. *Journal of Sports Science, 39*(17), 2015-2022.

Martin, P.E. & Cavanagh, P.R. (1990). Segment interactions within the swing leg during unloaded and loaded running*, Journal of Biomechanics*, *23*(6), 529-536.

Mendiguchia, J., Castano-Zambudio, A., Jimenez-Reyes, P., Morin, J-B., Edouard, P., Conceicao, F, Dodoo, J., and Colyer, S.L. (2021). Can we modify maximal speed running posture? Implications for performance and hamstring injuries management. *International Journal of Sports Physiology and Performance, 17*(3), 374-383.

Schuermans, J., Daneels, L., Van Tiggelen, D., Palmans, T., and Witvrous, E. (2017). Proximal neuromuscular control protects against hamstring injuries in male soccer players. *American Journal of Sports Medicine, 45*(6), 1315-1325.

Schuermans, J., Van Tiggelen, D., Palmans, T., Danneels, L., and Withvrous, E. (2017). Deviating running kinematics and hamstring injury susceptibility in male soccer players: Cause or consequence? *Gait and Posture, 57*, 270-277.

Suits, W.H. (2021). Clinical measures of pelvic tilt in physical therapy. *International Journal of Sports Physical Therapy, 16(*5), 1366-1375.

ACKNOWLEDGEMENTS: Thanks to Neil Bezodis for providing a review of this manuscript.

DISCLOSURE STATEMENT: Erin Feser is the Head of Science for Omorpho but was blinded from data processing and statistical analyses. This study did not receive financial support from Omorpho and the remaining author reports no conflicts of interest.