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Peak medial (but not lateral) hamstring activity is significantly lower during stance phase of running. An EMG investigation using a reduced gravity treadmill

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ABSTRACT

The hamstrings are seen to work during late swing phase (presumably to decelerate the extending shank) then during stance phase (presumably stabilizing the knee and contributing to horizontal force production during propulsion) of running. A better understanding of this hamstring activation during running may contribute to injury prevention and performance enhancement (targeting the specific role via specific contraction mode). Twenty active adult males underwent surface EMG recordings of their medial and lateral hamstrings while running on a reduced gravity treadmill. Participants underwent 36 different conditions for combinations of 50%–100% altering bodyweight (10% increments) & 6–16 km/h (2 km/h increments, i.e.: 36 conditions) for a minimum of 6 strides of each leg (maximum 32). EMG was normalized to the peak value seen for each individual during any stride in any trial to describe relative activation levels during gait. Increasing running speed effected greater increases in EMG for all muscles than did altering bodyweight. Peak EMG for the lateral hamstrings during running trials was similar for both swing and stance phase whereas the medial hamstrings showed an approximate 20% reduction during stance compared to swing phase. It is suggested that the lateral hamstrings work equally hard during swing and stance phase however the medial hamstrings are loaded slightly less every stance phase. Likely this helps explain the higher incidence of lateral hamstring injury. Hamstring injury prevention and rehabilitation programs incorporating running should consider running speed as more potent stimulus for increasing hamstring muscle activation than impact loading.

1. Introduction

Hamstring muscle strain injury is common in sports that involve running, and represents a significant burden across sports such as football [1], Australian rules football [2], American Football [3] and Gaelic football [4]. However, it remains unknown why the prevalence of hamstring injury during running disproportionately affects the biceps long head by approximately 4:1 [1].

Hamstring mechanics in running have been studied extensively [5–8], and together studies suggest that the biomechanical loading on hamstrings throughout the gait cycle is heterogeneous.

Hamstrings undergo an active stretch-shortening contraction during the late swing phase of running gait [9] and the activity seems speed dependent [10]. There remains conjecture however surrounding the phase of running that places the largest mechanical demands on the hamstrings. A better understanding of this loading may contribute to injury prevention and performance enhancement through training to specifically target individual muscles during their weight-bearing (stance) or non-weight-bearing (swing) roles as applicable.

Positive pressure, or "anti-gravity" treadmills allow creation of a controlled weight-bearing environment and have been used to reintroduce loads in a progressive manner [11]. Running with reduced bodyweight (BW) is associated with alterations in motor patterns and muscle activity reduction [12]. Exploring the activation of the medial and lateral hamstrings while simultaneously varying locomotion speed and altering bodyweight could shed light on the importance of the swing and stance phases respectively as well as their interaction. Therefore, the aim of this study was to quantify muscle activation patterns of the hamstrings over different weight bearing percentages and running speeds. We hypothesized that the biceps femoris will be activated more than the medial hamstrings (semitendinosus/semimembranosus) irrespective of running speed and altered bodyweight.

2. Methods

Twenty experienced male runners (age 35.4 ± 7.8 years, weight

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lateral hamstring (LH)

	50%	60%	70%	80%	90%	100%
6	24.0%	22.7%	25.4%	24.1%	29.3%	29.4%
8	33.7%	29.5%	37.9%	38.6%	37.1%	36.4%
10	37.8%	36.8%	41.2%	42.7%	45.3%	42.8%
12	39.5%	41.5%	40.6%	48.3%	48.7%	49.7%
14	43.9%	46.1%	46.9%	55.3%	50.5%	53.3%
16	52.0%	49.0%	55.6%	60.7%	62.1%	64.0%

medial hamstring (MH)

	50%	60%	70%	80%	90%	100%
6	17.6%	17.8%	21.5%	20.8%	26.1%	26.4%
8	25.2%	24.0%	33.7%	35.1%	31.0%	34.7%
10	31.5%	34.9%	37.2%	41.7%	43.6%	44.8%
12	39.2%	36.2%	38.7%	46.4%	47.9%	51.1%
14	44.4%	41.8%	44.1%	50.4%	49.3%	55.2%
16	55.2%	48.0%	54.1%	56.8%	57.8%	62.6%

Fig. 1. Average peak EMG values for normal subjects, 6 km/h–16 km/h, 50% altered bodyweight up to 100% bodyweight. This figure shows percentages of submaximal voluntary contraction during the 36 conditions. Increasing speed resulted in larger peak activations throughout all measured muscles. Higher relative bodyweight increases muscle activity slightly while increasing gait speed had a much larger effect.

77.6 ± 8.4 kg, height 179.1 ± 5.6 cm) provided written consent to participate in this study (ASPETAR: F2013000001). Participants had no history of muscle injuries. Participants ran for 6 min at 12 km/h on an AlterG® treadmill to warm up with no BW assistance (100% BW) [13]. After the initial familiarization and once subjects reported feeling comfortable in the treadmill in a variety of reduced bodyweight conditions, measurements started. Thirty-six running trials were each a combination of running speeds from 6 km/h to 16 km/h increasing in 2 km/h increments and altering BW from 50% BW to 100% BW increasing in 10% increments. Trial conditions were presented in a random order for each participant at each condition. Participants were instructed to run or walk until they felt comfortable, and then indicate the point where their gait felt "normal".

EMG activity was recorded by means of surface electrodes from 2 muscles on both legs of the subjects (i.e. 4 EMG channels). These included the medial hamstring (MH) semitendinosus and the lateral hamstring (LH) biceps femoris long head. The electrodes were placed according to SENIAM guidelines (seniam.org) by palpating the muscle bellies and orienting the electrodes along the main direction of the fibers [14]. Briefly, they were placed by a physiotherapist with the participants relaxed and lying prone where the mid-point of the distance between the ischium and the popliteal crease was marked. The position and orientation of the medial and lateral hamstrings were then identified after palpating the tendons during both relaxed and submaximal knee flexion with the addition of medial and lateral tibial rotation. Electrodes were placed aligned with the direction of the muscle bellies and the intersection of the mid-point of the posterior thigh. EMGs and accelerations were recorded at 2000 Hz (Delsys Trigno Wireless System (Boston, MA)) with two additional accelerometers on the shin in order to define the gait cycle during running [15]. All EMGs were recorded at 2000 Hz using a Delsys Trigno Wireless System (Boston, MA), rectified and low-pass filtered with a Butterworth third-order low-pass zero-lag filter and a cut-off frequency of 30 Hz. Heel strike (t_0) was identified by minima in the shank vertical acceleration and the out bound by maxima in the shank vertical acceleration (t_{-50} and t_{50}). The running data was continuously monitored and each heel strike was extracted and normalized leading to 101 separate time points (t_{-50}-t_0-t_{50}). For convenience here we have termed the 50% prior to heel strike "swing phase" and the 50% after "stance phase". We note that during the 50% post heel strike the foot will not be continuously in contact with the ground and we simply use these terms to reduce confusion. To assess relative muscle activation across the different loading conditions, the EMG signal was normalized to its respective peak value obtained during the running trials and the peak amplitude calculated as well as the area under the curve (iEMG) for both discrete time periods (i.e. swing and stance phase).

2.1. Statistical analysis

EMG data for the 50% prior and post heel strike ("swing" and "stance" phases respectively) of a minimum of 6 (maximum 32) consecutive footfalls were extracted for both the left and right legs and were averaged for subsequent analysis using Matlab (2014b, Mathworks). The peak EMG values, as well as the area under the curve (iEMG) prior and post heel strike were averaged for each participant and examined for each of the 36 running trials. Descriptive and inferential statistics were employed to describe the data using both Microsoft Excel for Windows (Office 2016) and SPSS (version 21.0). Levene's test for homogeneity of variances was performed, and subsequent to these results, independent-samples *t*-tests assuming homogeneous variances were conducted to compare pre and post heel strike peak amplitude and iEMG. Initial comparison was made between left and right foot at each of the 36 trial conditions. After Bonferonni correction for multiple comparison, no statistically significant differences in peak amplitude and iEMG were seen between left and right legs. Accordingly, data from the left and right legs were pooled for all subsequent analysis. To describe the magnitude of any relationship identified Cohen's approach was used (where $r = 0.5$ is large, $r = 0.3$ is moderate, and $r = 0.1$ is small [16]).

3. Results

Relative muscle activity for each of the 36 individual trial conditions are presented in Fig. 1. The relative differences in muscle activity were seen to be greatest when increasing speed from 6 to 16 km/h while holding the treadmill indicated altered per cent BW constant (range: 30–36% increase) whereas increasing per cent BW from 50% to 100% showed a smaller increase in muscle activity (range 9–14%). Visual inspection of the muscle activity (Fig. 1) shows strong differences between the peak activation and the contribution of each muscle throughout conditions. Hamstrings are loaded pre and post heel strike during high speed treadmill running, and the lateral hamstrings appear to be more active than the medial hamstrings throughout the gait cycle, more so during the stance phase than the medial hamstrings.

To summarize, when averaging all 36 conditions peak EMG for the lateral hamstrings was similar for both swing and stance phase ($p = 0.310$, $ES = 0.32$, "small-medium effect" [16]) whereas the medial hamstrings showed an approximately 20% reduction during stance compared to swing phase ($p = 0.005$, $ES = 0.94$, "large") (Fig. 2).

4. Discussion

The aim of this study was to determine if the lateral hamstrings are activated more than the medial hamstrings during running, and if there was an interaction between running speed and indicated body weight. When comparing the muscle activity of the hamstrings in this study, the results show that locomotion speed is a more potent driver of muscle activation than percent bodyweight [17]. The hamstring activation pattern shows two distinctive peaks. The pre heel strike (swing phase) muscle activity peaks are higher than the post heel strike (stance phase) peaks for both the medial and lateral hamstrings. The peak activation for both phases was slightly (but not statistically significantly) higher for the lateral hamstrings throughout the gait cycle whereas the medial hamstring peak was approximately 20% lower during stance (large effect size). There was a non-significant reduction in the area under the