LEG STIFFNESS ASYMMETRY DURING RUNNING IN HIGH LEVEL FEMALE TRACK ATHLETES

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The purpose of this study was to assess potential leg stiffness asymmetry in female track athletes during race-paced running. Sixteen high level female athletes from two different event groups (sprints and endurance) completed six to ten 55 m runs. Three-dimensional motion analysis was used to calculate dominant and non-dominant limb leg stiffness measures which were subsequently used to identify potential leg stiffness asymmetry. Results indicated a low-moderate prevalence of leg stiffness asymmetry among endurance runners (29%) however a greater percentage of athletes with leg stiffness asymmetry were identified in the sprints group (66 %). Leg stiffness asymmetries among sprinters may place these athletes at increased injury risk and regular monitoring of athletes for early injury risk identification may be warranted

KEY WORDS: Athletics, mass-spring model, sprints, endurance, gait.

INTRODUCTION: Modelling the lower limb as a simple spring allows coaches, scientists and researchers to quantify the compliance or resistance of the leg under an applied force. This ‘spring-mass’ model is often referred to as lower limb or leg stiffness. Whilst a simplistic representation of the complexities of lower limb under load, measures of leg stiffness have been linked to both performance and potential injury risk in athletes (Butler, Crowell, & Davis, 2003).

For track athletes, lower limb stiffness is important component in performance with established links between higher levels of leg stiffness and increases in stride frequency (Farley & Gonzalez, 1996), running velocity (Kuitunen, Komi, & Kryolainen, 2002) and running economy in endurance athletes (Spurrs, Murphy, & Watsford, 2003). Given its links to performance, leg stiffness assessment and monitoring is important in track athletes.

In addition to established links with performance, leg stiffness measures have also been implicated as placing athletes at increased risk of injury, particularly in sports involving repetitive loading (Moresi, Bradshaw, Greene, & Naughton, 2012). An optimum ‘range’ of leg stiffness appears plausible outside of which potential injury risk may increase. It’s suggested that too high a level of leg stiffness may place and athlete at increased risk of overuse, repetitive type injuries with too little stiffness placing an athlete at increased risk of soft-tissue injury (Butler et al., 2003). Recent prospective research into leg stiffness measures and hamstring injury in Australian Rules football players, suggest leg stiffness asymmetries may also increase injury risk among athletes (Pruyn et al., 2012). However, potential leg stiffness asymmetry and possible links to injury among track athletes remains unknown.

Thus, the aim of the present study was to assess the prevalence of leg stiffness asymmetry in track athletes during running.

METHODS: Sixteen female state and national level track athletes (9 sprinters, 7 endurance runners) volunteered for the study (Table 1). All participants were injury free at the time of data collection. The test procedure was approved by the University Ethics Committee and informed consent (including parental consent for under 18 athletes) was obtained. Participants test familiarisation was conducted prior to data collection.

Participants completed a self-directed warmup followed by six to ten sprints over approximately 55m to ensure a minimum of three contacts for each limb were obtained for analyses. Athletes were instructed to run at race pace for their chosen or best performed event. Full recovery was taken between each trial to avoid any potential fatigue effects.

Table 1 : Participant Descriptives. Mean (standard deviation).

Group	Age (yrs)	Height (m)	Weight (kg)	Training Years	Training Hours (per week)	Personal Best Performances		
						100m (s)	200m (s)	400m (s)
Sprints (n=9)	20.7 (3.5)	1.71 (0.05)	59.92 (4.11)	10.0 (5.3)	11.3 (3.9)	11.62 (0.15)	23.78 (0.40)	53.93 (1.60)
						800m (mins)	1500m (mins)	5000m (mins)
Endurance (n=7)	16.9 (2.7)	1.66 (0.04)	49.92 (5.30)	11.3 (3.9)	10.7 (4.2)	2:11 (0.01)	4:24 (0.00)	15:32 (0.00)

Three-dimensional motion analysis (250 Hz; Vicon MX, Oxford Metrics Ltd., Oxford, United Kingdom) and force plate data (1000 Hz; Kistler, 9281CA, Switzerland) were captured during all trials and used to calculate leg stiffness (k_{leg}) measures. Kinematic data was filtered using a low-pass, fourth-order Butterworth filter with a cut-off frequency of 23 Hz (Millett, Moresi, Watsford, Taylor, & Greene, 2014). K_{leg} was calculated as the ratio between the peak vertical ground reaction force (F_{peak}) divided by the change in leg length (Δ_{leg}), as outlined by McMahon and Cheng (1990). All stiffness measures were normalised to body weight and standardised to an average velocity using linear regressions. Average leg stiffness measures for both limbs were calculated. A leg stiffness symmetry index (SI) was calculated as the difference between the dominant and non-dominant leg stiffness measures divided by the average of both stiffness measures multiplied by 100 (Sadeghi, Allard, Prince, & Labelle, 2000). In addition to the SI, intra-limb stiffness variability was calculated as a coefficient of variation expressed as a percentage of the mean (Moresi, Bradshaw, Thomas, Greene, & Brayborn, 2013). Athletes were categorised as either exhibiting significant asymmetry, inconclusive asymmetry or symmetrical. Symmetrical leg stiffness was defined as when the SI was 10% or less. Significant asymmetry was defined as a SI greater than 10% and the observed intra-limb variability. Inconclusive asymmetry was defined as a SI greater than 10% but less than the observed intra-limb variability (Moresi et al., 2013). A frequency analysis was conducted to asses leg stiffness asymmetries among athletes. All data was collated and analysed statistically using the Statistics Package for Social Sciences (v22, IBM Corporation).

Table 2: Comparison of leg stiffness (k_{leg}), velocity adjusted leg stiffness ($k_{leg\text{-}adj}$), peak vertical ground reaction force (F_{peak}), leg length change (Δ_{leg}), running velocity (Vel) and contact time (CT) between sprinters and endurance runners for dominant and non-dominant limbs during race-pace running trials. Mean (standard deviation)

Group	Limb	k_{leg} (N/m/kg)	$k_{leg\text{-}adj}$ (N/m/kg)	F_{peak} (%BW)	Δ_{leg} (m)	Vel (m/s)	CT (s)
Sprint	Dominant	173.25 (30.86)	149.94 (29.74)	4.47 (0.24)	0.14 (0.01)	8.66 (0.08)	0.11 (0.01)
	Non-Dominant	162.87 (32.48)	176.79 (32.01)	4.45 (0.27)	0.15 (0.01)	8.45 (0.29)	0.12 (0.01)
Endurance	Dominant	147.12 (9.66)	142.61 (9.36)	4.38 (0.10)	0.16 (0.01)	6.13 (0.34)	0.15 (0.02)
	Non-Dominant	148.16 (10.86)	145.73 (10.80)	4.29 (0.18)	0.15 (0.01)	6.37 (0.62)	0.15 (0.02)

RESULTS: The dominant and non-dominant leg stiffness measures for both groups and their components are contained in Table 2. Velocity adjusted leg stiffness scores appeared similar between groups with the exception of the non-dominant leg among sprinters. Leg stiffness asymmetry calculations revealed higher average leg stiffness SI scores within the sprint group (mean SI = 16.8 ± 11.2 %) than in the endurance group (mean SI = 6.2 ± 5.4 %). The endurance athletes showed relatively high frequencies of leg stiffness symmetry with approximately 29% of endurance athletes displaying a significant leg stiffness asymmetry (Figure 1). In contrast, approximately 66% of sprint athletes displayed a leg stiffness asymmetry with the remaining 24% classified as symmetrical.

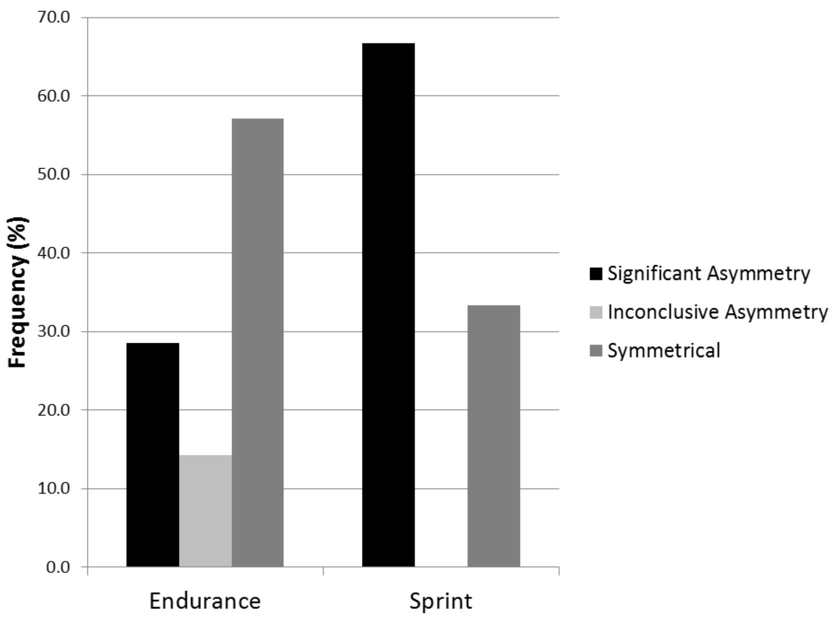

Figure 1: Percentage of sprint and endurance athletes whose leg stiffness symmetry index was classified as being; significant asymmetry, inconclusive asymmetry and symmetrical.

DISCUSSION: Both sprinters and endurance athletes exhibited similar levels of leg stiffness during running when standardised for running velocity. Previous research found differences in leg stiffness measures between male endurance and power athletes (Hobara et al., 2008) during repeat jumping tasks. Presumably repeat jump leg stiffness should reflect leg stiffness during running, however the present study did not find similar stiffness differences between groups. Current research suggests leg stiffness asymmetry may increase injury risk in athletes based on repeat hopping tasks (Pruyn et al., 2012). Whilst the present study identifies limb asymmetry in track athletes, future research may be needed to evaluate the links between leg stiffness measures during repeat jump and running tasks and to establish potential differences in leg stiffness between event groups within track and field athletes.
Although there is limited data on female leg stiffness measures, the present study found leg stiffness levels slightly greater than previous research into netballers (Millett et al., 2014). In addition to the obvious difference in sporting background, it should be noted that the athletes in the present study were running faster (7.70 m/s) than the standardised velocity used in the previous study (6.03 m/s) which may have led to greater leg stiffness levels among the present athletes.

The main focus of the present study was the investigation of potential leg stiffness asymmetry in track athletes. Given the relatively 'uniform' loading expected on both lower limbs during training and competition one might expect track athletes to exhibit similar leg stiffness properties on both limbs during running. The present study found low-moderate levels of leg stiffness asymmetry (29%) in endurance athletes and high levels of asymmetry in sprinters (66 %). Previous research suggests leg asymmetry may be a potential risk factor in hamstring injury (Pruyn et al., 2012). Given the high prevalence of hamstring injury among Australian sprinters (Bennell & Crossley, 1996), further research into possible links between stiffness asymmetry and hamstring injury among high level sprinters appears warranted.

CONCLUSION: The results of the present study suggest a relatively high percentage of female sprinters may present with a significant leg stiffness asymmetry during running. Additionally, high level endurance athletes appear to show low-moderate levels of leg stiffness asymmetry. Given the results of recent research suggesting leg stiffness asymmetry may place athletes at increased risk of injury, further investigation into the prevalence of stiffness asymmetry and potential links to injury among female sprinters is needed. Preventative athlete screening for leg stiffness asymmetry may be of benefit to coaches and practitioners as a means of early injury risk identification and potential monitoring and intervention.

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