EFFECTS OF FOOT STRIKE PATTERN AND STEP FREQUENCY ON ACHILLES TENDON STRESS DURING RUNNING

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INTRODUCTION

Distance running is a common activity for adults with over 29 million in the United States running weekly [1]. Injury to the lower extremities is common in running athletes with Achilles tendon (AT) injuries accounting for 5-18% of all running-related injuries [2]. During running high magnitude forces are transmitted to the AT. The repetitive loading may lead to micro tearing, inflammation and degeneration of the AT.

The human AT may experience greater magnitudes of stress relative to other tendons. Most tendons experience peak stress values below 30 MPa; however, during dynamic activities such as hopping the AT undergoes peak stresses that approach 80 MPa [3]. General running technique influences tendon stress due to the transmission of forces to the AT as it is influenced by the muscle forces of the gastroc-soleus complex and motions at the ankle. Current interventional strategies to reduce the risk or reoccurrence of running-related injuries include altering step rate and foot-strike pattern [4, 5].

The objective of our study was to examine the effects of foot strike pattern and step frequency on AT stress during running.

METHODS

Nineteen female runners (age: 21.5 ± 1.3 yrs; height: 166.4 ± 5.6cm; mass: 59.5 ± 8.7kg; weekly mileage: 31.9 ± 18.8km) participated. Individuals were not eligible to participate if they reported pregnancy, cardiovascular pathology, surgery within the last year, current lower extremity pain and/or less than 5 on the Tegner Activity Level Scale – a measure for regular participation in recreational activities that require running.

Prior to running trials, 2D transverse images of the AT cross-sectional area were measured in prone of the right ankle via ultrasound imaging. Participants were fitted with the same model of footwear and equipped with 47 markers for 3D motion capture. After instruction, participants ran down a 20-meter runway under six conditions including a rearfoot strike (RFS) and non-rearfoot strike (NRFS) pattern at their preferred cadence, +5% preferred cadence and -5% preferred cadence.

Step frequency for each condition was established with a metronome and visually monitored. Speed was controlled to 3.33-3.68 m/s using a photoelectric timing system and foot strike pattern was verified with an inshoe pressure system. Mid- and fore-foot strike indices were combined such that a NRFS pattern was defined as the subject’s center of pressure (COP) located on the anterior two-thirds part of the foot at initial contact; RFS was defined as a subject’s COP occurring on the rear third. Kinematic data were captured at 180Hz using 15 motion analysis cameras while kinetic data were simultaneously collected using a force platform at 1800Hz. Muscle forces were estimated using static optimization. Strain and strain rate were estimated from the AT elastic properties presented by Wren et al. [6]

Multivariate statistics with repeated measures were used to examine differences between foot strike patterns and cadence (α=0.05). Bonferroni post-hoc analyses were used to examine pair-wise comparisons.

RESULTS AND DISCUSSION

Peak AT stress (p<0.001, ES= 4.87) and peak force (p<0.00, ES=4.59) were different between the NRFS and RFS patterns. Additionally, the RFS pattern exhibited reduced strain (p<0.00, ES= 4.91) and strain rate (p<0.001, ES= 4.22) compared to the
NRFS pattern with differences of 24% and 15%, respectively. Figure 1 illustrates the time-normalized AT stress in the stance limb over the stance phase during the running cycle for each foot strike pattern.

A reduction in peak AT stress and strain was exhibited with a 5% above preferred step frequency relative to the preferred condition using a RFS ($p<0.001$, ES= 0.16) and NRFS ($p=0.005$, ES= 0.14) pattern. Strain rate was not different ($p>0.05$) between either foot strike condition.

Our findings demonstrate a reduction in peak AT stress and strain between RFS and NRFS patterns. Estimated peak Achilles stress in this study ranged from 57 MPa to 75 MPa at 3.5 m/s (+/- 5%) using subject-specific AT measurements. In comparison, a study performed by Ker [7] measured peak AT stress at 53 MPa while running at 4.5 m/s. Komi [8] reported peak AT stress of 110 MPa in barefoot running at 3.8 m/s in two subjects using buckle transducer data as well as strain values of up to 5% per stride. Our study estimated strain values to be between 6-7%. The difference in values obtained may be attributed to methodological differences including running speed and methods we used for estimating muscle forces.

CONCLUSIONS

The results suggest that running with a RFS pattern may reduce peak AT stress compared to a NRFS pattern. Increases in step frequency of 5% above preferred, regardless of foot strike pattern, resulted in lowered peak AT stress. The utilization of a RFS pattern and changes to step frequency may be beneficial in the treatment and prevention of AT-related injuries.

Runners may consider altering their foot strike pattern as it has been shown to occur with minimal instruction [9]. We recommend a progressive, transitional period be implemented if changes in foot strike pattern and step frequency is indicated as changes appear to introduce novel loading on the AT during running.

REFERENCES


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