ACHILLES TENDON FORCES IN FOREFOOT AND REARFOOT RUNNING

Allison H. Gruber, Brian R. Umberger, Carl Jewell, Samuel del Pilar II and Joseph Hamill

Biomechanics Laboratory, University of Massachusetts, Amherst, MA, USA
email: agruber@kin.umass.edu web: http://www.umass.edu/biomechanics/

INTRODUCTION

Compared to rearfoot (RF) running, forefoot (FF) running has been suggested to decrease the risk of developing running related injuries due to reduced vertical loading rate and lack of the initial impact peak of vertical ground reaction force [1]. However, impact parameters are not the sole cause of running injuries. Other features of FF running could be protective or harmful with respect to injury compared to RF running.

Previous reports have speculated FF running may place increased stress on the Achilles tendon (AT) because of greater plantar flexor muscle forces associated with this foot fall pattern [2]. Although FF running produces greater plantar flexor moments during stance compared to RF running [3], the force transmitted through the AT for a given joint moment will be affected by the length of the AT moment arm. Static measurements have indicated the AT moment arm is longer when the foot is plantar flexed and shorter when in a dorsiflexed position [4]. Thus, the greater plantar flexor moments in FF running might not necessarily lead to greater AT forces. The purpose of this study was to determine the force in the AT during the stance phase of running with a FF pattern compared to the RF pattern.

METHODS

Ten natural RF runners (7 males, 3 females; age 27±6 yrs; height 1.8±0.1 m; mass 71.1±10.3 kg) participated in this study. Reflective markers were placed on the right foot and leg of the subjects. A centrally located AMTI force platform (1200 Hz) was surrounded by eight Qualysis Oqus cameras (240 Hz) along a 20m runway. Subjects ran over the force platform at 3.5m·s^{-1} ± 5% while performing the FF and RF running patterns. The FF pattern was defined as making initial contact with the ball of the foot and preventing the heel from touching the ground. The RF pattern was defined as making initial contact with the heel. Marker position data and GRF data were filtered using a Butterworth low-pass filter with cutoff frequencies of 12Hz and 50Hz, respectively. Sagittal plane ankle joint moments were calculated using a Newton-Euler inverse dynamics approach. Group means of each variable were calculated before determining the AT force generated in each running condition.

A custom MATLAB program was developed to determine the AT force. A second order polynomial was derived to estimate the AT moment arm as a function of ankle joint angle using data from Arnold et al. [5]. An estimate of the passive joint moment [6] was subtracted from the net joint moment to determine the active muscle moment. The active ankle moment was divided by the AT moment arm at each instant of stance to determine the AT force. We assumed the force in the AT was zero whenever the active ankle moment was dorsiflexor. The difference in peak ankle joint moment generated between each footfall pattern was assessed with a student’s t-test (α = 0.05). The group mean peak AT force was compared between footfall patterns. Differences in ankle joint moment and AT force were also assessed for early (0-33%), mid (34-66%) and late stance (67-100%).

RESULTS AND DISCUSSION

Peak ankle plantar flexor moment was 226.41 Nm and 194.19 Nm for FF and RF running, respectively (p < 0.001) (Figure 1). FF running generated greater ankle plantar flexor moments for early and mid stance (p < 0.001) but there was no difference during late stance (p = 0.737).
Peak AT force was 5843.54 N for FF running and 4919.04 N for RF running (Figure 1D). FF running generated greater AT force during early and mid stance but not late stance. The AT force values found in the present study are similar to those found by the plantar flexors in previous studies [7].

Greater AT forces generated during mid stance of FF running may indicate this footfall pattern may increase the risk of soft tissue injury to the plantar flexor muscles or Achilles tendon, including muscle strain, tendonitis or tendon rupture. Consequently, the suggestion that FF running may be protective against running injuries compared to RF running is unsubstantiated. It may be more likely that FF running may be protective against bone injury such as stress fracture due to repeated impact loading whereas RF running may be more protective against some soft-tissue injury such as Achilles tendonitis or plantar fasciitis. Therefore, recommending a runner to alter footfall pattern in order to prevent or treat an injury may not be warranted.

CONCLUSIONS

Results from the present study indicate the FF running pattern results in greater AT forces during the stance phase compared to RF running. Therefore, FF running may not be protective against all running related injuries as previously suggested [1]. Recommendations to alter footfall pattern to prevent or treat running related injuries should be made with caution.

REFERENCES


Figure 1: Parameter values over the stance phase of FF (gray) and RF (black) running for: A) Ankle joint angle; B) Achilles tendon moment arm length; C) Net (solid line) and passive (dashed line) ankle joint moment; D) Achilles tendon forces.