THE EFFECT OF FLATFOOT DEFORMITY AND TENDON LOADING ON THE WORK OF FRICTION MEASURED IN THE POSTERIOR TIBIAL TENDON

Stacie I Ringleb, Kenichiro Arai, Kristin D Zhao, Lawrence J Berglund, Harold B Kitaoka, Kenton R Kaufman
Biomechanics Laboratory, Division of Orthopedic Research, Mayo Clinic College of Medicine, Rochester, MN, USA
E-mail:Kaufman.Kenton@mayo.edu Web:mayoresearch.mayo.edu/mayo/research/biomechanics

INTRODUCTION

Posterior tibial tendon dysfunction (PTTD) is the most common cause of acquired flatfoot deformity in adults (Myerson et al., 1996). While numerous etiologies have been proposed, the cause of PTTD and its progression are still unknown. We hypothesized that abnormal gliding resistance and tendon excursion increases the work of friction, which may lead to PTT degeneration and failure. The purpose of this study was to improve our understanding of PTT gliding resistance and excursion: 1) in the intact foot and simulated flatfoot and 2) when the PTT is loaded at different levels.

METHODS

Seven male fresh-frozen cadaveric lower extremities, disarticulated at the knee, were studied (67±24 years). The proximal tibia and fibula were potted in PMMA and mounted in a custom testing apparatus. Ring shaped force transducers (diameter 1.5 cm) were attached to distal and proximal ends of the PTT. Distally, a 1.5 cm section of the PTT was removed and a transducer was attached to the tendon on the proximal side and anchored to the navicular. The proximal end of the tendon was attached to a cable, which was placed around a pulley that incorporated a rotatory potentiometer to measure tendon excursion. Static loads (0.5, 1 and 2 kg) were applied to the cable. The foot was moved through the range of motion in the sagittal (plantarflexion/dorsiflexion), coronal (inversion/eversion) and transverse (internal/external rotation) planes for three trials. Tests were conducted for the intact foot and after a flatfoot deformity was created by sectioning the peritalar soft tissue constraints (Kitaoka et al., 1998). The force in the proximal sensor was subtracted from the force in the distal sensor to calculate the gliding resistance (An et al. 1993; Uchiyama et al., 1995), which was plotted against PTT excursion, to yield a hysteresis curve. The hysteresis curve was truncated such that an equal range of motion was considered for each condition (i.e., 1.5 cm of excursion in the coronal and transverse planes and 0.3 cm in the sagittal plane). The area within the truncated curve was defined as the work of friction (Fig.1). For statistical analysis, a Wilcoxon signed rank test ($p<0.05$) was used to test differences between intact and simulated flatfoot. A Friedman test ($p<0.05$) was used to test differences in each tendon loading level.

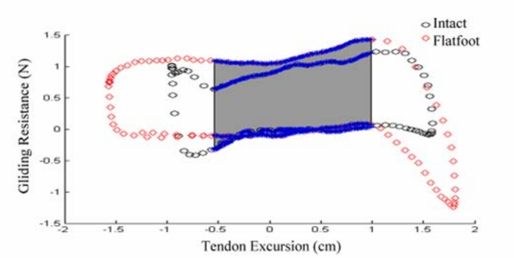

Fig.1 Sample hysteresis curve in the coronal plane for the intact and flatfoot conditions at 2kg. The shaded areas represent uniform truncation of the curves for all test conditions used to calculate the work of friction values.

RESULTS AND DISCUSSION

The hysteresis curves were consistent and repeatable for each testing condition. Standard deviations of the calculated work of friction from three cycles of manipulation were less than 6% of mean values. The maximum PTT excursion in sagittal, coronal and transverse planes 1) in the intact condition was 0.60±0.13 cm, 2.42±0.18 cm and 2.39±0.44 cm, respectively and 2) in the flatfoot condition was 0.68±0.14 cm, 2.95±0.21 cm and 2.84±0.28 cm, respectively.

Flatfoot deformity increased the work of friction significantly in the coronal and transverse planes ($p<0.05$) but did not in the sagittal plane. In all three planes of motion, the work of friction increased between 0.5 kg and 2 kg ($p<0.05$) (Fig.2).

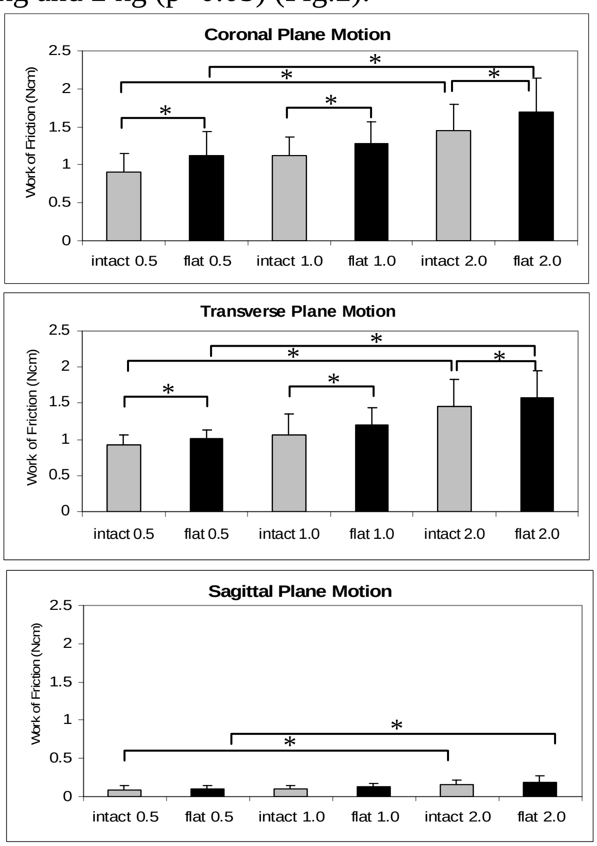

Fig.2 Work of friction in the intact and flatfoot conditions with the PTT loaded at 0.5, 1 and 2 kg (*$p<0.05$).

Previous studies examined the change in gliding resistance when the hindfoot was positioned in neutral, maximum dorsiflexion, and maximum planter flexion and the PTT was manually moved 10 mm (Uchiyama et al., 2000). This study showed that the sagittal plane PTT excursion in the physiologic range of motion is smaller (6±1 mm), while the coronal and transverse plane excursions were significantly larger.

SUMMARY AND CONCLUSIONS

This study combined both gliding resistance and PTT excursion to assess the work of friction in the PTT during passive motion of the hindfoot. The work of friction increased with tendon loading in all three planes of motion and was greater in the flatfoot condition than the intact condition in the coronal and transverse planes. These results suggested that non-operative treatment should be focused on limiting coronal and transverse plane motions. This may decrease the degenerative effects, while permitting sagittal motion to allow for more normal ambulation.

REFERENCES

An, K. et al. (1993). *Biomed Sci Instrum*, **29**, 1-7.

Kitaoka, H. et al. (1998). *Foot Ankle Int*, **19**, 447-451.

Myerson, M. et al. (1996). *J Bone Joint Surgery [Am]*, **78**, 780-792.

Uchiyama, S. et al. (1995). *J Orthop Res*, **13**, 83-89.

Uchiyama E. et al., (2000). *Proceedings from ORS*, 0191.

ACKNOWLEDGEMENT

This study was funded by the Mayo Foundation.