BIOMECHANICAL EFFECTS OF PLANTAR FASCIA RELEASE AND POSTERIOR TIBIAL TENDON DYSFUNCTION– A FINITE ELEMENT AND CADAVERIC FOOT SIMULATION

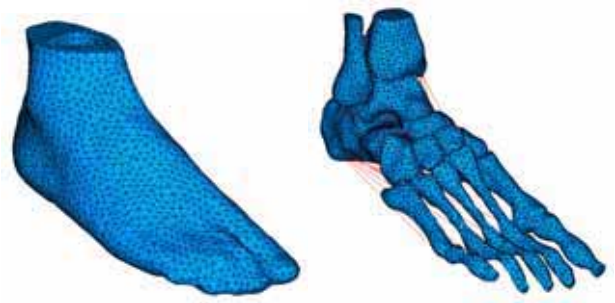
[1]Jason Tak-Man Cheung, [1]Ming Zhang and [2]Kai-Nan An
[1]Rehabilitation Engineering Centre, The Hong Kong Polytechnic University, Hong Kong, China,
[2]Biomechanics Laboratory, Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota, USA;
email: jason.cheung@polyu.edu.hk

INTRODUCTION

The plantar aponeurosis and the posterior tibial tendon are important for maintaining the normal foot arch. Failure or dissection of these structures may lead to arch instability and increase the load bearing of surrounding structures of the foot such as the interlocking tarsal joints, joint capsules and plantar ligaments. In this study, a finite element (FE) and cadaveric foot simulation was done to investigate the biomechanical effects of plantar fascia release (PFR) and posterior tibial tendon dysfunction (PTTD).

METHODS

A geometrical accurate FE model of the human foot and ankle was developed from 3D reconstruction of 2mm coronal MR images from the right foot of a normal male subject in the neutral unloaded position [1]. The FE model (Figures 1) consisted of 28 bony segments embedded in a volume of encapsulated soft tissue. A total number of 72 ligaments and the plantar fascia were included and defined by connecting the corresponding attachment points on the bones.



(a) (b)

Figure 1: The FE meshes of the (a) encapsulated soft tissue, (b) bony and ligamentous structures.

A hyperelastic material model was adopted to represent the nonlinear and incompressible nature of the encapsulated soft tissue. Other tissues were idealized as homogeneous, isotropic and linearly elastic. The interactions among the bones were defined as contact surfaces to allow relative bone movements. Nonlinear contact stiffness was defined to simulate the contact behavior between the articulating surfaces. A horizontal ground support inclined at 10 degrees relative to the plantar foot was used to establish the frictional contact interaction of the foot-ground interfaces during midstance.

The superior surface of the soft tissue, distal tibia and fibula was fixed throughout the analysis. The ground support was constrained to move in the same direction of ground reaction force vector, which was applied perpendicularly at the inferior ground support. The extrinsic muscles forces during midstance were estimated from muscles cross-sectional area and EMG data with a linear EMG-force assumption [2]. Musculotendon forces were applied at their corresponding points of insertion by defining contraction forces via axial connector elements. Simulation of PFR and PTTD were done by removing the plantar aponeurosis and the tendon forces from the FE model.

The FE predicted results were validated with experimental measurements on six cadaveric foot specimens under similar loading and boundary conditions. Quasi-static foot simulation was done to measure the relative bone rotation, plantar pressure and strain of the plantar fascia (Figure 2).

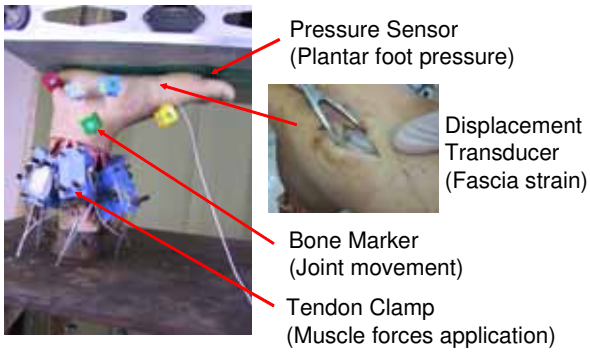


Figure 2: Experimental setup of cadaveric foot simulation.

RESULTS AND DISCUSSION

Both PFR and PTTD decreased the arch height with the former having a greater effect. The reduction of arch height intensified with a combination of PFR and PTTD but did not cause total collapse of foot arch. Both PFR and PTTD increased the strains of the plantar ligaments. The effect of PTTD on the metatarsal stress distribution is minimal while PFR induced medial shift of peak von Mises stress from the third to the second metatarsal. The lack of foot arch support with PFR and PTTD may lead to attenuation of surrounding soft tissue structures and elongation of foot arch, resulting in a progressive acquired flatfoot deformity.

REFERENCES

1. Cheung JT, et al.. *J Biomech* **in press**, 2005.
2. Kim KJ, et al.. *J Musculoskeletal Res* **5**, 113-121, 2001.

ACKNOWLEDGEMENTS

This work was supported by the Hong Kong Jockey Club endowment, the research studentship from The Hong Kong Polytechnic University and a grant from the Research Grant Council of Hong Kong (Project No. PolyU 5249/04E). The support on cadaveric study from the Institute of Clinical Anatomy, Southern Medical University, Guangzhou, China is acknowledged.