EFFECT OF PLANTAR FASCIA STIFFNESS ON FOOT ENERGY ABSORPTION DURING OVERGROUND WALKING

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INTRODUCTION

The foot plays a vital role in locomotion, providing support and standing balance as well as aiding in shock absorption and propulsion. The foot-to-ground interaction during locomotion allows for the modulation of the force generating capacity of the ankle plantar flexor muscle-tendon unit and recent studies have shown the foot's ability to shift ankle muscle operating conditions during ground contact to influence locomotion [1, 2]. The ankle joint has been implicated for its importance in providing energy to propel the body forward. However, the functions of the foot structures in locomotion are less clear. Intrinsic foot structures play a role in foot movement that can affect gait and local changes in these structures can have significant effects on movement and balance. While the ankle provides positive (propulsive) energy, the metatarsal-phalangeal (MTP) joint causes negative (dampening) energy to be done by the foot [3], where mechanical energy is absorbed during forward propulsion (Figure 1).

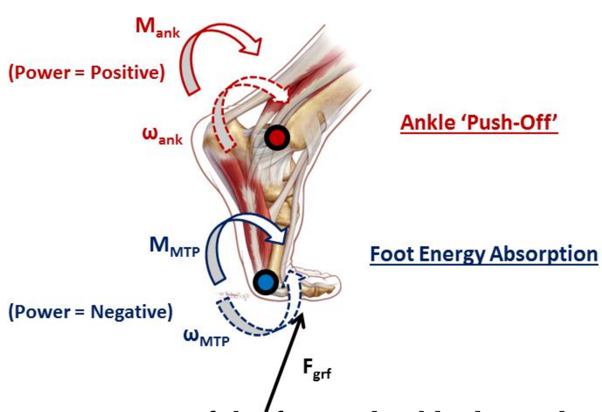

Figure 1: Diagram of the foot and ankle during late stance, where rotation of the MTP joint acts to dampen (i.e., perform negative work) the ankle push-off work.

We anticipate that a stiffer foot will decrease the mobility of the MTP joint and deformation ability of the foot, thereby decreasing the magnitude of energy absorption. The plantar fascia is a key structure in regulating MTP joint mobility during locomotion and may regulate the magnitude of foot energy absorption. **Therefore, the overall goal of this study is to investigate the effects of plantar fascia stiffness on foot mechanics.**

METHODS

Four healthy subjects (two males and two females, ages 24.0 ± 2.2 yrs, height 1.75 ± 0.07m, and body mass 75.0 ± 19.2 kg) with no previous foot surgery, current plantar fasciitis, osteoarthritis, or musculoskeletal injuries that would compromise walking ability participated in gait analysis and ultrasound scans. All subjects gave informed consent for this protocol approved by the Institutional Review Board at East Carolina University. An eight camera 3D motion capture system (Qualisys, Gothenburg, Sweden) and an embedded force plate (AMTI, Watertown, MA) were used to collect kinetic and kinematic data during overground walking. Subjects walked at four speeds (1.2 m/s, 1.3 m/s, 1.5 m/s, and 1.7 m/s), where 1.5 m/s is considered a normal walking speed. An Aixplorer ultrasound system (SuperSonic Imagine, Aix-en-Provence, France) was used to perform ultrasound elastography scans of the plantar fascia while subjects were lying prone, with feet hanging just off of an examination table. Elastography is a cutting edge medical imaging technology that can be used to non-invasively examine tissue material properties in vivo.

Walking data was processed and analyzed using Visual3D software (C-Motion Inc., Germantown, MD). Elastography measurements were taken by selecting a 1mm diameter circular region of interest located centrally in the tissue, and calculating the mean shear modulus of this region. Regression analysis was used to determine relationship between peak negative power and plantar fascia stiffness across the four walking speeds.

RESULTS AND DISCUSSION

The regression analysis of average peak negative power as a function of plantar fascia stiffness is shown in Figure 2. Foot energy absorption, as measured by peak negative power, increased with walking speed, and was more dramatic at higher speeds (Figure 3). Plantar Fascia stiffness had a strong, positive relationship with foot energy absorption at all walking speeds. There is a moderate relationship of body mass and plantar fascia stiffness (Figure 4).

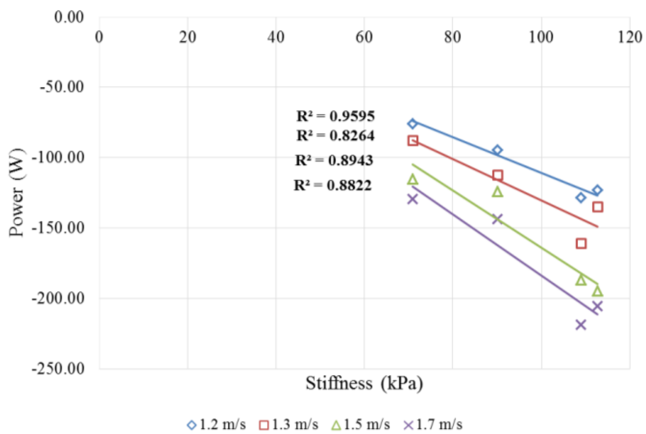

Figure 2: Linear regression analysis of plantar fascia stiffness and average peak negative power across all walking speeds.

We did not make an actual measure of deformation of the MTP joint. However, given that power absorption increased with stiffer feet, it is likely that the deformation stayed the same, as foot stiffness varied across individuals.

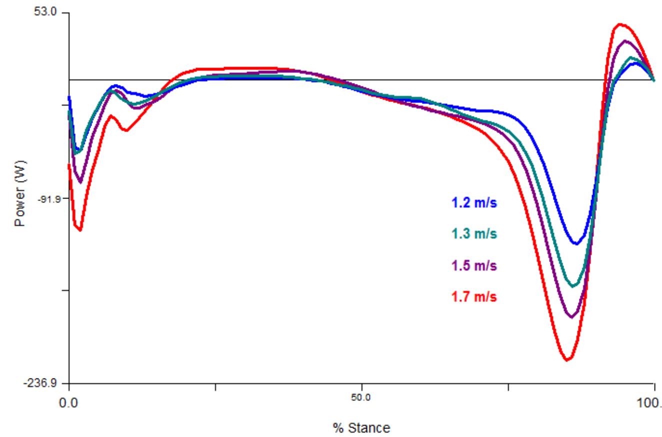

Figure 3: Distal foot power curves across all speeds for a representative subject.

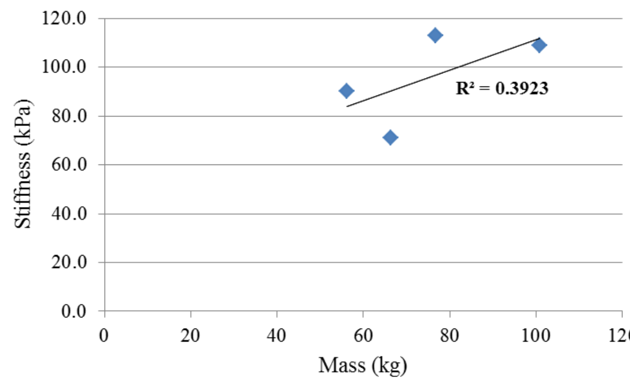

Figure 4: Relationship between body mass and plantar fascia stiffness.

CONCLUSIONS

The results are contrary to our hypothesis. It seems as though increased stiffness of the foot results in greater energy absorption by the foot. This might increase the energy costs of locomotion. However, it could potentially be advantageous in terms of performance. Further research is needed to clarify this relationship.

REFERENCES

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