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Evidence for early stance phase pre-loading of the plantar aponeurosis

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Introduction

An inverse dynamics approach has been used to gain an insight into the mechanical behaviour of the plantar aponeurosis (PA) at different walking speeds. Mechanical [1] and finite element models [2] have evaluated its biomechanics in quasi static conditions. To our knowledge only one study has addressed the dynamic behaviour of the PA with relation to the Achilles tendon force [3]. The aims of this study were to create a multibody model to quantify PA tension and to examine how PA tension changes with walking speed.

Methods

Three healthy young subjects with no history of foot injuries or abnormalities participated in this study. A linear ultrasound probe was employed to identify the proximal attachment of the PA onto the plantar heel. An *ad hoc* 12 markers protocol, modification of [4], was designed to record the kinematics of heel, metatarsal bones and toes at different walking speeds.

Commercial software for multibody dynamics analysis (MSC.Adams) was used to build the model geometry and to calculate the elongation trajectories for five segments of the PA based on stance phase kinematics data (Figure 1). The metatarsal heads were modelled as cylinders under the metatarso-phalangeal joints. The windlass mechanism of the PA was modelled by contact elements that constrained the PA segments to wrap around the metatarsal heads. Bulk PA stiffness [5] was distributed equally among the five digits and was used to estimate segmental PA tension.

Results

Peak PA tension occurred in late stance phase (~1.5 BW) for all walking speeds and was similar in magnitude to cadaver simulation data [3]. Early stance phase PA tension increased systematically with walking speed (Figure 2).

Conclusion

Preliminary results demonstrate model validity and reveal an interesting relation between PA tension and walking

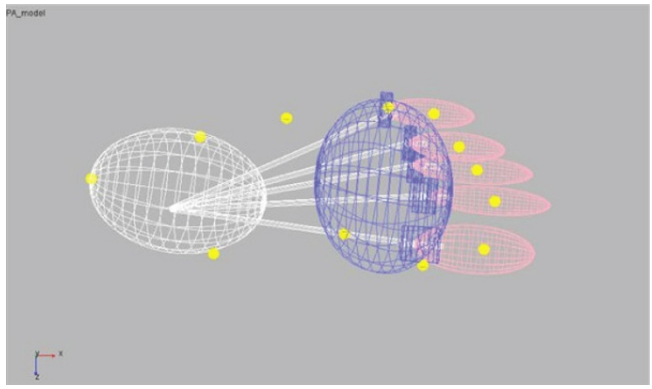

Figure 1
The 7 segments multibody model. In yellow the motion agents driving the segments in the inverse dynamics analysis.

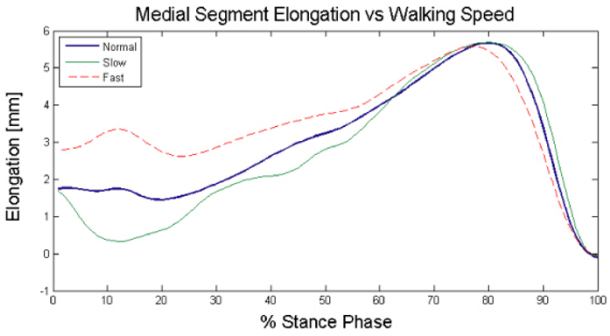

Figure 2
Example elongation trajectories for the medial segment of the PA in one subject walking at different speeds.

speed. The increase in PA tension with walking speed during early stance may represent a pre-loading protective mechanism to further support the longitudinal arch at higher impact forces.

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