INFLUENCE OF FOOT ORIENTATION AND BONE STRUCTURE ON PLANTAR PRESSURE DISTRIBUTION

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INTRODUCTION

Foot orientation is an important component of variability in barefoot plantar pressures [1], a standard approach for assessing risk of ulceration in patients with diabetic neuropathy. Modeling of plantar pressure distribution can be used for the design of therapeutic footwear. In recent three-dimensional finite element (FE) models [2, 3], the orientation of the foot and the relative alignment of the bones was either based on unloaded positioning at the time of imaging or was roughly approximated by using kinematics information. The goal of the present study is to perform sensitivity analyses of i) foot orientation in the frontal plane and ii) relative metatarsal (MT) alignment on plantar pressure distribution.

METHODS

Magnetic resonance images were obtained from the right foot of a male subject (24 yrs, 95 kg, 1.88 m). Bones (MT, phalanges, and sesmoids) and soft-tissue (ST) contours were digitized using custom Matlab (Mathworks Inc., Natick, MA) code and a FE mesh (57,544 eight-noded hexahedral elements) was generated using TrueGrid (XYZ Scientific Inc.) (Figure 1).

The bones were modeled as rigid and ST as incompressible hyperelastic material. Frictional contact between the plantar surface of the foot and the rigid floor was modeled.

The foot was first positioned such that the inferior aspects metatarsal heads (MTH) were approximately parallel to the floor (neutral position). The floor was then displaced towards the foot to obtain contact and horizontal and vertical forces of 500 N and 90 N respectively were applied. The frontal plane orientation of the foot was changed by ±1° from neutral position to test the sensitivity of plantar pressure distribution to this variable. In an additional simulation, of one of the rotated models (neutral + 1°), the second MT was plantarflexed by 1.5 degrees and the first MT was dorsiflexed by 1.5 degrees. The bones were constrained to stay fixed with respect to each other once loading commenced.

Figure 1: Three-dimensional FE model of the forefoot. Arrows show the application of loads to the floor.

RESULTS AND DISCUSSION

In the neutral model, there were no focal areas of high pressure (Figure 2a). Eversion by only one degree loaded MTH4 more prominently (MTH4: 40% increase); inversion by the same amount elevated MTH1 pressures by 35%. Dorsiflexion of MTH2 with respect to MTH1 allowed transfer of loads from MTH1 to MTH2 areas (MTH1: 30% decrease, MTH2: 15% increase with respect to the base model) (Figure 2b).

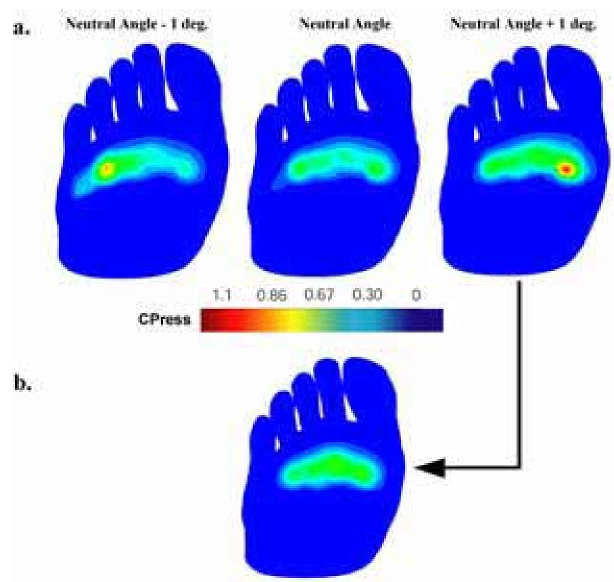

Figure 2: **a.** Plantar Pressure for orientation of the foot. **b.** Increase in MTH2 pressure.

These results show that the prediction of plantar pressures using the current FE model is acutely sensitive to foot orientation and bone alignment, probably much more sensitive than an actual foot in vivo. Before conducting simulations for footwear design, an optimization protocol could be used to provide the bone configuration and foot orientation that best represents experimental barefoot pressures. This study also demonstrates the possibility of changing the alignment of a generic model in order to represent different plantar pressures distributions (e.g. MTH1 predominant).

REFERENCES

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