Finite Element Modeling of the Human Foot and Footwear

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Abstract: A finite element (FE) model of the human foot and ankle was developed from 3D reconstruction of 2 mm coronal MR images from the right foot of a normal male subject using the segmentation software, Mimics. Solid models of 28 foot bones and encapsulated soft tissue structures models established in Solidworks software were imported into ABAQUS for creating the tetrahedral FE meshes. The plantar fascia and 72 ligaments were defined by connecting the corresponding attachment points on the bones using tension-only truss elements. Contact interactions among the major joints were prescribed to allow relative bone movements. A foot support was used to establish the frictional contact interaction between the foot-support interfaces. The contour of the arch-supporting foot orthoses was obtained from digitization of the subject's foot via a 3D laser scanner. Algorithms were established in Matlab software to create surface models from the digitized foot surface. Solid model of the foot orthoses established in the Solidworks software was properly partitioned in ABAQUS for creating the hexahedral FE meshes. The encapsulated soft tissue and orthotic material were defined as hyperelastic while other tissues were idealized as homogeneous, isotropic and linearly elastic. The ground reaction and extrinsic muscles forces for simulating the stance phase of gait were applied at the inferior ground support and at their corresponding points of insertion by defining contraction forces via axial connector elements, respectively. The FE predictions are being validated by experimental measurements conducted on cadavers and on the same subject who volunteered for the MR scanning.

Keywords: Human Foot and Ankle, Footwear Design, Biomechanics, Hyperfoam, Hyperelasticity, Contact Pressure, Interface Friction, Cadaveric Experiments.

1. Introduction

Many researchers have pointed out that biomechanical factors play an important role on the etiology, treatment and prevention of many foot disorders. Therefore, it is essential to understand the biomechanics associated with the normal foot before any foot orthosis or surgical intervention can be applied. Information on the internal stress and strain of the foot and ankle is essential in