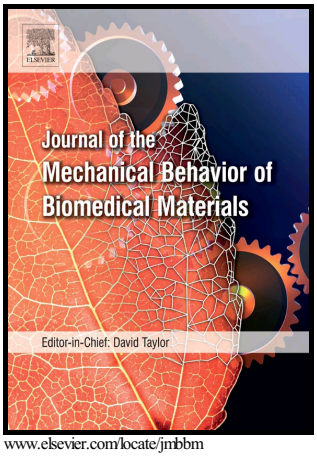
Parameter identification of hyperelastic material properties of the heel pad based on an analytical contact mechanics model of a spherical indentation

Ryo Suzuki, Kohta Ito, Taeyong Lee, Naomichi Ogihara



www.elsevier.com/locate/jmbbm

PII: S1751-6161(16)30333-2
DOI: http://dx.doi.org/10.1016/j.jmbbm.2016.09.027
Reference: JMBBM2084

To appear in: *Journal of the Mechanical Behavior of Biomedical Materials*

Received date: 3 April 2016
Revised date: 4 September 2016
Accepted date: 21 September 2016

Cite this article as: Ryo Suzuki, Kohta Ito, Taeyong Lee and Naomichi Ogihara Parameter identification of hyperelastic material properties of the heel pad base on an analytical contact mechanics model of a spherical indentation, *Journal o the Mechanical Behavior of Biomedical Materials* http://dx.doi.org/10.1016/j.jmbbm.2016.09.027

Parameter identification of hyperelastic material properties of the heel pad based on an analytical contact mechanics model of a spherical indentation

Ryo Suzuki[1], Kohta Ito[1], Taeyong Lee[2], Naomichi Ogihara[1]

[1]Department of Mechanical Engineering, Keio University, Yokohama, Japan

[2]College of Science & Industry Convergence, Ewha Womans University, Seoul, Korea

[*]Corresponding Author. Naomichi Ogihara. Department of Mechanical Engineering, Keio University, 3-14-1, Hiyoshi, Kohoku-ku, Yokohama 223-8522, Japan. ogihara@mech.keio.ac.jp

Abstract

Accurate identification of the material properties of the plantar soft tissue is important for computer-aided analysis of foot pathologies and design of therapeutic footwear interventions based on subject-specific models of the foot. However, parameter identification of the hyperelastic material properties of plantar soft tissues usually requires an inverse finite element analysis due to the lack of a practical contact model of the indentation test. In the present study, we derive an analytical contact model of a spherical indentation test in order to directly estimate the material properties of the plantar soft tissue. Force-displacement curves of the heel pads are obtained through an indentation experiment. The experimental data are fit to the analytical stress-strain solution of the spherical indentation in order to obtain the parameters. A spherical indentation approach successfully predicted the non-linear material properties of the heel pad without iterative finite element calculation. The force-displacement curve obtained in the present study was found to be situated lower than those identified in previous studies. The proposed framework for identifying the hyperelastic material parameters may facilitate the development of subject-specific FE modeling of the foot for possible clinical and ergonomic applications.

Keywords

foot; plantar soft tissue; finite-element analysis; elasticity

1. Introduction

Computer modeling of the foot using a finite element (FE) method has recently been applied to predict movements, deformations, and mechanical stresses in the foot bones and the plantar soft tissues in order to obtain a basic understanding of the biomechanics of the foot (Chen et al., 2001; Cheung and Zhang, 2005, 2008; Gu et al., 2010; Chen et al., 2012; Luximon et al., 2012), computer-aided designs of footwear (Cheung et al., 2006; Yu et al., 2008, 2013), analysis of foot pathologies such as the diabetic foot (Jacob and Patil, 1999; Gefen, 2003; Thomas et al., 2004; Fernandez et al., 2012; Guiotto et al., 2014; Chatzistergos et al., 2014), metatarsal fracture (Gu et al., 2011; Brilakis et al., 2012), plantar fasciitis (Gefen, 2002; Cheung et al., 2006; Cheng et al., 2008), and hallux deformity (Budhabhatti et al., 2007; Isvilanonda et al., 2012; Wong et al., 2014, 2015),