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Technical note

Evaluating the effective shear modulus of the cytoplasm in cultured myoblasts subjected to compression using an inverse finite element method

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ARTICLE INFO

Article history:
Received 30 December 2010
Received in revised form
5 April 2011
Accepted 7 April 2011
Published online 19 April 2011

Keywords:
Cellular mechanics
Mechanical properties
Reverse engineering
C2C12 skeletal muscle cells
Confocal microscopy

ABSTRACT

In the present study, we employ our recently developed confocal microscopy-based cell-specific finite element (FE) modeling method, which is suitable for large deformation analyses, to conduct inverse FE analyses aimed at determining the shear modulus of the cytoplasm of cultured skeletal myoblasts, G_{cp}, and its variation across a number of cells. We calibrate these cell-specific models against experimental data describing the force–deformation behavior of the same cell type, which were published by Peeters et al. (2005b) [J. Biomech.]. The G_{cp} calculated for five different myoblasts were contained in the range of 0.8–2.4 kPa, with the median value being 1 kPa, the mean being 1.4 kPa, and the standard deviation being 0.7 kPa. The normalized sum of squared errors resulting from the fit between experimental and calculated force–deformation curves ranged between 0.12–0.73%, and Pearson correlations for all fits were greater than 0.99. Determining the mechanical properties of the cytoplasm through cell-specific FE will now allow calculation of cell stresses using cell-specific FE under various cell loading configurations, in support of experimental work in cellular mechanics.

1. Introduction

Computational modeling is increasingly being used in mechanotransduction studies, to correlate between mechanical loading applied and sensed by cells, and their biochemical and biophysical responses. Loads in cells, and loads that cells are able to sense, are strongly affected by the mechanical properties of the cell components, such as those of the cytoplasm and nucleus, as well as by the mechanical properties of the cell surroundings. The last decade brought about breakthroughs in measurement techniques to determine cell stiffnesses, including atomic force microscopy (e.g. Collinsworth et al., 2002, Darling et al., 2008 and Mathur et al., 2001), micropipette aspiration (e.g. Hochmuth, 2000 and Zhao et al., 2009), cell compression and cytoindentation (e.g. Koay et al., 2003 and Peeters et al., 2005a), magnetic and optical tweezers (e.g. Kamgoué et al., 2007, Laurent et al., 2002) and bead rheometry (e.g. Bausch et al., 1998). These techniques are generally able to provide either hyperelastic or time-dependent viscoelastic cell material properties.

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doi:10.1016/j.jmbbm.2011.04.006