IDENTIFICATION OF THE MECHANICAL PROPERTIES OF THE THIGH MUSCLES USING A NUMERICAL EXAMPLE

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Introduction

In vivo quantification of mechanical properties is limited by current imaging techniques. Nevertheless, inverse methods coupling mechanical tests with medical imaging are developed to identify the hyperelastic properties of muscles [Avril, 2010] and [Tran, 2007]. Gokhale's study (2008) develops an inverse approach from a numerical example to analyze the influence of the experimental noise. The purpose of the present study is to develop a numerical example, including a representative noise level, in order to quantify the expected identification error of the mechanical properties for the thigh muscles.

Material and methods

A Finite Element Model Updating is developed to identify the hyperelastic properties of *in vivo* thigh muscles from displacement fields measured with the Digital Image Correlation applied on US images. The thigh is compressed with a loading of 1 kPa.

The numerical modeling consists in developing a 2D plane strain Finite Element (FE) model. A MRI acquisition of the thigh (1.5T, GE) is performed allowing a manual contour detection of four muscles and the fat tissue (Figure 1). Each region is characterized by a compressible, homogeneous and Neo-Hookean behavior (C_{10}, D).

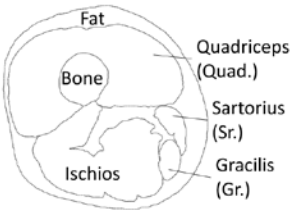

Figure 1: muscles and fat tissue geometries used for the FE model

The identification of the 10 Neo-Hookean parameters is performed by the minimization of a cost function with a BFGS algorithm. The cost function is defined as the quadratic discrepancy between the measured and simulated displacements. To validate the proposed identification, a numerical example is developed in order to simulate experimental displacement fields. In this example, the reference Neo-Hookean parameters are initialized with values from the literature [Avril, 2010] and [Tran, 2007]. FE nodal displacements are then projected on a grid (64x64) and a noise whose level is representative of the experimental noise, previously measured at 0.2 mm, is added. This noise is defined as a white Gaussian ($\delta = N(0, \sigma^2)$). Then, the error on each identified parameter is estimated.

Results

The low identification error (<1.95%) obtained without noise (EWON) validates the inverse approach. With a noise of 0.2 mm (EWN), the results of the error for the identified C_{10} parameters are very low (<2%) compared to the high error revealed for D (from 7.5 to 60%).

	Fat	**Quad.**	**Ischios**	**Gr.**	**Sr.**
C_{10} ref (kPa)	0.8	1.75	3	2.2	3.75
D ref (MPa^{-1})	30.8	18	18	18	18
C_{10} EWON (%)	0	0	0	0.09	0.08
D EWON (%)	0.03	0.19	0.02	1.13	1.95
C_{10} EWN (%)	0.62	0.11	0.17	2	1.91
D EWN (%)	13.88	10.02	10.42	7.59	60.42

Table 1: Identification error for C_{10} and D parameters with (EWN) and without (EWON) noise

Discussion

A way to decrease the D error will be to group the D parameters of the gracilis, sartorius and ischios muscles which have similar morphological and functional properties. The perspective of this numerical work will be to apply the developed inverse method in order to experimentally (compressive test) identify the *in vivo* mechanical properties of the thigh muscles.

References

Avril et al, J Biomech Eng, 132 (3), 2010
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Tran et al, CMBBE, 10 (6), 401-407, 2007

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