MECHANICAL CHARACTERIZATION OF PLANTAR ADIPOSE TISSUE

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Introduction

The plantar adipose tissue (AT) is composed by adipose chambers and connective septa and it is located between foot bony segments, plantar fascia and skin. Its main mechanical roles are to provide a damping system able to adsorb foot impact and to bear the body weight during static standing [1]. In recent years, different computational models of the foot have been developed to analyse the occurring phenomena, in relation to quantities that are non-obtainable through in vivo studies, *e.g.*, stress and strain fields [2], [3]. Unfortunately, many models still have some limitations, *e.g.* the lack of information on the proper mechanical characterization of the plantar AT, which changes its microstructural conformation according to the different foot regions. For this reason, the aims of this study are as follows: i) to perform experimental tests on all plantar AT; ii) to define a proper constitutive formulation of the tissue; iii) to develop a computational model of the foot that considers the distribution of the mechanical behaviour of the AT for the plantar region.

Materials and Methods

Experimental tests were performed on plantar AT collected from four male human donors, (56±18 years) undergoing amputation due to cancer, at the University Hospital of Padova (CESC Code: AOP2649). Samples were collected from the heel pad (HP), lateral (L), medial (M) and metatarsal (Met) regions (Fig. 1a) and tested with uniaxial unconfined compression tests (Model Match-1, ©Biomomentum). Preconditioning cycles were applied before: 1) loading-unloading (strain rates 7-70-700 %/s^{-1}) or 2) stress-relaxation (resting time 300s) protocols (Fig. 1b).

A 3D Finite Element model of the foot, composed of plantar AT, bones, ligaments, tendons and plantar fascia, was developed starting from CT data (Abaqus Explicit 2019, Dassault Systemes Simulia Corp., Providence, RI) (Fig. 1c). An almost-incompressible visco-hyperelastic constitutive model was adopted to describe the mechanical response of the plantar AT and the experimental results were used for the evaluation of its parameters. Different numerical analyses were developed to mimic physiological activities, *e.g.*, static standing or gait cycle.

Results

Experimental results showed a different plantar AT behaviour within the foot regions, with a major elastic modulus in the M region (about 380 kPa) and a lower in the Met one (less than 30 kPa). Numerical results reported for the stance phase of the gait cycle showed that HP and Met regions, inside the plantar soft tissue, showed the greatest displacement and contact pressure values, while the L and M ones are less stressed (Fig.2).

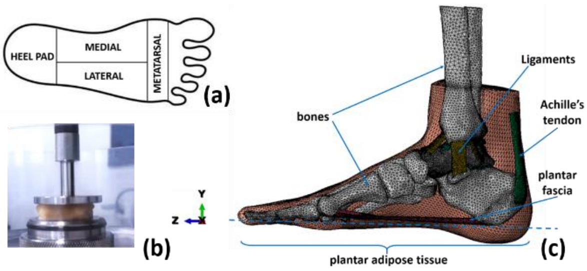

Figure 1: foot subdivision (a), compression test (b), foot Finite Element model (c)

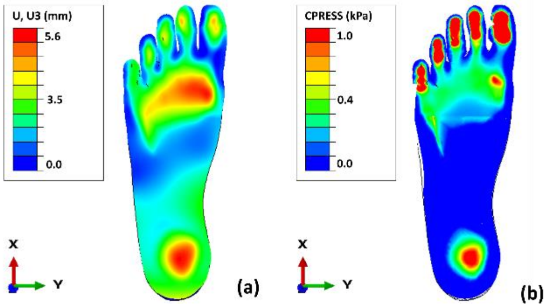

Figure 2: Displacement (a) and contact pressure (b) in the adipose tissue, obtained mimicking the stance phase of the gait cycle by the Finite Element analyses

Discussion

The computational model considers the real mechanical behaviour of the adipose tissue in the different foot regions, providing information on its mechanical behaviour during physiological loading conditions. A step forward could be the simulation of interactions between foot and footwear, providing information *e.g.*, in the design of specific insoles for sportsmen in order to prevent pathologies such as metatarsalgia.

References

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