MECHANICAL PROPERTIES OF PLANTAR TISSUES: A COUPLED EXPERIMENTAL AND NUMERICAL APPROACH

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Introduction

Plantar tissue is the first part of the body that interacts with the ground during locomotion (Fig. 1a) [1]. It is a soft connective tissue composed by adipose tissue and skin. These tissues play a key role in distributing body weight and in adsorbing shock e.g. during static standing and gait cycle. Different factors, such as age, sex, body max index (BMI) or disease can affect plantar tissues configurations and their mechanical properties. One of such disease is diabetes, a systemic disorder that affects thousands of people worldwide and that can lead to severe complications [2]. In this context, the mechanical properties of plantar adipose tissues were investigated by means of a combined experimental and computational approach, accounting for the non-homogeneous distribution.

Materials and Methods

Foot plantar tissues were collected from seven human donors, according to *Body Donation Program* of the Institute of Anatomy, Padova (M: 4, F: 3; mean age 64±23 years) (Fig. 1a). Confined compression tests and unconfined compression tests were carried out using a multi-step procedure (Fig. 1b). After preconditioning, each step was composed of 15% strain at 3000%/s strain rate, and subsequent 300 s of resting to allow the almost complete development of relaxation phenomena.

A three-dimensional finite element model of the foot, including bones, adipose tissues, skin, cartilage and ligaments (Fig. 1c), was realized with the finite element pre-processor Abaqus CAE 2019 (Dassault System). The plantar adipose tissues were described with a visco-hyperelastic constitutive model [3] and the model parameters were identified considering the experimental data from the developed tests [4]. Static standing condition was simulated in order to identify the stress-strain distribution on tissues.

Results

Experimental results showed differences in the mechanical behaviour between adipose samples taken from different plantar regions, e.g. higher stiffness in the metatarsal and lateral regions than in the anterior or posterior ones (Fig. 1d). Results also highlighted the non-linear stress-strain relationship and time depend effects that are typical of the visco-hyperelastic soft tissues behaviour (Fig.1e). Furthermore, computational results allowed to observe the stress and strain distribution, as well as the pressure field.

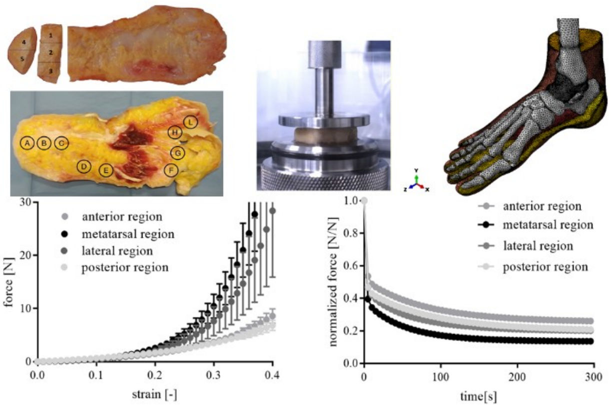

Figure 1: (a) plantar tissues samples; (b) confined compression test (c) numerical model of foot; (d) equilibrium force-strain data (d) and normalized force-time (e).

Discussions

While experimental tests have been useful to assess the mechanical properties of adipose tissues from different foot regions, the computational model provided information on mechanical behaviour of plantar tissues during functional loading conditions. Numerical model could also be a valuable tool to simulate different foot configurations, such as the interaction between foot and footwear or the comparison between the mechanical response of tissues in healthy and pathologic conditions. These insights could help in the design of specific insoles for diabetic patients to minimize pain caused by plantar ulcers.

References

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