BME PARIS
BioMedical Engineering
MASTER'S PROGRAM

Internship proposition

Academic Year: 2024-2025
Acronym: **ADIPOSE**

Project title:
Analysis of the mechanical behavior of adipose tissue in unconfined compression tests for cyclic loading and constitutive modeling: A basis for pressure ulcer prevention
Funding :
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Project description:

Project Overview and Hypothesis:

Pressure ulcers are a well-documented complication, predominantly affecting vulnerable populations such as the elderly or individuals with disabilities. These lesions typically develop when **mechanical loads are applied to the skin for prolonged periods**, such as during physical interaction between a person and a medical device (e.g. wheelchair, prosthesis, exoskeleton) or support surfaces (e.g. hospital bed). The prevention of pressure ulcers remains a significant challenge, due to the financial costs associated with prolonged hospitalisation and the human costs of reduced quality of life, loss of autonomy and social isolation. Nevertheless, the current diagnostic tools are inadequate and fail to accurately identify the risks, thereby hindering the implementation of effective prevention strategies.

The existing literature on pressure-induced injury has primarily focused on muscle, with **adipose/fat only becoming a consistent topic of discussion in literature from 2004 onwards**. Nevertheless, individuals at the highest risk of developing a pressure ulcer, such as those with a spinal cord injury, exhibit a notable alteration in their subcutaneous adipose tissue in the ischial region (Sonenblum et al., 2021, 2020). Moreover, the potential involvement of adipose tissue in pressure-induced injury has been proposed by studies examining the role of intramuscular adipose tissue (Lemmer et al., 2019; Sonenblum et al., 2021) and through genetic biomarkers, including circulatory adipogenic biomarkers that are associated with Pressure Ulcer Injury history and intramuscular adipose tissue in individuals with spinal cord injuries (Bogie et al., 2020). These findings indicate that a reduction in adipose tissue, alterations in adipose characteristics, and an increase in intramuscular adipose tissue in individuals at risk may result in diminished mechanical support. This highlights the necessity for further investigation into the role of adipose tissue at a macroscopic scale.

Existing studies have characterized the mechanical properties of adipose tissue using methods such as unconfined compression (Comley and Fleck, 2009; Gefen and Haberman, 2007; Miller-Young et al., 2002) indentation (Samani et al., 2007; Samani and Plewes, 2004) and uniaxial tension tests (Chen and Weiland, 2011).). However, few have provided hyperelastic parameters to describe the nonlinear response or viscoelastic/poroelastic parameters for time-dependent behaviors. Confined compression tests for subcutaneous adipose tissue remain largely unexplored despite its demonstrated poroelastic nature. Moreover, early damage markers such as focal necrosis in subcutaneous fat (Chen et al., 2023; Witkowski and Parish, 1982) highlight the need for further studies to link mechanical and histological properties, enabling improved prevention of pressure injuries. This project aims to address these gaps by combining mechanical testing with histological analysis to better understand the macroscopic and microscopic roles of adipose tissue under loading..

Specific Objectives of the Master's Project

The specific objectives of the Master's Project are therefore

1. **Characterize (porcine) Adipose tissue time-dependent Mechanical Properties** : Develop protocols for confined and unconfined compression tests building upon methodologies previously developed at the IBHGC, as outlined in (Lavigne et al., 2022).

2. **Histological analysis.** Establish staining protocols to investigate adipose tissue organisation and composition under loading.

3. **Hyper-Viscoelastic constitutive modelling**. Assuming a fully nonlinear strain energy density-based hyper-viscoelastic constitutive model, use a least squares optimization approach (utilizing the Levenberg-Marquardt algorithm) to fit model behavior to experimental data to reproduce the compressive muscle behavior.

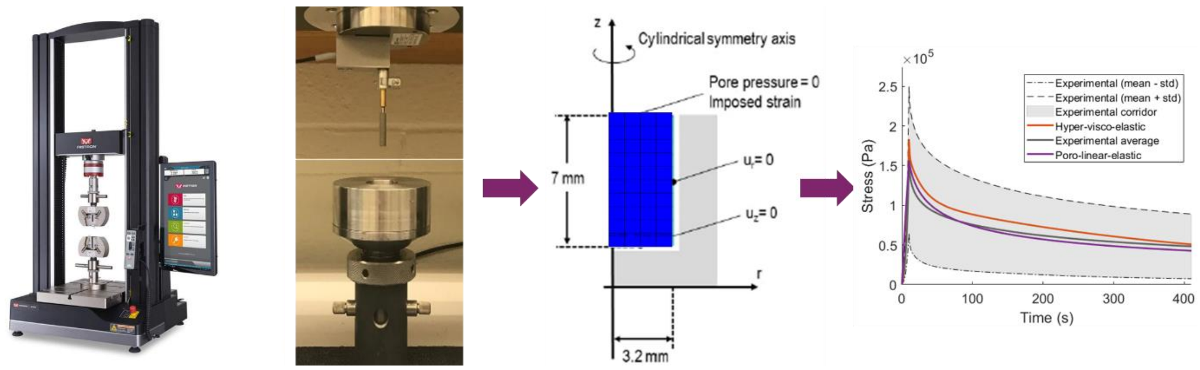

Figure 1 Illustration of poroelastic modeling capabilities in replicating the viscoelastic behavior of passive muscle tissue, as explored in Lavigne et al. (Lavigne et al., 2022) *The model builds on data from* (Vaidya and Wheatley, 2020) *which analyzed porcine Tibialis Anterior muscle under fast and slow confined and unconfined compression conditions.*

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