Soft Tissue Mechanical Properties: Comparison Between Clinical and Laboratory Measurement Techniques

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Introduction

Sideways falls cause over 90% of fragility hip fractures, a significant problem for individuals over 65 [1]. The soft tissues overlying the hip (trochanteric soft tissues) attenuate the impact force on the femur. A deepened understanding of the mechanical behaviour of the trochanteric soft tissues during a sideways fall impact may improve fracture risk prediction. Biological soft tissues exhibit a highly nonlinear mechanical response. To our knowledge, no experiments have been conducted on trochanteric soft tissues that measure the behaviour at low and high forces. Therefore, there is a lack of understanding of how soft tissue mechanical behaviour measured from tests on living subjects at low force levels correlates with the behaviour of these tissues during a sideways fall impact – a highly dynamic, high-force scenario.

Materials and Methods

Excised trochanteric human soft tissue and ballistic gelatin samples were tested at low forces with an automated handheld indentation device (MyotonPro, Myoton AS, Tallinn, Estonia) and at high forces via macro indentation tests using a hydraulic mechanical testing system (858 MiniBionix II, MTS Systems, Eden Prairie, MN, USA). Using the MTS system, a stress relaxation test and a quasi-static force-controlled test were designed and performed to determine the time-dependent and hyperelastic properties of the samples. A Prony series stress relaxation function was fit to the stress relaxation data, and a power function was fit to the force-displacement curves output from the quasi-static force-controlled test. Computed tomography images of the subjects and their excised soft tissue samples permitted automated measurements of the trochanteric soft tissue thickness (TSTT), adipose thickness, and muscle thickness.

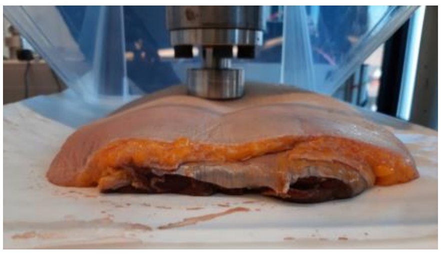

Fig. 1 A trochanteric soft tissue sample tested with a flat, cylindrical indenter on the MTS testing system.

Results

A significant correlation was established between the mechanical properties, such as stiffness (R = 0.58, p = 0.0027), of the trochanteric soft tissues at low and high forces. Fig. 2 displays the stiffness levels at 1000N as a function of the Myoton stiffness, measured at forces less than 1 N. The tests at high forces characterized the trochanteric soft tissues as hyper-viscoelastic materials. The mechanical properties were found to be associated with trochanteric soft tissue thickness. For example, the stiffness at 1000N decreased by 2.9 kN/m per mm increase in thickness (R = -0.73, p = 5.5e-05). The thickness of the samples was also related to the BMI of the subjects.

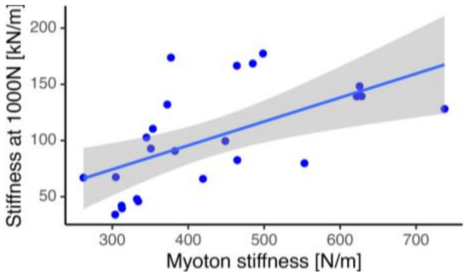

Fig. 2 The stiffness at 1000N measured with the MTS experiments versus the low-force stiffness measurement measured with the MyotonPro device.

Discussion

The results indicate that the properties of the soft tissues at high forces can be extrapolated from clinical measurement techniques that can be performed on living subjects, such as the local measurement of soft tissue stiffness with the MyotonPro device. The data also revealed the importance of considering the time-dependent behaviour of the trochanteric soft tissues, especially in the milliseconds after impact. Finally, the study confirmed that the trochanteric soft tissues could reduce the force on the femur by cushioning the impact and that increased soft tissue thickness could indicate a reduced risk of hip fracture.

References

[1] Hayes, W.C. et al., *Calcif Tissue Int* **52**, 192–198, 1993.

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