NUMERICAL QUANTIFICATION OF DEFORMATION IN A RAT TIBIA DURING GAIT

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Introduction

The characterization of the bone tissue deformation during everyday locomotion is a key factor in understanding and modelling the bone adaptive response. With regards to human beings, numerical studies merging Finite Element (FE) models and kinetic analysis of the human body enhanced the knowledge on bone mechanics during daily activities. Although many animal models involve the rats' tibia to study bone modelling, only few reports on the in-vivo monitoring of bone deformation exist and no gait-based FE analysis has been published yet. On this purpose, the authors propose a simplified FE model of the rat tibia subjected to muscular and joint forces evaluated at two time steps of the gait stance phase.

Methods

A simplified rigid body model of the rat tibia was developed accounting for the musculo-skeletal construct and muscle forces as taken from literature. The knee and ankle reactions were estimated for two time steps of the stance phase (Figure 1a). The left tibia of a Sprague-Dawley rat was scanned with a micro Computer Tomography (μCT) system to acquire 20μm resolution images and processed to obtain an FE model [Piccinini, 2012]. A quasi-static analysis was performed with muscles and joint forces as boundary conditions.

Results and Discussion

The values reported in Table 1 highlight the amplitude of deformation experienced by the rat tibia during the gait, Fig 1(b). The wide and inhomogeneous range of strains involves both compression and tension. In particular, the midshaft tibia is heavily deformed with strain peaks over 1500με. Longitudinal strain values in section S2 are consistent with [Rabkin, 2001], confirming the modelling approach despite the numerous assumptions. These results establish a reference for the studies on rats bone adaptation involving the mechanical stimulation of tibiae and allow for the comparison with external loading conditions.

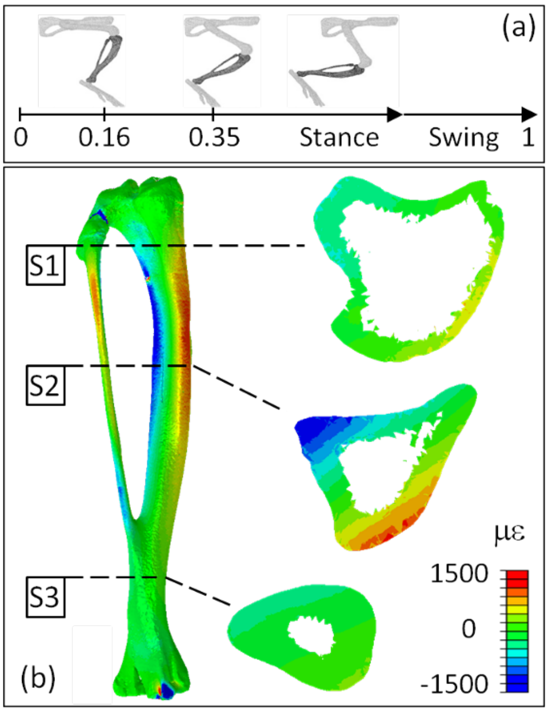

Figure 1: (a) time steps of the gait cycle and (b) deformation in the longitudinal direction.

Section	Time	ε_{min} (με)	ε_{max} (με)	U (kPa)
S1	0.16	-269	540	0.51
	0.35	-782	718	4.91
S2	0.16	-553	421	1.1
	0.35	-1349	1150	12.2
S3	0.16	-295	210	0.69
	0.35	-239	245	0.95

Table 1: Deformation values: minimum and maximum principal strains (ε_{min} and ε_{max} respectively) and strain energy density U.

References

Piccinini et al, Comput Meth Biomech Biomed Eng, In Press, 2012.
Rabkin et al, J Biomed Mater Res, 58: 277–281, 2001.