MECHANICAL PROPERTIES OF THE BICEPS BRACHII ALONG ITS PROXIMO-DISTAL LOCATION

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Introduction

The *in vitro* measurements of mechanical properties of passive skeletal muscle depend on several experimental factors as showed by Binder-Markey et al. [1]. On the other hand, some experimental parametric studies tackle the issue of the influence of several factors and their importance using healthy skeletal muscle [2-4]. Hereby, to better investigate the transverse anisotropy of skeletal muscle we propose to use an anisotropic hyperelastic model by using recent data obtained by Simon and Zidi [4].

Methods

Equibiaxial tests were performed with transversal slices of Wistar rats' muscles. Each of the 48 samples was grouped with two factors, the zone (distal, medial or proximal) and the temperature testing (22°C or 37°C). From every sample, we got two experimental curves (along the axis 1 and 2), hence the third factor "Axis" to perform a three-way ANOVA. To take into account the hyperelastic and anisotropic properties of the skeletal muscle, we used an exponential strain energy function with the contribution of two families of orthogonal fibers aligned as:

$$W = \frac{b_1}{2c_1}\left(e^{c_1(I_4-1)^2} - 1\right) + \frac{b_2}{2c_2}\left(e^{c_2(I_6-1)^2} - 1\right) \qquad (1)$$

Results

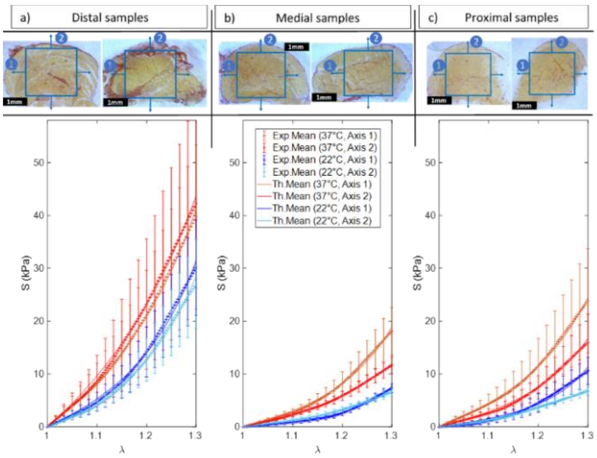

Figure 1: Group of averaged tensile curves ± SEM (n=6-8 for each group) divided into 3 graphs by distal, medial and proximal location (resp. a, b and c) with its sample structures represented by histological sections stained with Sirius red.

Figures 1 and 2 show that the stiffness values of the skeletal muscle tissue, represented by the parameter b and Smax, may on average have doubled depending on the collected sample location ($p < 0.01$). Furthermore, it was also shown that during the tests, when the storage temperature of the samples increases from 22°C to 37°C, the stiffness of the muscle tissue becomes more important ($p < 0.05$), which may be due to the rigor mortis phenomenon. Thanks to the significantly higher exponential parameter along the first axis ($p < 0.001$) (Fig. 2 and Table 1), this study confirmed the increasing isotropy index (Eq. 2) with stretching for the medial and proximal samples [4]. This index is given by:

$$I(\lambda) = S_1(\lambda)/S_2(\lambda) \qquad (2)$$

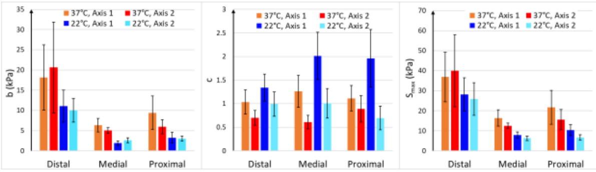

Figure 2: Mean values ± SEM grouped by specimen location for b (the stress-like parameter), c (the exponential parameter) and the maximal nominal stress.

Parameter	b (kPa)	c	S_{max} (kPa)
p-value Axis	0.857	4.55E-04	0.604
p-value Zone	1.40E-03	0.612	1.77E-04
p-value T(°C)	0.034	0.024	0.037

Table 1: p-value of material parameters (b and c) and maximal nominal stress by factor (Axis, Zone and Temperature).

Discussion

From equibiaxial traction tests, the used anisotropic model permitted to identify the mechanical properties of skeletal muscle. The results obtained in different zones and for several temperature tests, showed that these experimental factors play a preponderant role in the mechanical behavior of the biological tissue. This is probably due to a greater proportion of connective tissue and a different pennation of the myofibers, as observed in the histological sections.

References

1. Binder-Markey et al., Journal of Biomechanics 129:110839, 2021.
2. Jalal and Zidi, Journal of the Mechanical Behavior of Biomedical Materials 129:110839, 2018.
3. Jalal and Zidi, Journal of Biomechanics 85:204-9, 2019
4. Simon and Zidi, Journal of the Mechanical Behavior of Biomedical Materials 136:105521, 2022.

Acknowledgements

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