Heterogeneous Changes in *Quadriceps Femoris* Heads Rigidity Assessed by Shear Wave Elastography After Voluntary Eccentric Exercise-Induced Muscle Damage

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Summary

Maximal isokinetic eccentric contractions generate muscle damage, leading to significant functional impairments such as delayed onset muscle soreness and maximal voluntary torque loss. Resting muscle rigidity is also affected at long muscle lengths, with a homogeneous distribution within *quadriceps femoris* muscle heads but heterogeneous effects among muscle heads – most pronounced in the bi-articular *rectus femoris* (RF).

Introduction

Skeletal muscle maximal voluntary eccentric contractions can generate damage in activated muscles, favored by the viscoelastic properties of the muscle tissue, *e.g.* muscle stiffness. It has been previously reported that intra- and inter-muscular stiffness can be heterogeneous [1]. This study aimed to compare the inter- and intra-muscular damage-induced changes in resting mechanical properties within *quadriceps femoris* muscle using shear wave elastography measurements.

Methods

Nine healthy male participants performed a single bout of isokinetic eccentric maximal voluntary contractions (*i.e.*, 8 series of 15 contractions). Delayed onset muscle soreness, isometric maximal voluntary contraction (iMVC) and resting shear wave velocity (SWV), *i.e.*, muscle tissue rigidity of *quadriceps femoris* muscle were assessed at five knee flexion angles, in both proximal and distal parts for SWV of the *vastus lateralis* (VL), *vastus medialis* (VM), *vastus intermedius* (VI) and RF. All the parameters were measured before (BASELINE), immediately after (POST), one day (D1), two days (D2) and three days (D3) after the exercise.

Results and Discussion

A significant decrease in total work was observed in the 7th ($p < 0.02$) and the 8th series ($p < 0.05$ | Fig.1A) during the eccentric exercise. Muscle soreness was significantly increased at POST, D1 and peaked at D2 ($p < 0.02$ | Fig.1B). iMVC torque, independently of knee angle, was significantly diminished immediately after the eccentric exercise (-25%) with a slight recovery at D2 (-19%) but remained depressed at D3 (-14%, $p < 0.001$ | Fig.1C). Increases in SWV were observed, especially at long muscle length (Fig.1D) as previously reported [2], from +14% to +31% at 100° according to muscle heads. RF was the most affected muscle head, as previously detected with MRI [3], with a prolonged increase in resting SWV until D3 (Table 1), but no regional changes within muscle heads were observed.

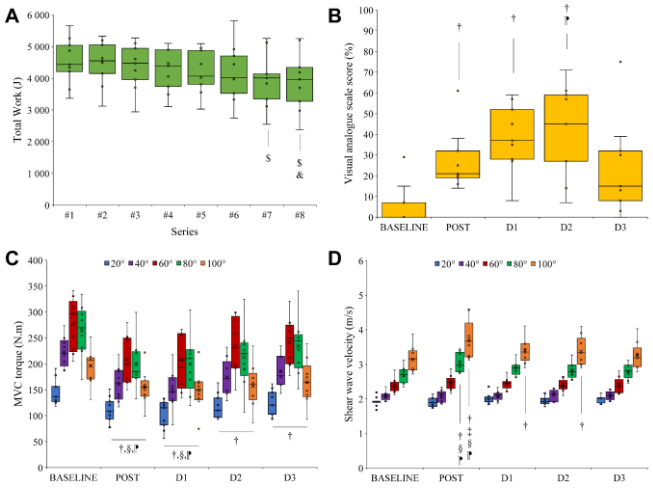

Figure 1: **A**- Isokinetic eccentric work during the damaging exercise and **B**- Delayed onset muscle soreness, **C**- iMVC torque and **D**- SWV for different knee angles at Baseline, POST, D1, D2 and D3. Statistical differences from $: Serie#1, &: Serie#2. †: Baseline, ‡: D1, §: D2, and ‖: D3.

Conclusions

Shear wave elastography can accurately assess regional variability of tissue mechanical properties, showing a specific increase in resting rigidity of the *quadriceps femoris* bi-articular head (*i.e.*, RF) but without significant differences between proximal and distal parts.

References

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[3] Prior BM et al. (2001). *Eur J Appl Physiol*, **85**: 185-190.

Table 1: Resting RF SWV measured in proximal and distal parts *quadriceps femoris* heads at long muscle length (knee angle of 100°).

SWV in m/s		Baseline	Post	D1	D2	D3
Rectus femoris	Whole muscle	2.97 ± 0.52	3.95 ± 1.11†,‡,§,‖	3.52 ± 0.69†	3.31 ± 0.71†	3.23 ± 0.63†
	Proximal	2.93 ± 0.51	4.01 ± 1.04	3.61 ± 0.80	3.37 ± 0.77	3.31 ± 0.65
	Distal	3.01 ± 0.56	3.88 ± 1.24	3.44 ± 0.59	3.36 ± 0.69	3.16 ± 0.64

Statistical differences from †: Baseline, ‡: D1, §: D2, and ‖: D3.