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## ► To cite this version:

Jérémie Bouvier, Augustin C. Ogier, Cyril Martin, Alexandre Fouré. Effect of knee angle and submaximal voluntary contraction intensity on vastus medialis and vastus lateralis rigidity. 28th annual Congress of the European College of Sport Science (ECSS), Jul 2023, Paris, France. hal-04077762

**HAL Id: hal-04077762**

**<https://hal.science/hal-04077762>**

Submitted on 23 May 2023

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# EFFECT OF KNEE ANGLE AND SUBMAXIMAL VOLUNTARY CONTRACTION INTENSITY ON *VASTUS MEDIALIS* AND *VASTUS LATERALIS* RIGIDITY

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## Introduction

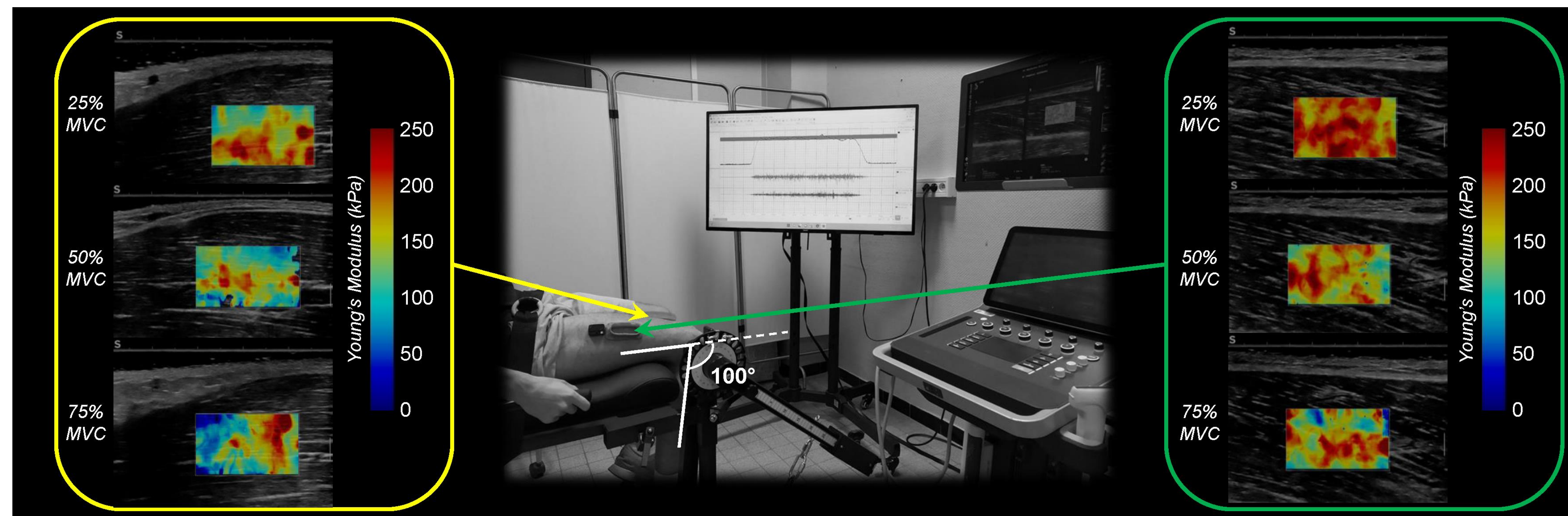
Ultrasound shear wave elastography (SWE) provides a local and accurate assessment of muscle rigidity (*i.e.*, an estimation of the Young's modulus calculated from shear wave velocity (Bercoff et al. 2004)) leading to a closer estimation of individual muscle tension than surface electromyographic (sEMG) measurements (Hug et al. 2015).

Few studies investigated the influence of joint angle on muscle rigidity during submaximal voluntary elbow, hip and plantar flexions (Zimmer et al. 2023, Lin et al. 2022, Kato et al. 2021).

The aim of the present study was to **investigate the effect of knee joint angle on the local mechanical properties of the *vastus medialis* (VM) and the *vastus lateralis* (VL) during isometric submaximal voluntary contractions** from SWE mapping.

## Methods

- Population:** Twelve participants (6 females and 6 males, age:  $30 \pm 6$  y, height:  $169 \pm 9$  cm, mass:  $65 \pm 12$  kg).
- Torque measurements:** Custom-made chair with a force sensor. Signal recorded with a Powerlab system (ADInstruments).
- SWE explorations:** VM and VL assessment with an Aixplorer MACH30 (SuperSonic Imagine).
- sEMG measurements:** VM and VL assessment with wireless electrodes (Delsys).
- Test session** at 50° and 100° of knee flexion (0°: knee fully extended) – **randomised** (Figure 1).
  - 3 maximal voluntary contractions (MVC).
  - 2 trials of sub-maximal voluntary contractions at 25%, 50% and 75% MVC – **randomised**.
    - ✓ Realtime measurements of force signal & surface EMG activities.
    - ✓ SWE measurements before (pre-contraction), during the plateau and immediately after (post-contraction) each contraction.



**Figure 1:** Experimental setup used during shear wave elastography explorations and maps acquired in one subject for knee angle position at 100° [0°: knee fully extended] during isometric submaximal contractions (*i.e.*, 25%, 50% and 75% of maximal voluntary contraction [MVC] torque) on *vastus medialis* (left maps) and *vastus lateralis* (right maps).

- Data analyses:** MVC torque defined as the greatest of the 3 trials | EMG root mean square (RMS) assessed from the contraction plateau | Young's modulus during contraction = Measurement during the plateau minus measurement at rest before the contraction.
- Statistical analysis:** Paired Student's t test for MVC | 3-way ANOVA for EMG RMS | 2-way ANOVA for SWE data (one for each muscle).

## Results

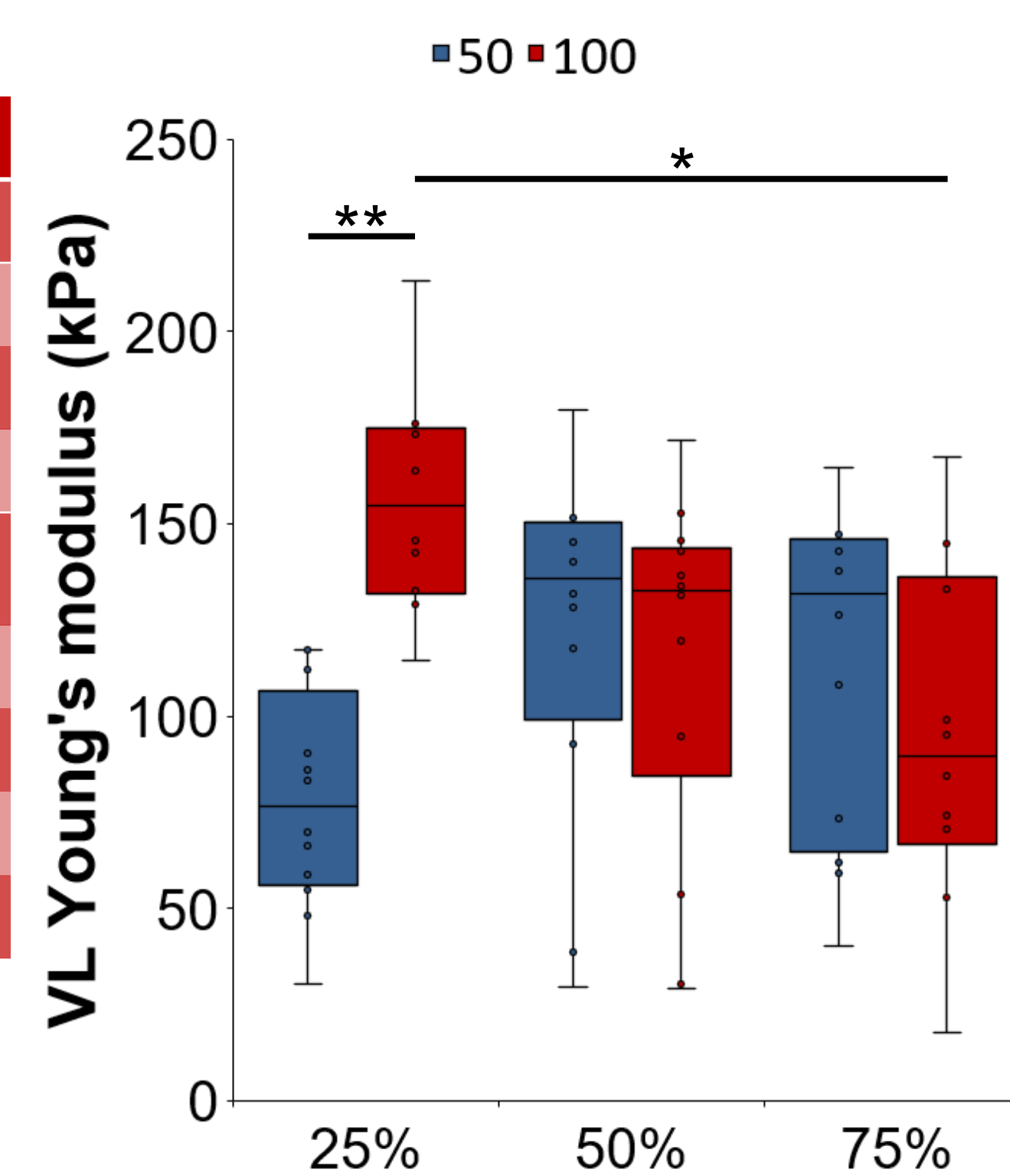
- No difference between MVC torque at 50° and 100° ( $P < 0.05$ ).
- Lower EMG activity at 50° in comparison to 100° for 50% and 75% MVC for both VL and VM ( $P < 0.05$  – Table 1).
- Higher resting Young's modulus of *vastii* (mean VM and VL values) muscles at 100° than at 50° ( $P < 0.01$ ) and after contraction than before only at 100° ( $P < 0.05$  – Table 1).
- No change in Young's modulus of the VM for all torque levels and knee angles ( $P > 0.05$ ).
- Higher Young's modulus of the VL at 100° than at 50° for 25% MVC ( $P < 0.01$  – Figure 2).
- Higher Young's modulus of the VL at 100° for 25% MVC than for 75% MVC ( $P < 0.05$  – Figure 2).

**Table 1:** Maximal and submaximal voluntary contraction torque, mean relative electromyographic root mean square (EMG RMS) and Young's modulus obtained in both *vastus lateralis* (VL) and *vastus medialis* (VM) at 100° and 50° of knee flexion.

	50°	100°
MVC torque (N.m)	158 ± 42	152 ± 57
EMG RMS (% max)	75% MVC	48.4 ± 8.4 *
	50% MVC	27.6 ± 8.3 *
	25% MVC	15.6 ± 7.4
Resting Young's modulus (kPa)	18 ± 4 **	28 ± 5
Pre-contraction	18 ± 5	26 ± 5
VL   VM	18 ± 5   17 ± 2	26 ± 5   26 ± 4
Post-contraction	19 ± 4	29 ± 5 †
VL   VM	18 ± 4   19 ± 3	29 ± 6   29 ± 4

Angle effect: \*:  $p < 0.05$  and \*\*:  $p < 0.01$  | †: different from Pre-contraction ( $P < 0.05$ ).

**Figure 2:** Muscle Young's modulus of the *vastus lateralis* (VL) during the isometric submaximal voluntary contractions (*i.e.*, 25%, 50% and 75% of maximal voluntary contraction torque). \*:  $p < 0.05$  and \*\*:  $p < 0.01$ .



## Discussion

The SWE explorations reveal the local mechanical state of the muscle during isometric submaximal voluntary contractions.

On the basis of SWE measurements and contrary to the VM, the relative contribution of the VL during isometric voluntary contraction appears to be dependent on the initial muscle length and the relative knee extension torque level as previously reported for the *biceps brachii* (Zimmer et al. 2023).

The influence of inhomogeneous intramuscular architecture changes and muscle tension during submaximal contractions needs to be further examined.

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