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# Elbow force generation capacities evaluation of post-stroke and multiple sclerosis patients: a pilot study

Elyse Larribau<sup>1</sup>, Aurélie Tomezzoli<sup>1</sup>, Boris Cassard<sup>2</sup>, Marie Babel<sup>1</sup>, Emilie Leblong<sup>2</sup>, Charles Pontonnier<sup>1\*</sup>

<sup>1</sup>Univ Rennes, Inria, CNRS, IRISA, Rennes, France

<sup>2</sup>Pôle Saint-Hélier, Rennes, France

\*Corresponding author. Email: [cpontonn@irisa.fr](mailto:cpontonn@irisa.fr)

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## 1. Introduction

Shared control has now become a benchmark in the development of assistance systems (cobots, exoskeletons) designed to partially or fully replace or assist a user's activity. Shared control refers to a collaborative and cooperative approach in which both man and machine contribute to the control of a system. Robotics for people with disabilities has long been concerned with these issues, as robotic devices require both a good interpretation of the user's intentions and the generation of a control adapted to the needs of the identified task and the user. Common applications in the context of disability are assistance with everyday tasks, such as grasping an object, opening a door, drinking, navigating... For the upper limb, the simplest assistance modes compensate for gravity by estimating the actions of gravity on the assisted limb (Manzano et al. 2023). More complex controls consider the residual effort-generating capacities of subjects, directly adapting the level of assistance according to the task to be assisted thus requiring the estimation of the force generation capacity of the subject. Patients with neurological diseases (multiple sclerosis, stroke...) experience a reduction in their force generation capacities, but also potentially in their motor control, from sensory integration to force production. The assistance system needs to be individualized according to impairment and force generation capacity variability. Thus, understanding and quantifying these capacities through measurement and modeling is of prior importance to enhance the control of such systems. However, the literature lacks a fair representation of the force generation capacities of such subjects, usable as an input of the control scheme. In the current study, we explored the possibility to assess joint torque capacities of patients presenting post-stroke sequels or multiple sclerosis impairment to use it as guidance in a shared control scheme of an

assistive exoskeleton for daily life activities, using an isokinetic ergometer.

## 2. Methods

### 2.1 Experimental protocol

3 participants volunteered for this pilot experimentation, giving their informed consent. Participant 1 (male, 42yo, 1.74m, 65kg) was healthy. Participant 2 (male, 57yo, 1.80m, 75kg) was a patient with chronic stroke presenting upper limb muscle weakness and moderate spasticity, with no residual pain. Participant 3 (female, 55yo, 1.62m, 59kg) was a patient with multiple sclerosis and presenting upper limb muscle weakness and retraction (pain in moderate flexion), without spasticity. Participants 2 and 3 were patients of the Pôle Saint-Hélier in Rennes, which is a clinical partner of the project.

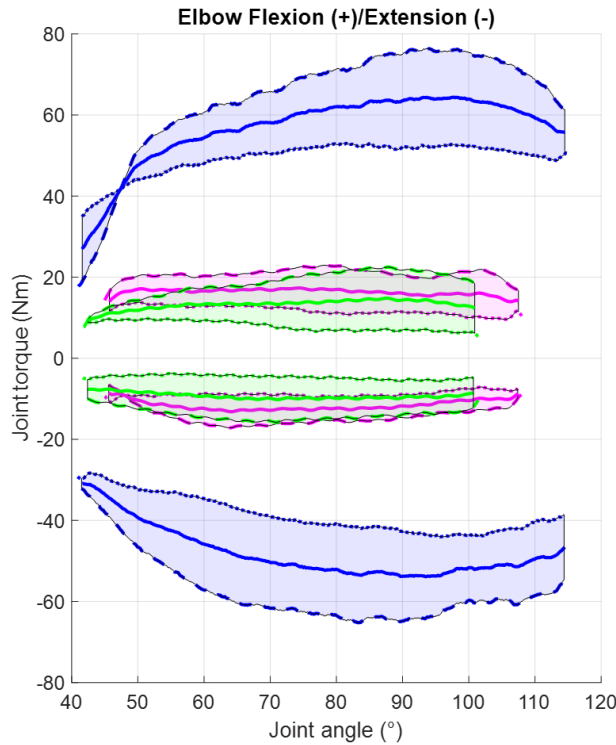
The experimental procedure consisted in recording a trial of 3 repetitions of maximal voluntary concentric and eccentric contraction in elbow flexion/extension at a velocity of 30°/s on an isokinetic ergometer (Contrex MJ). Only the movement of the joint under study was left free so that only the contribution of the muscles linked to this joint can be analyzed. The angular position of the joint was measured using a goniometer in the neutral or lowest position of the ergometer for a given participant to readjust the anatomical joint angle.

### 2.2 Joint torque-angle curves

Isokinetic plateaus were extracted by considering trial portions where the angular velocity reached by the subject was equal to 80% of the nominal trial velocity, resulting in 3 isolated isokinetic repetitions per trial. Concentric and eccentric curves were interpolated on a common angle abscissa and averaged among the 3 repetitions. Assuming that the torque-velocity relationship is linear at small angular velocities, eccentric and concentric curves were also averaged to obtain an estimate of the isometric torque. Maximal torques and joint angle at maximal torque were extracted from the estimated isometric torque curves.

## 3. Results and discussion

Figure 1 presents the averaged torque-angle curves of the 3 subjects in elbow flexion/extension. Apart from the reduction in joint torque capacity, one can see that the shapes of the curves are different. Results of subject 1 were very similar to the ones already reported in Haering et al. 2019, highlighting typical torque-angle curves for the elbow. At small flexion values, the curve stalls, suggesting an experimental issue.



**Figure 1.** Joint torque-angle curves in elbow flexion/extension for the 3 subjects. Blue: subject 1 (healthy), Magenta: subject 2 (stroke), Green: subject 3 (multiple sclerosis). Shaded areas correspond to the concentric/eccentric difference, the fill line being the estimated isometric torque.

As expected, subjects 2 and 3 presented smaller maximal torque, smaller range of motion and a maximal torque angle differing as well. The drastic reduction of the force capacities of the subjects reflects their impairment, possibly caused by muscle weakness, reduced muscle length, or recruitment capacity by the central nervous system (Jørgensen et al. 2017). Since subject 2 was subject to spasticity, we assumed that the curves could present stalls corresponding to spasticity triggers. However, it was damped by the repetitions since the trigger occurred at different joint angles. Subjects 2 and 3 both presents flattened curves, that may be explained by the lack of recruitment capacity along all the range of motion more than the muscle capacity itself. Subject 3 was painful in moderate flexion; therefore, the range of motion was particularly limited for this subject. Such preliminary assumptions should be investigated with electromyography measures.

Table 1 confirms this interpretation since the maximal isometric torque of subject 1 in flexion and extension was reached at typical values for healthy people, whereas it was not the case for subjects 2 and 3. However, the maximum flexion torque was higher than the maximum extension torque for all subjects.

**Table 1.** Maximal estimated isometric joint torque  $\tau$  developed by the subjects and corresponding joint angle  $p$  (ef elbow flexion, ee elbow extension)

	Subject 1	Subject 2	Subject 3
$\tau_{ef}$ (N.m)	64.4	17.3	14.8
$p_{ef}$ (°)	97.8	70.3	86.7
$\tau_{ee}$ (N.m)	53.9	13.2	10.2
$p_{ee}$ (°)	93.5	60.1	70.2

## 4. Conclusions

These very preliminary results showed that it was possible to assess the joint torque generation capacities of such impaired patients. The case study remains very limitative and cannot be representative of the intrinsic variability in motor control and force generation that such impairments may induce, but these first results are promising. The experimentation should be reproduced on a larger cohort and extended to other upper limb joints. Challenging classical joint-angle relationships with these experimental data could lead to an interactive estimation of the capacities of the subject to be included in the control loop.

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## Conflict of interest statement

The authors have no conflict of interests related to this publication.

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