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MEDICAL LEAFLET
SPASTICITY

Robot-assisted therapy to assess and rehabilitate upper limb spasticity in brain-injured patients

AXINESIS
ADVANCING REHABILITATION

Medical leaflet
no. 1
May 2023

SPASTICITY

is a main clinical disorder associated with CP and stroke.

(Schinwelski et al., 2019; Yeargin-Allsopp et al., 2008)

Stroke, with a prevalence of 1 to 4 people, remains a leading cause of death-, and creates important disabilities, with high socio-economic impacts[1,2]. **Cerebral Palsy** (CP) is also a common brain lesion since it affects 1 in 500 births with a prevalence of 17 million children Worldwide[3]. Both lesions can be associated with sensory (e.g. kinaesthesis disability), motor (e.g. uni- or bi-lateral plegia, spasticity) and cognitive (e.g. hemineglect) impairments that require **intensive**, **functional and long-term rehabilitation**[4–6]. Among those motor impairments, this leaflet highlights **spasticity impacts on the patients' daily life and their rehabilitation**.

Spasticity is a **main clinical disorder** associated with **CP** (more than 70% of cases) and **stroke** (more than 40% after 6 months post-stroke)[7,8]. This motor disorder, related with upper motor neuron syndrome, is a speed-dependent hyperexcitability of the myotatic reflex (i.e., the stretch reflex) due to a lack of central control[7,9]. This lack of central control results, among other impairments, to an inadequate increase of muscle tone, called hypertonia.

Figure 1:
Representation of a spastic upper limb

The speed-dependency relationship of this hypertonia allows the distinction between neural (i.e. spasticity, speed-related) and non-neural (i.e. mechanical properties, no speed impact) components of the muscle passive resistance[10]. From the clinical perspective, the spasticity could be observed by **a permanent contraction of the flexor and adductor muscles** in either the affected hemi-body (hemiplegia context in both populations), the lower limbs (diplegia in CP), the four limbs (quadriplegia in CP)[7,8] (Figure 1).

For these neurophysiological and clinical consequences, recent studies highlighted the **functional spasticity impacts**[7,11]. Schinwelski et al.[7] showed that stroke patients with spasticity presented **muscle weakness, limitations in activities of daily living** (ADL) **and reduced quality of life**. More precisely, these authors showed correlations in stroke patients between the score of modified Ashworth scale[a] and the measures of Medical Research Council[b] ($r<-0.42$; $p<0.001$), modified Rankin scale[c] ($r>0.38$, $p<0.001$) and quality of life items from Short Form-36 scale[d] ($r<-0.28$; $p<0.05$). Akodu et al.[11] have also highlighted the **functional impact of spasticity** in CP children. This study showed the relation between higher spasticity, as assessed with modified Ashworth scale, and lower CP children abilities concerning personal care, ADL, positioning, transferring, and mobility ($|r|>0.34$; $p<0.05$). Given the spasticity prevalence and its functional impacts in brain injured patients, this impairment should be taken into consideration in the rehabilitation of stroke patients and CP children.

A recent systematic review showed that a rehabilitation technique alone, such as stretching, is not effective for decreasing the patient's spasticity[12]. Furthermore, rehabilitation goals are not only focused on impairments, such as spasticity, but also on the patient's ability to perform ADL to facilitate their participation in social activities[13]**.** This global approach of the patient is in accordance with the International Classification of Functioning domains[14]. To achieve these objectives, one neuro-rehabilitation recommendation is **to promote high repetition of movements to stimulate neuronal plasticity and functional improvement**[4,15]. However, moderate to severe spasticity may prevent this intensive therapy as higher muscle tone makes it more difficult to mobilise the limb. According to those considerations and regardless of pharmacological/surgical intervention[9,16], we believe that **robotic-assisted therapy provides intensive rehabilitation,** regardless of the patient's spasticity.

a - 0 to 4 scale, higher score corresponds to more severe spasticity
b - 0 to 5 scale, higher score corresponds to higher muscle strength
c - 0 to 5 scale, higher score corresponds to lower functional abilities
d - For each item, 0 to 100 score, higher score corresponds to better quality of life

Robotic-assisted therapy (RAT) is defined as the use of mechatronic systems (i.e. combinations of sensors, motors, mechanics and controllers) in a rehabilitation context[17]. RAT has been used for many years to assess[18] and rehabilitate the upper[19] and lower[20] limbs in brain injured patients. For the upper limb rehabilitation, evidence showed that **RAT improve motor control and functional abilities in ADL**[19] but should be combine with conventional therapy[21].

This combination is recommended for the following reasons. Robots allow a high repetition of movements; those repetitive movements promote **neuroplasticity and patient's motor recovery**[4,5]. From this recovery, the therapist can keep its time and energy to transfer **the patient's motor improvements** to their ADL[17]. More specifically for a spastic patient, RAT is also interesting since (1) this impairment can be quantitatively assessed by the robot and (2) robotic devices have potential to adapt the level of assistance during rehabilitation according to this assessment. Both features are illustrated below with REAplan® (Figure 2). **REAplan® is an end-effector robot** than can move the patient's upper limb in a **horizontal plane** via a handle that the patient can grasp or to which he or she may be attached by an orthosis if his or her hand is too weak. Indeed, we developed a **standardised protocol** that evaluate peak resistance force of the upper limb (in N, the higher the score, the greater the force to mobilise the member), as a reflection of **upper limb spasticity**[22]. The protocol aimed to passively mobilise the patient's upper limb in a back-and-forth trajectory (30 cm). This passive mobilisation was performed at 5 different velocities (i.e. 10, 20, 30, 40 and 50 cm/s). As spasticity is speed-dependent[7,9], our hypothesis was to observe a higher upper limb resistance force at the higher speeds of mobilisation, compared to the lower speeds of mobilisation.

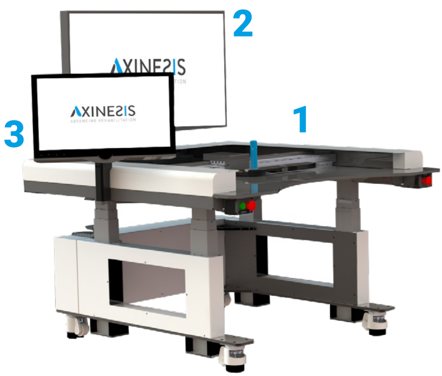


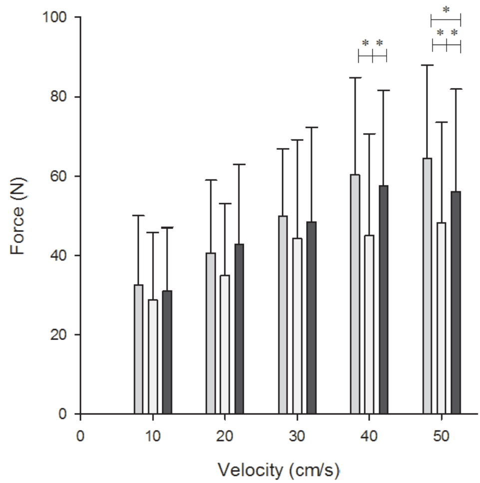
Figure 2: Illustration of the robotic device REAplan®

1 = Planar end-effector robot;
2 = Visual interface for the patient;
3 = Therapist's interface.

Figure 3: *This figure illustrate upper limb resistance force (in N, y-axis) in function of assessment velocities (in cm/s, x-axis) and three conditions: just before (gray bars), just after (white bars) and 1 day after (black bars) a motor nerve block.*

The authors showed that the resistance force at the higher mobilization speeds (40 and 50 cm/s) significantly decreased after motor nerve block (p<0.05). Those results highlighted that the resistance force assessed with REAplan® is a reflection of spasticity.

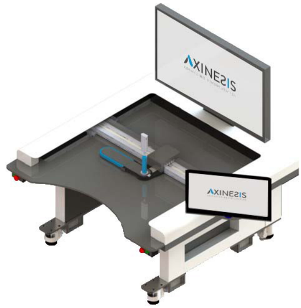
More details in Dehem et al.[22]



From this protocol and the recruitment of twelve patients, we highlighted three results. First, we showed that the higher the mobilisation speed, the higher the resistive force of the upper limb (r>0,99; p<0.001). Secondly, this resistance force at the two higher speeds (40 and 50 cm/s) significantly decreased after motor nerve block[e] (p<0.05; Figure 3). Thirdly, those results were highly correlated with a spastic non-instrumented tool, the modified Ashworth scale for elbow flexor muscles (r>0.6; p<0.05)[22]. Finally, those results legitimised this standardised protocol to quantify resistance force of the upper limb, as a reflection of spasticity in stroke patients. From this study, two clinical and research applications are provided. First, this standardised protocol could be used **to quantitatively assess the impact of a spastic treatment** such as botulinum toxin, surgery, rehabilitation, etc. Second, these results improved the REAplan® algorithms in order **to assist the patients in function of** their kinematic performance[23] but also in accordance with **their spasticity**[22]. Concerning spasticity assistance, the robot will increase the force to extend the spastic limb and safely accompany it in the return movement. These assist-as-needed algorithms allow **to intensively rehabilitate each patient**, by repeating a large number of movements, **whatever their level of motricity and spasticity**.

e - The motor nerve block consisted of a musculocutaneous injection of Lidocaine in order to decrease the spasticity of the elbow flexor muscles (i.e. the biceps brachii and brachialis)

In conclusion, stroke patients and cerebral palsy children have various impairments that could impact their abilities in activities of daily living and their social participation. From these impairments, spasticity can affect the rehabilitation effectiveness since it limits the high repetition of movements, necessary to promote neuroplasticity and patient's recovery.



This leaflet highlighted the interest of robot-assisted therapy to assess and rehabilitate upper limb movements in patients with spasticity. A robotic device, such as the REAplan®, can quantitatively assess the patients force resistance from passive upper limb movements, as a reflection of spasticity. This assessment enables the robot to adapt the assistance provided to the patients' movements in accordance with their upper limb spasticity. It could be suggested that robot-assisted therapy is an effective way to intensively rehabilitate brain-injured patients of any age (CP children or stroke adults) and whatever the types and severity of impairments, such as spasticity.

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