Unravelling mechanisms underlying the automatic control of posture and movement

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***Abstract*— This abstract is a resume of the talk given by Prof. Eric Perreault during SSNR 2016 in Baiona. Proff. Eric Perreault is the chair of biomedical engineering and professor of biomedical engineering and physical medicine and rehabilitation at the Northwestern University, McCormick school of engineering, IL, USA.**

I. MOTIVATION ON NEUROHEABILITATION

The human arm presents a stable mechanical interface to its environment, allowing it to make reliable contact with objects and to maintain stable postures. One of the factors involved in this process is the muscles stiffness, which is affected not only by the muscle geometric and its force, but also by spinal reflexes. Some techniques for stiffness assessment are discussed and the specificity of stretch reflex modulation is evaluated when the arms stability is challenged.

Understanding how the mechanical properties of the arm are modified during functional tasks may elucidate the underlying neuromotor control, which becomes paramount in the development of robotics solutions that interacts with the human upper limb.

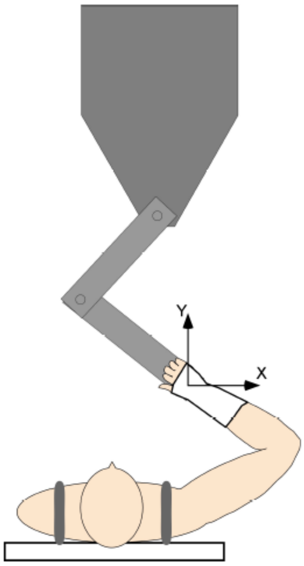

Fig. 1. Robotic device for evaluate end-point stiffness

II. DESCRIPTION OF THE WORK

A. Muscles

Muscle-skeletal system is the first component involved during the movement. Muscles behave elastically for short range movement. The stiffness depends mainly on the muscle geometric and force. It has been shown that a geometric model of the muscle could describe quite well the stiffness of the muscle.

Furthermore, this could be measured by the application of planar, stochastic displacement perturbation to the human arm. The idea on the basis of this method is that the force applied on the hand could change the elastic mechanical properties of the hand. Consequently, two-joint robotic manipulator that applied endpoint perturbations evaluated the endpoint stiffness Fig 1. It has been found that the elastic properties depends both on the generated force level and on the position of the endpoint. Anyway, some pathologies modify the structure of the muscle, so it is opportune to find alternative ways to measure the stiffness, for instance, the Shear Wave Elastography.

The elastography is a medical imaging modality that maps the elastic properties of soft tissue. It works by creating a distortion in the tissue and observing the tissue response to infer its mechanical properties. The distortion can be induced by using an acoustic radiation force to remotely create a 'push' inside the tissue. The disturbance created by this push travels sideways through the tissue as a shear wave. By using an image modality like ultrasound to see how fast the wave gets to different lateral positions, the stiffness of the intervening tissue is inferred.

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B. Stretch Reflexes

The spinal reflexes could affect the stiffness of the muscle. The human motor cortex is deeply involved in reflex regulation and it is common to speak of transcortical reflex loops. Such loops appear to add flexibility to the human stretch reflex allowing it to adapt across a range of functional tasks. It has been demonstrated that the inhibition of the spinal reflex implies a reduction of the stiffness and consequently of the force that muscle can produce. Indeed, by using TMS to inhibit cells within the cortex, the reflex modulation observed in the postural maintenance task involves the cells in the motor cortex inhibited by TMS, whereas the modulation observed in the action initiation task does not involve these inhibited cells. These results suggest that the pathways contributing to the motor responses often grouped together as long-latency stretch reflexes can vary with task, and may contribute to our understanding of the functions attributable

to this fundamental motor response.
Control of the human arm is achieved through a combination of rapid involuntary responses and slower, more complex voluntary commands. When a joint is rapidly displaced, the earliest muscle responses result from the involuntary activation of monosynaptic reflexes that excite the lengthened muscles. Between these extremes of involuntary and voluntary control, long-latency muscle responses are commonly observed. These occur sufficiently rapidly to be considered involuntary while possessing modulatory capacity reminiscent of voluntary control. Evidence of long-latency reflex modulation during postural tasks performed in different mechanical contexts has prompted suggestions that modulation serves to regulate limb stiffness.
Those stretch reflexes have a large contribution to the regulation of limb stability and stiffness. We can observe an increase of reflex sensitivity during tasks performed in unstable environments. Stretch reflexes can assist an imposed stretch, opposite to what would be expected from a stabilizing response. Motor cortical pathways mediate the stretch reflex modulation in tasks that requires changes in limb stability, and these differ from pathways contributing to reflex modulation that depends on how the subject is instructed to react to an imposed perturbation. Reflex modulation caused by altered task instruction was unaffected by cortical silence. This demonstrates that task-dependent changes in reflex function can be mediated through multiple neural pathways and that these pathways have task-specific roles.
The main features of stroke survivors are the muscle weakness and abnormal pattern activation causing difficulty to execute reaching task. Indeed, the movements of stroke survivors during this kind of task are slow and segmented. External perturbations could help to recover in part the movement, since they trigger the early release of a prepared motor response.

C. Triggered Reactions

The startReact is a phenomenon that occurs when in presence of a movement plan, an acoustic stimulus triggers the early initiation and the execution of the planned movement. It has been shown that startReact improved the elbow flexion; indeed elbow flexion movements were not statistically different from the control. On the other hand, the elbow extension movements were still segmented and slower than age matched healthy subjects. The cause could be a task-inappropriate flexor activity during startReact elbow extension originates from unsuppressed classic startle reflex.

III. CONCLUSIONS

The intrinsic properties of the musculoskeletal system provide the first response to external perturbations. Only by studying the biomechanics of the muscles including its stiffness, a deeply knowledge of the neural control of posture and movement can be achieved, which is paramount in human-robotics interaction. Another point to take into account is that brainstem pathways contribute to the processing of proprioceptive inputs and the automatic regulation of movement in humans. In this line, considering the diversity of pathways is important for understanding neurological impairments and adapting the rehabilitation process.