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The Role of Afferent Feedback from the Human Knee Extensors in Their Control during Human Movement

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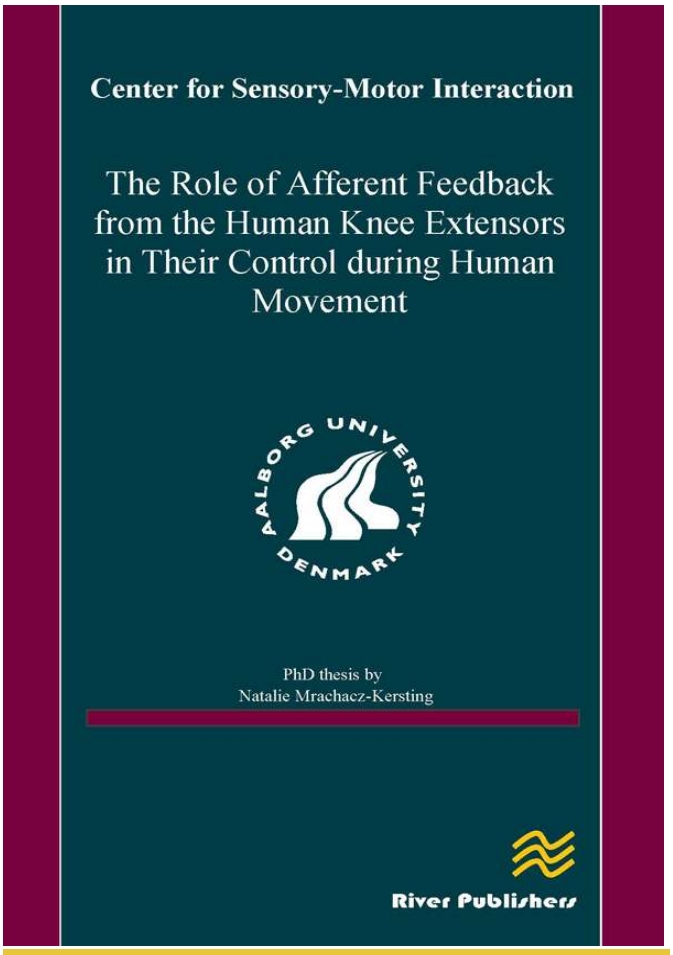
Sir Charles S. Sherrington (1906) was one of the first to recognize the complexity of spinal reflex circuits. Autogenic reflex pathways influence the muscles from which they arise whereas heterogenic pathways influence the activation of muscles apart from the muscles of origin. Both types of pathways are also influenced by supra-spinal structures. To effectively comment on the significance of these pathways, data on their neural interconnectivity has to be combined with the functional consequences using biomechanical data such as the resulting changes in joint stiffness.

Joint stiffness is made up of the algebraic sum of the stiffness of all muscles and ligaments crossing it. The muscle stiffness constitutes passive, intrinsic and reflex stiffness. However, in the execution of a movement, several joints are typically displaced and it was initially proposed by Winter (1981) that dynamic balance is maintained during standing, walking and running as the total leg stiffness never varies. The contribution made by the reflex stiffness to the total joint stiffness has been quantified only for the ankle joint of the lower limb where it attains values of up to 50%. Similar data is not available for the knee joint.

This PhD project was designed to investigate the functional significance and the neural pathways underlying the human quadriceps stretch reflex; in particular the following aspects were studied: i) the reflex and non-reflex stiffness of the quadriceps muscles quantified by the methods developed for the ankle joint (Sinkjær et al., 1988), ii) the integration of the afferent information arising from the stretch reflex at the spinal and cortical level, iii) how the central nervous system makes functional use of this afferent information. The stretch reflex was elicited by a whole joint rotation using either a stationary or a portable stretch device. Subjects without a prior history of neurological diseases participated in the various studies presented in this thesis. Such data will also be important in the artificial control of the quadriceps during FES assisted standing in paraplegic patients.

The results demonstrate that the human quadriceps stretch reflex can contribute importantly to the total knee joint stiffness. Electromyographic (EMG) recordings revealed that the response is comprised of at least three burst similar to the soleus stretch reflex. These burst were labeled short (SLR), medium (MLR) and late (LLR) latency reflex. While the mechanical response is similar for ankle and knee extensors, this was not always the case for the neural responses observed. For example, while the SLR of the soleus is strongly enhanced during co-contraction compared to isolated plantar flexor activity, the SLR of the quadriceps is decreased during co-contraction. Such discrepancies may be reflective of the monosynaptic and polysynaptic heteronymous projections to quadriceps motoneurons. The quadriceps motoneurons thus receive substantial excitatory and inhibitory inputs from both their antagonists as well as the muscles spanning the ankle joint (Marque et al., 2001; Marque, et al. 2005). Such connections have been postulated to reflect a functional coupling between muscles acting as synergists. The studies presented in this thesis provide important information on the role of afferent feedback during an imposed stretch to a single joint and muscle group. However the results also emphasize the need to further investigate the role of heteronymous reflex pathways as these provide the ability to link muscles that span different joints.



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