EMG normalization methods to assess lower limb muscle activity differences between HSP patients and healthy controls: A pilot study

Hereditary Spastic Paraplegia (HSP) is a neurodegenerative disorder that is mainly characterized by progressive spasticity and weakness of the lower extremities [1]. The spasticity and muscle weakness often lead to gait impairments.

One method to analyze gait impairments is to measure muscle activity of the lower limb muscles that contribute to human locomotion using surface electromyography (EMG). In clinical practice, surface EMG has then the potential to be used as an objective measurement method to better understand the causes of gait impairments in HSP.

However, characteristics of surface EMG are dependent on multiple extrinsic and intrinsic factors, including the placement of electrodes and electrode size, alongside physical and anatomical features like depth of the source of signal or the thickness of subcutaneous tissue layer [2][4]. Therefore, for the purpose of inter-subject comparison, normalizing EMG signals is necessary. In literature, multiple normalization methods exist, but there is no consensus of the most appropriate normalization method yet. Commonly used methods include calculating either the peak or mean muscle activity during the task of interest as reference value, or using the muscle activity during a maximal voluntary contraction (MVC) as reference value for the same muscle [5][6]. In previous EMG studies, MVC is presented as gold standard in literature [6].

MVC allows for assessment of the muscle activity level during a task as the reference value is relative to the maximum capacity of the muscle [5]. Peak or mean muscle activation values depend on the task. Therefore, solely muscle activation patterns may be compared between individuals, but not the level of activity [5]. A MVC is usually performed using a dynamometer, a device measuring the maximum muscle force and provides an objective and precise measurement. Muscle activity is measured during maximum muscle force measurement by placing EMG electrodes on the muscle of interest.

In literature, EMG pattern analysis in patients with HSP already exists. The studies of Rinaldi et al. [7] and Serrao et al. [8] are one of the most relevant studies analyzing gait impairments in patients with HSP. Both are using the peak muscle activity during walking as normalization method to describe the influence of muscle co-activation on gait impairment in HSP. Both studies showed a significant increase in muscle co-activation of the ankle joint in patients compared to controls [7][8]. Analyzing the muscle co-activation describes the relationship of agonist and antagonistic muscles, but gives no information about the influence of the individual muscles for causing gait impairments in HSP. An analysis of the muscle activity of individual muscles has the potential to determine whether an individual's gait impairments are predominantly caused by weakness in one of the muscles. Therefore, MVC normalization is necessary to compare the level of muscle activity of individual muscles during walking between patients with HSP and healthy controls.

The aim of this pilot study is to assess lower limb muscle activity differences between patients with HSP and healthy controls during walking. Muscles investigated include M. Tibialis Anterior (TA) and M. Gastrocnemius Medialis (GM), as TA is mainly active throughout swing phase, therefore important for foot elevation and GM stabilizes the foot during midstance [9]. In the initial phase, clinical parameters in combination with the maximum muscle force of these two muscles are compared. Subsequently, patients are compared with healthy controls regarding the muscle activity of TA and GM during walking. The muscle activity is normalized to its peak value across all walking trials, which is the most commonly used normalization method for EMG in HSP in literature [7][8]. Additionally, muscle activity is compared using MVC as normalization method.

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