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Comprehensive quantification of the spastic catch in children with cerebral palsy

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ABSTRACT

In clinical settings, the spastic catch is judged subjectively. This study assessed the psychometric properties of objective parameters that define and quantify the severity of the spastic catch in children with cerebral palsy (CP). A convenience sample of children with spastic CP ($N = 46$; age range: 4–16 years) underwent objective spasticity assessments. High velocity, passive stretches were applied to the gastrocnemius (GAS) and medial hamstrings (MEH). Muscle activity was measured with surface electromyography (sEMG), joint angle characteristics using inertial sensors and reactive torque using a force sensor. To test reliability, a group of 12 children were retested after an average of 13 ± 9 days. The angle of spastic catch (AOC) was estimated by three biomechanical definitions: joint angle at (1) maximum angular deceleration; (2) maximum change in torque; and (3) minimum power. Each definition was checked for reliability and validity. Construct and clinical validity were evaluated by correlating each AOC definition to the averaged root mean square envelope of EMG (RMS-EMG) and the Modified Tardieu Scale (MTS). Severity categories were created based on selected parameters to establish face validity. All definitions showed moderate to high reliability. Significant correlations were found between AOC3 and the MTS of both muscles and the RMS-EMG of the MEH, though coefficients were only weak. AOC3 further distinguished between mild, moderate and severe catches. Objective parameters can define and quantify the severity of the spastic catch in children with CP. However, a comprehensive understanding requires the integration of both biomechanical and RMS-EMG data.

1. Introduction

Spasticity is the most common motor disorder in children with cerebral palsy (CP) (Cans et al., 2000). It alters muscle structure, may cause pain, and can hinder everyday activities such as gait. Lance (1980) defined spasticity as a motor disorder characterized by 'a velocity-dependent increase in the tonic stretch reflex'.

Clinicians assess spasticity by evaluating the level of resistance to passive muscle stretches (Schotles, Becher, Beelen, & Lankhorst, 2006). Tardieu, Shentoub, and Delaru (1954) were the first to describe the concept of "spastic catch", i.e. a sudden

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reactive resistance elicited by increased muscle tone as a reaction to a fast passive stretch. Nowadays, the catch is commonly assessed by means of the Modified Tardieu Scale (MTS) (Boyd & Graham, 1999). The velocity-dependent stretch reflex is defined by the angle of the spastic catch (AOC), which is the difference between the end range of motion (ROM) while slowly moving the limb and the spastic catch angle while moving fast. A large AOC indicates increased spasticity (Boyd & Graham, 1999). As the MTS integrates a velocity-dependent aspect, it closely relates to Lance's spasticity definition (1980) and is considered a valid tool to assess spasticity (Gracies et al., 2010; Mehrholz et al., 2005; Patrick & Ada, 2006; Platz, Eickhof, Nuyens, & Vuadens, 2005).

However, inconclusive intra- and inter-rater reliability of the MTS have been reported in children with CP (Haugh, Pandyan, & Johnson, 2006). Similar to other clinical scales, the MTS relies on the subjective feeling of the therapist who stops the movement when a catch is felt (Platz et al., 2005). van den Noort, Scholtes, and Harlaar (2009) additionally reported that goniometry, as used in the MTS, is an imprecise method to measure the AOC due to joint repositioning errors. Furthermore, the resistance felt at the spastic catch may comprise both the neural component of spasticity as defined by Lance (1980), and biomechanical components such as soft tissue compliance and joint integrity (Pandyan et al., 2006).

Therefore, it is now widely acknowledged that more robust, quantitative measures to assess spasticity are required. van den Noort et al. (2009) recommended the use of inertial sensors to measure joint angle characteristics more precisely. Others have shown that reactive torque can be objectively quantified using either hand-held dynamometers while manually stretching a spastic muscle (Akman et al., 1999; Lee, Chen, Ju, Lin, & Poon, 2004; Pandyan, Price, Rodgers, Barnes, & Johonson, 2001; Pandyan et al., 2006; Peng, Shah, Selles, Gaebler-Spira, & Zhang, 2004; Wu et al., 2010) or using a motor-driven system to stretch the muscle (Damiano, Laws, Carmines, & Abel, 2006; Engsberg, Ross, Orlee, & Park, 2000; Wood et al., 2005).

Although these biomechanical methods provide more quantitative results compared to the clinical methods (Wood et al., 2005), a valid tool for spasticity assessment should also include simultaneous measurement of muscle activity (Lance, 1980; Malhotra, Pandyan, Rosewilliam, Roffe, & Hermens, 2011; Voerman, Gregoric, & Hermens, 2005; Wood et al., 2005). In children with CP, muscle activity is most commonly measured using surface electromyography (sEMG) (Voerman et al., 2005). A comprehensive spastic catch measurement based on biomechanical signals and sEMG would capture: (1) an augmentation in muscle activity that corresponds to an increase in sEMG amplitude, (2) a consequent reactive torque to passive stretch, and (3) a change in joint angle characteristics (Calota, Feldman, & Levin, 2008; van den Noort, Scholtes, Becher, & Harlaar, 2010). This will allow for a more objective definition of the spastic catch.

Thus far, only two papers have reported sEMG measurements combined with biomechanical parameters to objectively define the AOC. van den Noort et al. (2010) evaluated the AOC in the gastrocnemius and medial hamstrings in children with spastic CP using sEMG and inertial sensors. They defined the catch as the angle corresponding to the time of maximum joint deceleration when the joint is passively moved at high velocity. Wu et al. (2010) objectively measured the AOC in the elbow flexors of children with CP using sEMG and a manually controlled device equipped with torque and angle sensors. They defined the catch as the angle corresponding to the time of maximum change in torque.

Although these studies provided a more objective spasticity assessment compared to the MTS, the psychometric properties of these methods warrant further investigation. Furthermore, these studies used the position of the catch as the measure to quantify the severity of spasticity, whereas Wu et al. (2010) have shown that this position is dependent on the stretch velocity and may therefore not solely reflect severity. Finally, the definitions for the AOC were predominantly based on isolated signals (velocity – van den Noort et al., 2010; or torque – Wu et al., 2010) and a more valid measure of a spastic catch includes the integration of signals (Wood et al., 2005).

In line with a multi-dimensional assessment method, it is believed that the integration of signals may provide an improved quantification of the AOC. The aim of this study was to investigate the reliability and validity of an objective spastic catch assessment. Biomechanical and sEMG parameters obtained from isolated and integrated signals, that could define the AOC and quantify the catch severity, were investigated.

2. Methods

2.1. Participants

Children with CP were recruited from the database of the Clinical Motion Analysis Laboratory (University hospital). Participants were eligible for inclusion if they were diagnosed with spastic CP and aged between 4 and 18 years. They were excluded in case of: (1) presence of ataxia or dystonia; (2) severe muscle weakness (score <2+ on the Manual Muscle Test – Sapega, 1990) and/or poor selectivity (Gage, 2004); (3) ROM less than 25% of the normal values for all lower limb joints (based on clinical examination); (4) cognitive problems that could hinder communication and cooperation during the assessment; (5) treatment with botulinum toxin type-A six months prior to assessment or previous lower limb orthopedic surgery, intrathecal baclofen or selective dorsal rhizotomy. Written informed consent for participation was sought from all parents. The experimental protocol was approved by the local Ethical Committee.

2.2. Measurement protocol

Prior to the objective spasticity assessment, all participants underwent a full lower limb clinical examination, including the Modified Ashworth Scale (MAS) (Bohannon & Smith, 1987) of the gastrocnemius (GAS) and medial hamstrings (MEH).