Use a Portable Device for Measuring Spasticity in Individuals with Cerebral Palsy

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Abstract. [Purpose] The aim of the present study was to correlate results obtained with a portable device for measuring spasticity at the ankle joint and Modified Ashworth Scale (MAS) evaluations of patients with cerebral palsy (CP). [Subjects and Methods] A non-controlled, observational, cross-sectional study was carried out involving 17 individuals with spastic CP. The evaluation of spasticity was performed with the MAS, followed by the measurement of the passive, articular moment-angle characteristics at the ankle by means of the portable device. [Results] No statistically significant differences were found between evaluations made with MAS and the portable device with the knee flexed and extended. A strong negative correlation was found between moment-angle and the MAS in the evaluations of knee flexion and extension under conditions of fast and slow movement of both the right and left limbs. [Conclusion] By using the portable device and the MAS, similar evaluations of ankle spasticity in individuals with CP were obtained. The negative correlation between the device and the MAS indicates that greater spasticity leads to a lower moment-angle.

Key words: Muscle spasticity, Cerebral palsy, Ankle

INTRODUCTION

Spasticity was originally defined as a motor disorder characterized by muscle tone-dependent increase in velocity and exacerbation of deep reflexes stemming from hypersensitivity of the stretching reflex1–3). Spasticity is currently defined as a sensory-motor control disorder resulting from upper motor neuronal lesions, presenting intermittent or sustained involuntary activation of the muscles4).

It is estimated that approximately 90% of children with cerebral palsy (CP) exhibit clinical symptoms of spasticity, with exacerbated muscle-tendon reflexes and resistance to rapid passive movement5). Excessive spasticity may result in the shortening of the spastic muscles and the weakening of the non-spastic antagonist muscles6), with consequent pain, muscle contractions and limitations of functional recovery7), affecting both motor function and quality of life8).

The reduction of spasticity is the aim of different therapy modalities, such as treatment with Baclofen, botulinum toxin A, rhizotomy, muscle-tendon stretching, etc. Therefore, the assessment of spasticity is important for clinical decision-making and follow up of treatment9). Unfortunately, the different forms of treatment for spasticity are not uniformly effective. The results are difficult to predict and improvements are often minimal, due to the difficulty in adequately quantifying spasticity10).

The modified Ashworth scale (MAS) is widely used in clinical practice for the evaluation of spasticity. This scale is based on the evaluation of resistance to passive stretching. The scores range from 0 to 4, with the inclusion of 1+, which is the moment of joint range of motion at which resistance to movement emerges11, 12). Despite its wide use and acceptance, the results of the MAS are questionable13) due to the subjective nature of the scale, the low degree of inter-examiner and intra-examiner agreement10) and the fact that it does not take into consideration the nature of velocity-dependent spasticity, which differentiates spasticity from other muscle tone disorders14, 15). Nonetheless, the MAS continues to be employed as the “gold standard” for evaluating spasticity, despite consensus that there is no standard measure of spasticity15).

The quantification of spasticity is a complex problem16–18). A number of researchers have sought to develop reliable, objective measures for the evaluation of spasticity to allow a discerning follow up of treatment and an assessment of the therapies employed19–21). To overcome the limitations of qualitative clinical assessment methods, in recent years, new methods are being developed that are based on biomechanical approaches. At the Bioengineering Department of Politecnico di Milano, a portable device for measuring the moment-angle characteristics at ankle joint in spasticity was developed. The use of this device may assist healthcare professionals to objectively assess spasticity, thereby enabling more appropriate forms of treatment and improved
monitoring of the efficacy of the therapy employed.

The aim of the present study was to correlate the results obtained using the portable device for measuring spasticity and the modified Ashworth scale (MAS) in evaluation of patients with cerebral palsy (CP) and compare the degree of spasticity during knee flexion and extension using the two methods.

**SUBJECTS AND METHODS**

The present non-controlled, observational, cross-sectional study received approval from the Human Research Ethics Committee of the Universidade Nove de Julho (Brazil) under protocol number 264689/09 and was carried out in compliance with the norms established by Resolution 196/96 of the Brazilian Board of Health. All parents or guardians of the subjects agreed to their participation a statement of informed consent.

Initially, 42 individuals were recruited from the physical therapy clinics of the abovementioned university. The following were the inclusion criteria: spastic cerebral palsy; spasticity in the plantar flexors; diparesis or tetraparesis; and age of six years or older (for greater cooperation and understanding regarding the procedures). The following were the exclusion criteria: cognitive impairment that affected understanding of the procedures; absence of mobility in the ankles; recent history of hip, knee or ankle surgery (postoperative period); and nervous system problems not associated with CP.

The children were first classified based on the Gross Motor Function Classification System (GMFCS)\(^{22-24}\) and topographic impairment. Anthropometric characteristics (height, weight and body mass index) were then measured.

Modified Ashworth scale: The degree of spasticity of the plantar flexor muscles with the knee in flexion and extension of the planar, graded the resistance felt with a single score according to the MAS\(^{14}\).

Portable device for measuring spasticity: The device developed by the Biomedical Technologies Lab of Politecnico di Milano was used. This device allows an estimation of the passive elastic properties of the ankle in a noninvasive way. These properties are determined through the measurement of plantar flexion and dorsiflexion moments that are applied by the examiner during the assessment, in relation to the angular movement of the ankle joint. This measurement (moment-angle) is performed throughout the entire excursion of the range of movement in the sagittal plane. The device is made up of different elements. The first is a light aluminum rod, that is attached to the foot by means of a soft support, which was instrumented with strain gauge sensors (Sensor 1\(^{7}\)). This sensor is calibrated to provide the moment of the force applied by the examiner. An inclinometer with an angle sensor (Sensor 2) is placed at the shank of the subject with a Velcro strap allows the measurement of the absolute angle of the shank on the vertical plane. Another inclinometer is attached to the wooden foot support (Sensor 3) and measures the absolute angle of the foot at each instant while the examiner is performing the assessment maneuver. The time course of the relative angle at the ankle joint is obtained from the absolute angles of foot and shank on the sagittal plane.

For the evaluation with the portable device, the same procedures used for the assessment of the degree of hyperreflexia using the MAS were performed. The procedures were also carried out, by repeating both movements of maximal plantar flexion and dorsiflexion as slowly as possible, to determine whether the device was capable of detecting differences in the moment-angle according to the velocity of the movement, as spasticity is velocity dependent.

The data of both evaluations were stored and processed to obtain the angles of the foot and leg and the moment applied by the examiner during the evaluation of the maneuver. These data were used, after obtaining the moment as a function of the angular position of the foot at each instant, for analyzing the passive ankle joint stiffness.

The portable device monitors the different sensors, processing their respective signals by means of an analog-digital conversion board (DAQPad-6020E, National Instruments) and a software program, specifically developed in LabView (National Instruments), for the acquisition (at a sample frequency of 100 Hz), storage and processing of the data, after connecting it to a USB port on a computer.

The calculation of the angle-moment ratio was performed by considering the maximum and minimum ankle joint angle values, respectively measured at a maximum dorsiflexion and minimum plantar flexion (positive for dorsiflexion and negative for plantar flexion) moments, whose absolute values were standardized to 4 Nm for all evaluated subjects, as suggested by Loram et al.\(^{20}\). The moment-angle relationship was quantified at both legs separately while the examiner was performing the assessment maneuver in four different conditions: by applying a slow or a fast movement with knee and hip flexed at 90°, and at the same two velocities but with extended leg.

The Kolmogorov-Smirnov test was used to determine whether the data was normally distributed. Parametric variables were expressed as mean ± standard deviation. The dependent Student’s t-test was used for the analysis of the degree of spasticity obtained from the MAS during knee flexion and extension. Repeated-measure ANOVA was used for the analysis the data obtained from the portable device in the four conditions considered. Pearson’s correlation coefficient...
cient were calculated to determine correlations between the degree of spasticity determined using the MAS and the angle-moment values from the portable device. The level of significance was chosen as 5% (p<0.05). The data were organized and tabulated using the Statistical Package for the Social Sciences (SPSS, v. 19.0).

RESULTS

After the application of the eligibility criteria, 17 individuals with CP participated in the present study, spanning levels I to V of the GMFCS. Table 1 displays the characteristics of the sample.

Table 1. Characteristics of the sample

<table>
<thead>
<tr>
<th>Children with CP n = 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (female/male)*</td>
</tr>
<tr>
<td>GMFCS (I/II/III/IV/V)*</td>
</tr>
<tr>
<td>Age (years)**</td>
</tr>
<tr>
<td>Height (cm)**</td>
</tr>
<tr>
<td>Weight (Kg)**</td>
</tr>
<tr>
<td>Body mass index (kg/m²)**</td>
</tr>
</tbody>
</table>

* expressed as frequency (n); ** expressed as mean ± standard deviation

For the degree of spasticity quantified using the MAS, no statistically significant differences were found regarding the triceps surae muscle, with knee flexed or extended, in either the right or left leg (p>0.05). Table 2 exhibits the results of the MAS.

Table 2. Results of degree of spasticity based on the modified Ashworth scale

<table>
<thead>
<tr>
<th>Modified Ashworth scale</th>
<th>Right lower limb</th>
<th>Left lower limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion</td>
<td>2.9 ± 1.3</td>
<td>3.0 ± 1.4</td>
</tr>
<tr>
<td>Knee extension</td>
<td>2.7 ± 1.4</td>
<td>3.0 ± 1.4</td>
</tr>
</tbody>
</table>

p-value of the dependent Student’s t-test

No statistically significant differences were found between angle-moment results at the different instances of the evaluation performed with the portable device: slow movement with knee flexed; fast movement with knee flexed; slow movement with knee extended; and fast movement with knee extended (p≥0.05) (Table 3).

Table 3. Measurement of moment-angle in flexion and extension made with device

<table>
<thead>
<tr>
<th>Device</th>
<th>Right lower limb</th>
<th>Left lower limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexed: slow movement</td>
<td>42.1 ± 15.6</td>
<td>41.4 ± 18.4</td>
</tr>
<tr>
<td>Knee flexed: fast movement</td>
<td>40.8 ± 15.5</td>
<td>36.8 ± 12.1</td>
</tr>
<tr>
<td>Knee extended: slow movement</td>
<td>38.9 ± 11.1</td>
<td>38.6 ± 19.6</td>
</tr>
<tr>
<td>Knee extended: fast movement</td>
<td>36.6 ± 18.5</td>
<td>35.6 ± 18.0</td>
</tr>
</tbody>
</table>

F = 2.0; p = 0.16

F = 3.2; p = 0.05

p-value of the repeated-measures ANOVA

DISCUSSION

The aim of the present study was to compare two methods of spasticity evaluation in a group of individuals with CP. Specifically, the values obtained using the MAS (degree of spasticity) were correlated with those obtained using the portable device (angle-moment) for the evaluation of spasticity of the triceps surae muscle at two lower limb positions, with knee flexed and extended.

Spasticity in the triceps surae was not significantly affected by the position of the knee (flexed or extended) (p>0.05) in the evaluations performed using the MAS or the portable device. A previous study found a significant difference in the functional evaluation of plantar flexion with the knee in flexion and extension in a group of children with spastic CP and hemiparesis, with greater impairment when the knee was extended7. When the evaluation of the ankle is performed with the knee in flexion, the action of the gastrocnemius muscle is minimized due to the fact that this is a bi-articular muscle, resulting in lesser influence on the spasticity of the muscle during the movement of plantar flexion. The result obtained in the present study may stem from the fact that the sample was heterogeneous with regard to the degree of motor impairment and functionality, resulting in high standard deviation values for the items studied.

The measurement of the angle-moment using the portable device was made with the knee in flexion and extension performing dorsiflexion movement, both slowly and quickly in both positions. These measurements were performed to determine the possible influence of the knee angular position and the velocity of the movement, as the gastrocnemius muscle is bi-articular and spasticity is velocity dependent.
Although no statistically significant differences were found in the mean angle-moment when dorsiflexion was performed either slowly or quickly, it should be stressed that the mean angle-moment results were lower when the movement was performed quickly, suggesting greater limitation of the movement. Venturini et al.27 compared two assessment tools for ankle dorsiflexion range of motion (a manual goniometer and a digital inclinometer) and found greater reliability of measurement with the inclinometer. In the present study, two digital inclinometers were used to capture the angular measurement in degrees with sensors which were similar to the sensors employed by Venturini et al.27

We found no studies in the literature correlating the results obtained using the MAS with those obtained using a portable device designed for the assessment of spasticity in children with CP. The MAS continues to be one of the main spasticity assessment tools used in clinical practice involving children with CP. In the present study, the results revealed a strong negative correlation between the degree of spasticity evaluated by the MAS and the angle-moment evaluated by the portable device, demonstrating that a greater degree of spasticity corresponds to a lesser angle-moment. Thus, the portable device demonstrated a strong correlation with the widely employed MAS. The present findings, although preliminary, demonstrate that the device in question is a promising tool for the quantitative assessment of spasticity. Further studies should be carried out to determine its validity and intra-examiner and inter-examiner reliabilities. Moreover, such studies should employ a larger sample of children subdivided into groups based on functional level and motor impairment.

One limitation of the present study was due to the fact that convenience sampling was performed: after selecting all individuals at physical therapy clinics of the university who met the eligibility criteria, it resulted in a heterogeneous sample with regard to functionality, with two individuals classified on Level I of the GMFCS and six classified on Level IV. Accordingly, there were considerable differences in the degree of spasticity, which may have led to the lack of statistically significant differences in the evaluations of flexion and extension when using the MAS and the portable device.

From the assessment performed with the portable device and the modified Ashworth scale, similar evaluations of ankle spasticity in individuals with CP were obtained, demonstrating that the portable device may be used as an additional resource for the evaluation of such patients in clinical practice. Further studies should be carried out to validate the use of this device and determine both its reliability and reproducibility for patients with CP. The device should also be compared with other instruments for the assessment of spasticity and the modified Ashworth scale during flexion and extension in a more homogeneous sample.

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14) Blackburn M, Van vliet P, Mockett SP: Reliability of elbow stretch reflex measurement with the inclinometer. In the present study, the results revealed a strong negative correlation between the degree of spasticity evaluated by the MAS and the angle-moment evaluated by the portable device, demonstrating that a greater degree of spasticity corresponds to a lesser angle-moment. Thus, the portable device demonstrated a strong correlation with the widely employed MAS. The present findings, although preliminary, demonstrate that the device in question is a promising tool for the quantitative assessment of spasticity. Further studies should be carried out to determine its validity and intra-examiner and inter-examiner reliabilities. Moreover, such studies should employ a larger sample of children subdivided into groups based on functional level and motor impairment.

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