Introduction

Children and adults with cerebral palsy frequently have decreased flexibility of muscle and tendon, which contributes to movement impairment and activity limitation. Physical therapy intervention may include exercise therapy, positioning, and/or use of orthoses to improve flexibility. Accurate objective measurement of muscle and tendon length is essential to quantify severity, guide intervention, and assess outcomes.

Flexibility is typically assessed clinically using goniometric measurement of passive range of motion. The maximum angle of joint excursion is measured, while an unknown amount of torque is applied by the examiner. Many investigators have reported high intra-rater reliability of goniometry for single joint muscles in adult subjects without neurological impairment. Reliability coefficients have been shown to decrease, however, with multiple testers, multi-joint muscles, and subjects who have spasticity. In studies of inter-session reliability of goniometric hamstring flexibility measurements in children with cerebral palsy, mean differences of 5 to 10 degrees have been reported, with 95% confidence intervals up to 16 degrees. This limits the usefulness of goniometry in clinical settings as well as in outcomes research.

Complete description of muscle and tendon flexibility requires additional information that is not typically obtained with goniometry. Tardieu, Holt, and others have used custom made laboratory equipment to measure the relationship between joint angle and torque applied during passive muscle/tendon stretch. Analysis of the torque-angle curve provides a more complete description of muscle and tendon flexibility.

In this study, we developed a method to measure hamstring flexibility objectively using a Biodex dynamometer to generate torque-angle curves. We then examined intra-session and inter-session reliability in children with spastic cerebral palsy, as well as intra-session reliability in children with typical development.

Subjects

1. Eleven children with spastic cerebral palsy (CP)
   - Ages 5 to 12 years (Mean 9.2, SD 2.5)
   - 6 males, 5 females
   - 6 with spastic diplegia, 5 with spastic quadriplegia
   - Gross Motor Function Classification Scale Levels 1 through 4
     - 3 subjects in Level 1
     - 1 subject in Level 2
     - 4 subjects in Level 3
     - 3 subjects in Level 4
   - No lower extremity surgery within the previous year, or Botox in the previous 6 months

2. Eleven children with history of typical development (TD)
   - Age and gender matched to the subjects with cerebral palsy
   - Ages 5 to 12 years (Mean 9.2, SD 2.5)
   - No history of musculoskeletal or neurological condition

Methods

Testing Schedule:

- All children were measured twice within one session for intra-session reliability.
- Children with CP were also measured again on a separate day within two weeks of the first session, for inter-session reliability.

Testing Protocol

- The positioning chair of the Biodex System 3 dynamometer was modified to provide firm stabilization of the pelvis and thigh, with a hip angle of 115 degrees.
- Passive mode was used to extend the subject’s knee slowly (2 degrees per second), from 95 deg. of flexion toward extension.
- The subject was instructed to relax and to ‘let it go as far as you can, then say stop’.
- The knee was immediately returned to the starting position.
- Each test included at least 5 repetitions.
- Surface electromyography (EMG) was used to monitor the medial and lateral hamstrings and the vastus lateralis. Muscle activity was defined as present if the EMG signal of any muscle remained 3 standard deviations above its baseline level for greater than 500 msec.
- Biodex torque, position, and velocity analog signals and electromyography signals were recorded and processed with RUN Technologies’ A-D board and Datapac 2K2 software. (Figure 5)
- Repetitions were eliminated from analysis if muscle activity was present, except at the end of the movement.
- Remaining repetitions were averaged. Torque due to gravity was subtracted, and gravity-corrected torque in Newton-meters was plotted against knee angle in degrees. Curve fitting was done using XLFit4 software and a reciprocal exponential model. (Figure 6a-c)

Table: Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>CP Group</th>
<th>TD Group</th>
<th>CP Group</th>
<th>TD Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ao</td>
<td>0.80</td>
<td>0.84</td>
<td>0.82</td>
<td>0.86</td>
</tr>
<tr>
<td>A-HCT</td>
<td>0.81</td>
<td>0.84</td>
<td>0.80</td>
<td>0.82</td>
</tr>
<tr>
<td>Stiffness</td>
<td>0.95</td>
<td>0.95</td>
<td>0.97</td>
<td>0.96</td>
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</tbody>
</table>

Conclusions: Intra-session reliability was high, with all ICCs above 0.75 for the CP and TD groups. The TD group demonstrated higher reliability for each measure than the CP group. Inter-session reliability for the CP group was generally lower but still high, with most ICC values greater than 0.75. For inter-session reliability in the CP group, reliability of the position at maximum subject tolerance (Amax) was lower than reliability of the given torque level (A-HCT).

Clinical Relevance: This study demonstrates a reliable method of measuring hamstring flexibility using a Biodex dynamometer. The advantage of using the Biodex rather than a goniometer is to allow measurement of musculotendinous characteristics, including angle at initial resistance, angle at a given torque load, angle at maximum tolerance, and the amount of resistive torque tolerated.

Funding for this study was provided by the Foundation for Physical Therapy Clinical Research Grant 2013, the Watt Foundation in Omaha, NE, in part by Project #8188 from the Maternal Child Bureau (Title V, Social Security Act), Health Resources and Services Administration, Department of Health and Human Services (DHHS), and in part by grant S90DD0533 from the Administration on Developmental Disabilities, Administration for Children and Families, DHHS.