Test-Retest Reliability of Isokinetic Dynamometry for the Assessment of Spasticity of the Knee Flexors and Knee Extensors in Children With Cerebral Palsy

**Samuel R. Pierce, PT, MS, NCS, Richard T. Lauer, PhD, Patricia A. Shewokis, PhD, Joseph A. Rubertone, PT, PhD, Margo N. Orlin, PT, PCS, PhD**


**Objective:** To assess test-retest reliability of the peak resistance torque and slope of work methods of spasticity measurement of the knee flexors and extensors in children with cerebral palsy (CP).

**Design:** Test-retest reliability study.

**Setting:** Pediatric orthopedic hospital.

**Participants:** Fifteen children with CP.

**Intervention:** Knee extensor and flexor spasticity was assessed with an isokinetic dynamometer using passive movements at 15°, 90°, and 180°/s taken 1 hour apart.

**Main Outcome Measures:** Peak resistive torque and work were calculated. The relative and absolute test-retest reliability was calculated using intraclass correlation coefficients (ICCs) and Bland-Altman plots, respectively.

**Results:** Relative reliability was good (ICC > .75) for slopes-of-work and peak resistance torque measurements at a velocity of 180°/s, whereas reliability of peak torque measurements was decreased (ICC < .51) at slower velocities for both muscle groups. The 95% limits of agreement of Bland-Altman plots contained most data points for both methods, but the width of the limits of agreement were wide.

**Conclusions:** The measurement of spasticity of the knee extensors and flexors in children with CP using peak resistance torque at 180°/s and the slope of work method has acceptable relative test-retest reliability. However, the absolute reliability of spasticity data should be considered cautiously.

**Key Words:** Cerebral palsy; Muscle spasticity; Rehabilitation.

© 2006 by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation
were seated on the isokinetic dynamometer in 80° of hip flexion, 90° of knee flexion, and with the ankle unrestricted. The trunk and legs were stabilized by using straps across the condyles of the femur. Distal attachment of the lower limb to the lever of the dynamometer was made approximately 3 cm from the ischial tuberosity and the medial condyle of the tibia for the medial hamstrings. The position of the electrode was traced on the lower extremity by using a water-soluble marker. Subjects were seated on the isokinetic dynamometer with one half the distance from the superior-lateral border of the patella to the greater trochanter for the vastus lateralis and at one half the distance along a line from the ischial tuberosity and the medial condyle of the tibia for the medial hamstrings. The position of the electrode was traced on the lower extremity by using a water-soluble marker. Subjects were seated on the isokinetic dynamometer in 80° of hip flexion, 90° of knee flexion, and with the ankle unrestricted. The trunk and legs were stabilized by using straps across the chest, waist, and upper thigh, respectively. The axis of the dynamometer was visually aligned with the knee joint’s axis, which was defined as a line between the medial and lateral condyles of the femur. Distal attachment of the lower limb to the lever of the dynamometer was made approximately 3 cm above the lateral malleolus. The distance from the force transducer to the axis of rotation was recorded. The subjects were instructed to relax as much as possible and to not assist the passive movement of the limb. One set of 3 continuous passive movements at a velocity of 5°/s from 90° of knee flexion to 25° of knee flexion and back to 90° of knee flexion was collected for gravity correction calculation of the limb’s weight during data processing. Electromyographic signals were assessed during the gravity correction to ensure that subjects were not actively assisting the motion.

One set of 10 continuous passive movements from 90° of knee flexion to 25° of knee flexion and back to 90° of knee flexion was completed at 15°, 90°, and 180°/s. The order of movement velocity was randomly assigned for each set of movements at each velocity. The acceleration during movement reversals was set for high, which was equivalent to approximately 9000°/s². A 60-second rest break occurred after each movement velocity was assessed. As a safety measure, an arbitrary force limit was set that would cause the test to terminate if a force level equivalent to half of the subject’s body weight in newtons was exceeded. Subjects could also terminate the test by using a handheld button if they felt any pain or were frightened. The time required for each data collection session was approximately 25 minutes. After the completion of the initial assessment, the electromyographic electrodes were removed and the subjects had a 1-hour break with unrestricted activity before reassessment. The electromyographic electrodes were then reapplied, and the subjects were repositioned on the dynamometer, which was not adjusted since their first assessment. Subjects were reassessed on the same limb for a second set of 10 movements at each movement velocity with a new random velocity order.

Force, angle, and velocity data were recorded from the isokinetic dynamometer with a sampling rate of 500 Hz by a personal computer by using a custom LabView program. A separate program written in Matlab was used for postprocessing and data analysis. The gravity-corrected knee flexor peak torque and knee extensor work were calculated for each repetition while the knee was extended between 85° and 30° to measure knee flexor spasticity. The gravity-corrected knee extensor peak torque and knee extensor work were calculated for each repetition while the knee was flexed between 30° and 85° to measure knee extensor spasticity. Positive torque values indicated that the resistance of the tested muscle group was greater than zero after gravity correction. Negative torque values indicated that the resistance of the tested muscle group was less than zero after gravity correction. Work and peak torques were not calculated until the limb was moving at a constant velocity. Two repetitions for the assessment of hamstring spasticity at a velocity of 180°/s were not included in data analysis because of a failure of the dynamometer to reach the target velocity. Data from the first 5° of motion in each direction were not analyzed to avoid the effects of inertia due to the limb moving from knee flexion to knee extension or vice versa. To calculate peak torque and work, force in newtons was first converted into torque (in Nm) by multiplying the force data by the moment arm of the load cell from the center of rotation of the knee. Work in joules was calculated by summing the area under the torque curve, which is torque multiplied by angular displacement in radians. The mean values for peak torque and work for each subject were calculated for each set of repetitions. The mean difference between sets was calculated by subtracting values from set 2 from set 1. A linear regression equation was calculated for each subject to determine the line of best fit of the mean work values for each set as a function of velocity. The slope of the regression equation was used as the measure of spasticity for the slope of work method.
This study was designed as a test-retest investigation. Normality of data was assessed and confirmed by using the Kolmogorov-Smirnov test for normal distribution. Relative reliability of peak torque and the slope of work were determined through the calculation of ICC\(^2\) by using SPSS, version 10.0.\(^e\) An ICC\(_{2,1}\) was selected because a single rater collected the measurements, and it is based on a repeated-measures analysis of variance.\(^,2\) ICC values above .75 were interpreted as good reliability, whereas values below .75 indicated poor to moderate reliability.\(^,2\) Absolute reliability of peak torque and the slope of work was determined through the use of Bland-Altman limits of agreement by using MedCalc, version 7.1.4.2.\(^,2\) Before analysis, histograms of the mean differences were examined to check for the assumptions of the limits of agreement.\(^,2\)

**RESULTS**

Table 1 presents ICC and mean difference calculations for the peak torque and slope of work methods of spasticity measurement. For the knee extensors and knee flexors, poor to moderate test-retest reliability (ICCs range, .31–.51) was found by using the peak torque method for movement velocities of 15° and 90°/s, whereas good reliability was found with peak torque measurements at 180°/s (ICC = .80). By using the slope of work method, good reliability (ICC > .75) was found for the knee extensors and knee flexors. When comparing ICC values for knee extensors and knee flexors, the knee extensors showed greater relative reliability than the knee flexors for all movement velocities by using the peak torque method, whereas the knee flexors were more reliably measured by using the slope of work method.

Bland-Altman plots of the slope of work and peak torque methods are shown in figures 1 and 2. Bland-Altman plots indicated that most points (93.3%) lie within the 95% limits of agreement for the knee flexors and knee extensors for both methods. However, the 95% limits of agreement were wide in relation to the mean difference of the 2 measurements. The widest range of the interval was 17.8 Nm during the assessment of the knee extensors at a velocity of 180°/s. The mean difference in 6 of 8 graphs was biased positively, which indicates that spasticity measurements in set 1 were higher than set 2 in most cases. Outlier data points tended to occur in subjects with higher levels of peak torque.

**DISCUSSION**

This investigation examined the test-retest reliability of the peak torque and slope of work methods of spasticity measurement of the knee flexors and knee extensors by using an isokinetic dynamometer in children with CP. Good relative test-retest reliability for the knee flexors and knee extensors was found by using the slope of work method and the peak torque method with a movement velocity of 180°/s. The ICC values for peak torque of the knee flexors (ICC = .80) and knee extensors (ICC = .86) at 180°/s were similar to the values for peak torque plantarflexor spasticity with high-velocity movements reported by Lamontagne et al\(^2\) (ICC = .75) in adults with SCI and by Boiteau et al\(^1\) (ICC = .84) in children with CP. Our investigation suggests that isokinetic dynamometry by using the peak torque method with movements at 180°/s and the slope of work method can be used to reliably measure knee flexor and knee extensor spasticity in children with CP.

However, when the movement velocity was 15° or 90°/s, poor reliability was found for the knee flexors (ICC = .31 and ICC = .38, respectively) and moderate reliability was found for the knee extensors (ICC = .51 and ICC = .50, respectively) by using the peak torque method. The ICC values for peak torque measurements of spasticity at 15° and 90°/s, especially for the knee flexors, may have been related to the lack of variability found between subjects because ICCs are sensitive to limited between-subject variance.\(^,2\) The limited between-subjects variance may have been the result of our convenience sample of children with CP, which was biased toward children with a high level of functional mobility. Because a moderate negative correlation has been reported between knee musculature spasticity and functional ability,\(^,12\) inclusion of some children with more severe functional limitations who may have presented with more spasticity may have increased the between-subjects variance, thereby potentially improving the reliability estimates. Also, some subjects in this study showed low levels of spasticity as indicated by negative peak torque and slope values, which might have further limited the between-subjects variance of the sample. Future reliability studies of spasticity in children with CP would benefit from sampling from a population of children with more heterogeneous levels of function and spasticity.

The relative reliability of peak torque measurements may have been influenced by the methodology selected for data collection. For example, our investigation found poor reliability for knee flexor and knee extensor peak torque with movements at 15°/s, whereas Lamontagne\(^2\) (ICC = .83) and Boiteau\(^1\) (ICC = .84) found good reliability for measurements of plantarflexor spasticity at 5°/s and 10°/s, respectively. However, both Lamontagne\(^2\) and Boiteau\(^1\) assessed peak torque at a defined point of the ROM, whereas our investigation calculated peak torque within a large ROM. By defining the specific point of the ROM that peak torque would be measured, reliability may increase if the peak torque at that point was consistent. However, the “true peak torque” may have been missed if it did not occur at the defined value of the range. In contrast, our investigation measured the peak torque value regardless of where it occurred in the range. This methodologic

---

Table 1: Relative and Absolute Test-Retest Reliability of Spasticity of the Knee Extensors and Knee Flexors for Peak Torque and Work Slope

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Velocity (°/s)</th>
<th>Set 1</th>
<th>Set 2</th>
<th>Mean Difference</th>
<th>ICC(_{2,1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensor peak torque (Nm)</td>
<td>15</td>
<td>2.4±1.6</td>
<td>2.1±1.7</td>
<td>0.3±1.7</td>
<td>.51</td>
</tr>
<tr>
<td>Extensor peak torque (Nm)</td>
<td>90</td>
<td>7.1±5.0</td>
<td>5.2±3.8</td>
<td>1.9±4.3</td>
<td>.50</td>
</tr>
<tr>
<td>Extensor peak torque (Nm)</td>
<td>180</td>
<td>13.5±9.8</td>
<td>10.6±8.9</td>
<td>2.9±4.5</td>
<td>.86</td>
</tr>
<tr>
<td>Extensor work slope (J·deg(^{-1})·s(^{-1}))</td>
<td>0.028±0.026</td>
<td>0.019±0.029</td>
<td>0.009±0.018</td>
<td>.75</td>
<td></td>
</tr>
<tr>
<td>Flexor peak torque (Nm)</td>
<td>15</td>
<td>0.2±1.0</td>
<td>0.7±1.3</td>
<td>−0.5±1.3</td>
<td>.31</td>
</tr>
<tr>
<td>Flexor peak torque (Nm)</td>
<td>90</td>
<td>1.1±2.0</td>
<td>1.3±1.4</td>
<td>−0.2±1.9</td>
<td>.38</td>
</tr>
<tr>
<td>Flexor peak torque (Nm)</td>
<td>180</td>
<td>6.1±4.0</td>
<td>4.8±3.3</td>
<td>1.3±2.1</td>
<td>.80</td>
</tr>
<tr>
<td>Flexor work slope (J·deg(^{-1})·s(^{-1}))</td>
<td>0.010±0.011</td>
<td>0.008±0.010</td>
<td>0.003±0.005</td>
<td>.84</td>
<td></td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD. The mean difference score may not reflect the subtraction of set 2 from set 1 because of rounding.
change in peak torque determination may have affected reliability. Finally, other aspects of the data collection protocol such as the number of movement repetitions, the ROM of movement, the movement velocities selected, and the elapsed time between sets may have affected the results of this investigation.

Although relative reliability addresses the degree to which subjects keep their rank in a sample through repeated measures, absolute reliability addresses the degree to which a subject’s observed score varies with repeated measures. The expected finding that 93.3% of data points lay within the 95% limits of agreement suggests adequate absolute reliability for both the peak torque and slope of work methods of spasticity measurement. Typically, a confidence interval surrounds a measurement to denote its accuracy. In studies assessing absolute reliability, the Bland-Altman limits of agreement provide such an interval about the mean difference of the measures. The large width of the 95% limits of agreement was not surprising because it has been suggested that sample sizes greater than 50 may be required to precisely estimate the 95% limits of agreement. In addition, Bland and Altman stated that the decision regarding what is an acceptable width for the 95% limits of agreement should be made clinically on an a priori basis and not based on statistical analysis. To date, there is insufficient information in the literature to determine the clinically meaningful change in spasticity when using isokinetic dynamometry. For this reason, a meaningful estimation of the 95% limits before the start of data collection was not attempted. The decision to calculate the 95% limits of agreement with our sample size of 15 was made to provide preliminary data regarding the absolute reliability and clinical meaningfulness of these measurements because these data have not yet been reported. Therefore, the interpretation of peak torque and slope of work data to assess spasticity change in individual children with CP needs to be considered cautiously because spasticity data collected with an isokinetic dynamometer may not be sufficiently sensitive to interpret small changes in spasticity over time. Additional research with a larger sample of children with CP that attempts to determine what is a clinically meaningful change would need to be completed to establish precise and clinically meaningful 95% limits of agreement.

Six of the 8 Bland-Altman plots show a bias in which the mean difference score is positive, which indicated that spasticity measurements for set 1 were higher than set 2. This decrease in peak torque and slope of work when comparing set 1 to set 2 for the knee flexors and knee extensors may have also been related to our methodology. Multiple investigators have reported a decrease in resistive torque in patients with spasticity after repeated passive movements by using an isokinetic dynamometer. By performing 10 passive movements at 3 different speeds twice over a span of 1 hour, muscle stretching or reflex habituation may have occurred. In addition, the find-
ing that most of our data outliers in the difference scores between sets 1 and 2 occurred in subjects with increased levels of spasticity may have also been because of a stretching effect because these subjects had the potential for more change than subjects with comparatively lower levels of spasticity. Finally, the negative peak flexor torques found in some subjects at 15° and 90°/s may have also been because of a stretching effect. Because the measurement for gravity correction was completed first, the passive-resistance torque values for the gravity correction may have been greater than the values for the spasticity assessments collected after some stretching may have occurred, which would have caused the negative values.

CONCLUSIONS
The measurement of spasticity of the knee flexors and knee extensors in children with CP by using the peak torque method at 180°/s and the slope of work method has acceptable relative test-retest reliability. However, the absolute reliability of these measures for the clinical interpretation of data for the assessment of change in spasticity in individual children should be considered cautiously. Future research should attempt to establish normative data regarding spasticity of the knee flexors and knee extensors in children with CP to allow more accurate interpretation of clinically meaningful change in individual subjects. Additional research exploring the relative and absolute reliability of spasticity measurements of peak torque and slope of work by using isokinetic dynamometry in other patient populations, other muscle groups, and with larger and more varied samples of children with CP is warranted.

References

Suppliers
a. Delsys Inc, PO Box 15734, 650 Beacon St, 6th Fl, Boston, MA, 02215.
b. Chattecx Corp, 101 Memorial Dr, PO Box 4287, Chattanooga, TN 37405.
c. National Instruments Corp, 11500 N Mopac Expwy, Austin, TX 78759.
d. The MathWorks Inc, 3 Apple Hill Dr, Natick, MA 01760-2098.
e. SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.
f. MedCalc Software, Broekstraat 52, 9030 Mariakerke, Belgium.