Use of a Hand-held Dynamometer and a Kin-Com®
Dynamometer for Evaluating Spastic Hypertonia in
Children: A Reliability Study

Background and Purpose. Studies in subjects with spastic hypertonia indicate that the higher resistance to stretch in the spastic muscles is not only due to hyperactive stretch reflexes but also to changes in the muscle-tendon unit (nonreflex components). The aim of this study was to compare the test-retest reliability of two methods: hand-held dynamometry and isokinetic dynamometry for the evaluation of nonreflex and reflex-mediated resistive force in the plantar flexors of young children with spastic cerebral palsy (CP).

Subjects. Ten children 2 to 7 years of age with a diagnosis of spastic CP (either diplegia [n=7] or hemiplegia [n=3]) participated in the study. Methods. The resistive force recorded at 0 degrees of dorsiflexion during passive ankle dorsiflexions executed at low and high velocities was evaluated twice at a 1-month interval with a Penny and Giles myometer (a hand-held dynamometer) and a Kin-Com® dynamometer. The electromyographic activity of the soleus and tibialis anterior muscles was recorded during Kin-Com® testing to detect unwanted activity during low-velocity tests and to identify trials with a reflex response during high-velocity tests.

Results. High intraclass correlation coefficients (ICCs) for the resistive force values recorded at the test and retest were computed for both the myometer (ICCs=.79 and .90) and the Kin-Com® (ICCs=.84 and .84) at low and high velocities, respectively. Coefficients of variation for force values measured at a 1-month interval at low and high velocities were 13.9% and 13.2% with the myometer and 11.8% and 12.8% with the Kin-Com®.

Conclusion and Discussion. The results suggest that the myometer can provide a measure of spastic hypertonia with a reproducibility and a variation in the measures that compare to those of a computer-controlled dynamometer. From a clinical point of view, the myometer is simpler and cheaper to use given the lower cost and the little time required for testing and data analysis. Care must be taken to select a velocity that is low enough not to evoke a stretch reflex (to isolate nonreflex components) and another that is high enough to elicit a reflex response, so that it becomes possible to differentiate the reflex and non-reflex components involved in spasticity. Such a distinction is important for the choice of treatment procedures.

Key Words: Cerebral palsy, Dynamometry, Myometry, Reliability, Spasticity.

Spasticity is a disorder of spinal proprioceptive reflexes, manifested clinically as tendon jerk hyperreflexia and an increase in muscle tone that becomes more apparent the more rapid the stretching movement. Recently, several researchers have questioned the contribution of the stretch reflexes to the increased muscle tone observed with spasticity. The mechanical response (resistive torque) to muscle stretch has been shown to increase...
without a parallel increase in the electromyographic (EMG) activity of the stretched muscle, suggesting a contribution of nonreflex origin. Some authors propose that changes in the properties of the muscular and connective tissues account in part for the increased passive resistance (nonreflex components) observed in muscles with long-lasting spasticity. During slow passive dorsiflexions that did not evoke a reflex contraction in stretched muscles, for example, the resistive torque measured in spastic plantar flexors was reported to be 50% to 94% greater than in nonspastic muscles. Increased stiffness of nonreflex components has been proposed to explain increased muscle tone that is not reflex mediated. We use the term "spastic hypertonia" to refer to the increased tonus of spastic muscles that can originate from changes in reflex or nonreflex components (stiffness).

In a clinical setting, spastic hypertonia can be assessed by estimating, in a subject at rest, the resistance felt while passively moving a limb over a given range of motion. Passive stretching of spastic muscles will elicit a sudden increase of resistance that can be perceived as a catch. Based on the amount of resistance and the angle at which it is felt, the evaluator rates the hypertonia using a scale ranging from 0 (normal) to 4 (incapacity to move the limb), such as defined by the Ashworth scale. The passive movement is assumed to be at a velocity high enough to reach the reflex threshold so that the resistive force reflects a reflex-mediated muscle contraction. Increased resistance associated with changes in nonreflex components cannot be rated by this method because no sudden increase of the reflex-mediated resistance (or catch) can be felt. This manual method is therefore less appropriate for assessing chronic spasticity when the contributions thought to be of nonreflex origin (stiffness) are expected to be greater. In such a case, a clinical method that provides a direct measure of the resistive force encountered at a given angular position and during passive movements imposed at a slow velocity and at a higher velocity would be more pertinent.

Recently, the use of a myometer has been proposed for measuring the resistive force to passive movement of spastic muscle groups. Intrarater reliability of the myometer was assessed over a 1-day interval in 30 subjects (28 subjects with spastic hemiparesis secondary to cerebrovascular accident and 2 subjects with spastic paraparesis) with a mean age of 47.8 years. Measurements obtained with the myometer of the resistive forces of the elbow flexors and ankle plantar flexors were highly reproducible, as demonstrated by intraclass correlation coefficients (ICCs) ranging from 0.89 to 0.92. A similar reproducibility level (ICC = 0.82) has been reported for resistive forces recorded with a myometer at 30-minute intervals during passive hip abductions in 10 adults (age range = 21-34 years) with chronic spasticity of the hip adductors of mixed origins (cerebral palsy [CP], n = 3; spinal cord lesion, n = 1; and ataxoid recessive spastic ataxia, n = 6). In the same study, the velocity during slow (18°/s) and faster (108°/s) passive hip movements was also reported to be highly reproducible (ICCs [2.1] = 0.85 and 0.95, respectively). Reproducibility of the velocity of the passive movements imposed manually is important because reflex responses can be velocity dependent. To our knowledge, the intrarater reliability of the myometer method has not been compared with that obtained with an isokinetic device (where velocity and angular position are controlled by computer) for the measurement of spastic hypertonia.

Our study was part of a project evaluating the effect of ankle-foot orthoses (AFOs) on spastic hypertonia and on gait in children with spastic CP. This report presents the results from the test-retest study carried out prior to the children wearing AFOs. The main objective of our study was to compare the test-retest reliability of the two methods (use of a hand-held myometer and a Kin-Com® dynamometer®) for the evaluation of spastic hypertonia of the plantar flexors in young children with spastic CP.

**Method**

**Subjects and Design**

Ten children, 2 to 7 years of age, with a diagnosis of CP participated in this study (Tab. 1). This diagnosis implies the presence of a nonprogressive brain condition arising from prenatal, perinatal, or postnatal causes. The types of movement disorders (spastic diplegia and spastic hemiplegia) have been classified based on the criteria defined by the American Academy of Cerebral Palsy and reviewed by Bleck. At the time of the study, the children were enrolled in one of the programs of a rehabilitation center for children, and all children were independent walkers. To be included in the AFO study, each child had to have a diagnosis (confirmed by a single neurologist) of spastic diplegia or spastic hemiplegia, be between 2 and

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This study was approved by the Hôpital de l'Enfant-Jésus Ethics Committee.

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Table 1. Characteristics of the Subjects With Spastic Cerebral Palsy (N=10)

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>4.7</td>
<td>102.8</td>
<td>16.1</td>
</tr>
<tr>
<td>SD</td>
<td>1.7</td>
<td>8.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Range</td>
<td>2-7</td>
<td>95-112</td>
<td>12-22</td>
</tr>
</tbody>
</table>

7 years of age, have at least 0 degrees of dorsiflexion at the ankle, be able to understand simple instructions, and comply with the requirements of the testing protocol (such as be able to relax and to remain seated for 45 minutes). Children who had surgery to the lower limbs or a mental capacity to cope with the testing protocol were excluded. Prior to the child entering the study, the parents signed an informed consent statement. The children were evaluated twice (test-retest), at a 1-month interval. This time interval was chosen to estimate the natural variation of the measures over a similar period to that needed to study the effects of therapy in the ongoing study. The children were assessed at the same time of the day (morning) with the same testing protocol at test and retest. The test order was randomized between sessions among the children but remained consistent for each child.

Experimental Procedure

Hand-held dynamometer testing.
The hand-held dynamometer used in the study was the Penny and Giles myometer (model D60 107 MK5). This device is a hand-held force transducer, connected to a liquid crystal display (LCD), that can record forces up to 300 N.

For our study, a special device was used to maintain the distal end of the transducer over the head of the metatarsals. The cord connecting the transducer to the recording system (LCD) was lengthened by about 46 cm (18 in) to ease the evaluation procedure. During testing, the child sat on a table with the hips flexed to 90 degrees and the knees flexed to 30 degrees, while the feet hung freely over the edge of the table. The trunk was stabilized by external support provided by a person positioned behind the child. The evaluator held the distal end of the child's leg with one hand while holding the myometer with the other hand. The head of the myometer was held perpendicular to the sole of the foot under the distal head of the metatarsals throughout most of the passive dorsiflexion from a resting plantar flexion of about 35 to 0 degrees of dorsiflexion; the end position was monitored visually by placing a mirror in front of the evaluator. The 0-degree dorsiflexion was chosen as the end position because this angle has proven easy to monitor with a visual guide and also because measurements at this angle are reliable. The force value displayed on the LCD at the end of each passive dorsiflexion was retained for analysis.

Three consecutive passive dorsiflexions were executed at each velocity; the order of velocity was kept constant for each test and retest of a given subject but varied across the subjects. The velocity of the passive dorsiflexions was controlled by having the examiner count so that the total movement time would be 3 seconds for low velocity (about 10°-12°/s) and less than half a second for high velocity (about 70°-100°/s). These are approximations of the velocity imposed manually, because no external devices were used to monitor velocity and ankle positions. Each dorsiflexion movement was interspersed by a 10-second rest, and a 1-minute rest period preceded the high-velocity tests.

Isokinetic testing. The isokinetic device used in this study was a Kin-Com® dynamometer. With this computer-controlled system, the velocity as well as the range of passive movement can be predetermined with high reproducibility. During testing with the Kin-Com®, positioning of the lower limbs was similar to that assumed during testing with the myometer. The trunk was stabilized with two straps crossing over the chest, with a belt around the waist; a strap over the thigh further stabilized the lower limb proximally. The foot was placed in a special boot, and the ankle joint axis was aligned visually with the dynamometer's rotational axis when the ankle was resting at 0 degrees of dorsiflexion.

Three series of 10 passive movements from 35 degrees of plantar flexion to 5 degrees of dorsiflexion were performed at 10°/s and then 190°/s. The end position of 5 degrees was selected so that the resistive force recorded at 0 degrees of dorsiflexion would be within the range of movement where the velocity is still constant at 190°/s. A 0.5-second rest separated the changes of direction, and a 1-minute rest was provided after each series. Muscle activity from the soleus and tibialis anterior muscles was recorded with Medi-Trace 10-mm surface electrodes. The electrodes were placed longitudinally over the proximal third of the tibialis anterior muscle, and for the soleus muscle they were placed below the lateral head of the gastrocnemius muscle and laterally to the Achilles tendon.

The EMG activity was monitored during the Kin-Com® testing in order to differentiate the trials with and without a reflex response and to monitor the capacity of the child to relax. Muscle
activity two standard deviations higher than the mean baseline activity (500 milliseconds) preceding the onset of the movement was used as a criterion to reject trials at low velocity, or to identify trials accompanied by a reflex response at high velocity. The EMG signals were first sent to a Grass polygraph (model 7D) for amplification and visual inspection and then recorded simultaneously with angle and force signals by a microprocessor for later analysis. Prior to each series of tests at high velocity (with the Kin-Com® and the myometer), the child stretched an elastic band with both hands for 3 seconds. This reinforcement maneuver was used to help standardize the events preceding the testing to try to maintain a comparable level of neuronal excitability from test to test.10

The Kin-Com® testing protocol provided more control for positioning and trunk and leg stabilization compared with the myometer testing protocol. Because the larger number of trials made with the Kin-Com® in addition to EMG monitoring provided conditions promoting test-retest reliability, we felt that the Kin-Com® testing represented the gold standard we used for comparison purposes. The EMG monitoring made it possible to discard trials with muscle activation in low-velocity tests in order to isolate the resistive force from the nonreflex components. For tests at high velocity, only trials accompanied by a reflex response were retained to make sure that a stretch reflex had been elicited. These differences in the protocols were designed to determine how the reliability of the protocol previously standardized for clinical use10,11 compared with a more rigorously controlled protocol in a laboratory.

Data Analysis

The mean resistive force values recorded at 0 degrees of dorsiflexion for each of the three passive dorsiflexions with the myometer were computed for the low- and high-velocity conditions at the test and retest. The mean resistive force values recorded at 0 degrees of dorsiflexion with the Kin-Com® for trials without concomitant EMG activity in the soleus or tibialis anterior muscle during the low-velocity tests (10°/s) and for trials accompanied by a reflex activation in the soleus muscle at high velocity (190°/s) were computed. A gravity correction was made to account for the weight of the foot and the boot. The force originating from the weight of the boot and lower limb was recorded while the subject sat at rest with the foot fixed in the boot at −10 degrees of dorsiflexion. The gravitational force was calculated for each ankle position, and corresponding force values were subtracted (passive dorsiflexion) or added (passive plantar flexion) depending on the direction of movement. The reproducibility of the force measured at the test and retest with the myometer and the Kin-Com® dynamometer at each velocity was estimated using ICCs (type 2.1)10 and their 95% lower confidence limit.19 The nonparametric Wilcoxon test was used to compare the force values recorded between velocities. A nonparametric test was chosen given the small number of subjects and because assumptions required for using parametric tests (normal distribution and homogeneity of variance) could not be substantiated. The probability level was set at .05.

Results

The mean values (±1 SD) of the resistive force recorded with the myometer and the Kin-Com® dynamometer at each velocity are illustrated in the Figure. For each testing condition, the mean values for the test and retest were similar. Intraclass correlation coefficients are reported in Table 2 with their 95% lower confidence limit in order to illustrate the variability of the point estimate. As shown by the ICCs (Tab. 2) for the myometer (ICCs=.79 and .90) and the Kin-Com® dynamometer (ICCs=.84 and .84), the resistive force values were highly reproducible for both the high- and low-velocity conditions. The coefficients of variation computed between the test and retest measures ranged from 11.8% to 12.8% for the Kin-Com® and from 13.2% to 13.9% for the myometer (Tab. 2). The mean force values recorded at low velocity with the two devices were significantly (P<.05) lower than corresponding values recorded at high velocity. Although for the Kin-Com® testing the low-velocity resistive force represented 37.8% of the resistive force recorded at high velocity, for the myometer the force recorded at low velocity corresponded to 63.7% of the force recorded at high velocity.

The trials at low velocity in some children had to be discarded, not because a reflex response was elicited but rather because they were either unable to remain quiet or unable to relax long enough to allow the completion of the passive dorsiflexion or because they voluntarily resisted the dorsiflexion by pushing in plantar flexion. Resisting dorsiflexion by pushing in plantar flexion resulted in large and sustained muscle coactivations characteristic of voluntary muscle contractions in these children.

Discussion

The results from this study indicate that measurements of spastic hypertonia of the ankle plantar flexors with a myometer and a Kin-Com® dynamometer, repeated at a 1-month interval in young children with spastic CP, are highly reproducible. These results also show that myometric measures of hypertonia in children with spasticity have a high intrarater reproducibility, as previously reported in adults with spasticity.10,11 The particular contribution of our study is the demonstration that a hand-held dynamometer can provide a measure of spastic hypertonia with a reproducibility level and a variation in the measures that compare with those obtained with a computer-controlled dynamometer. Such a finding suggests that a trained rater using a standardized protocol has the capacity of manually replicating, even in young children with spasticity, velocity and range of ankle passive movements.

The ability to reproduce passive movements at different velocities at the hip has recently been investigated in adults with spasticity.11 High ICCs

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The results of our study also demonstrate the stability of spastic hypertonia measures made at 1-month intervals with both methods in young children. This finding further supports the use of the myometer in young children as proposed by other investigators who found a high interrater reliability (ICCs=.89-.95) of hand-held dynamometry for measuring the resistive force of the plantar flexors in children with spastic CP. Their results, however, are at variance with those of a previous study that demonstrated a lower (ICC=.60) interrater reproducibility for resistive force values obtained for spastic plantar flexors in adults. The reliability of these measures probably needs to be addressed in children. Based on the results of a well-controlled study in adults, it was recommended that repeated evaluations of the plantar flexors be made by the same rater.

The mean resistive force recorded with Kin-Com® testing at low velocity represents the mechanical response to a muscle stretch that did not evoke a reflex response and therefore, we believe, reflects the nonreflex components of spastic hypertonia. Recent findings in our laboratory indicate that, in comparison with a control group, the resistive force recorded during slow passive dorsiflexions in young children with spastic CP was increased 50%. Such results suggest a contribution of the nonreflex components to the spastic hypertonia in young children with spastic CP and therefore warrant the evaluation of these components in daily practice.

As expected, the forces recorded at a low velocity with both devices were lower than corresponding values recorded at a high velocity. The resistive force recorded at low velocity (10°/s) with the Kin-Com® represented 37.8% of the resistive force recorded at high velocity (190°/s), whereas for the myometer it corresponded to 63.7%. The reason for this finding is likely
the myometer, and our results indicate that the 0-degree dorsiflexion angle is appropriate for reliable measures of force with a hand-held dynamometer. This choice of a reproducible end position is also very important in terms of clinical outcome because the relative contribution of both components is expected to change over time.5,6 whether the central nervous system lesion is present at birth or develops later in adult life, and to influence the choice of therapeutic procedures.

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References

3 Thilmann AF, Fellows SJ, Garvem E. The mechanisms of spastic muscle hypertonus variation in reflex gain over the time course of spasticity. Brain. 1991;114:233-244.
5 Dietz V, Quintern J, Berger W. Electrophysiological studies of gait in spasticity and rigidity: evidence that altered mechanical

Table 2. Intraclass Correlation Coefficients (ICCs) and Coefficients of Variation (CVs) for Force Recorded at 0 Degrees of Dorsiflexion During Passive Dorsiflexion at Low and High Velocities

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Force Recorded at 0 Degrees of Dorsiflexion</th>
<th>ICC</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Myometer</td>
<td>Kin-Com®</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>.791 (0.46) (n=9)</td>
<td>.841 (0.54) (n=8)</td>
<td>13.9</td>
</tr>
<tr>
<td>High</td>
<td>.901 (0.71) (n=10)</td>
<td>.838 (0.58) (n=10)</td>
<td>13.2</td>
</tr>
</tbody>
</table>

* ICC type 2.1.14
* 95% confidence intervals shown in parentheses.

related to the range between the two velocities of the muscle stretch with the myometer. Thus, if the high velocity attained with the myometer were lower than 190°/s (which is most likely) or if the low velocity were higher than 10°/s (which is possible), this would result in a smaller increase with velocity, as was observed with the myometer. The manually applied low-velocity movement may have been strong enough to reach the reflex threshold level. For example, in very spastic muscles, the reflex threshold has been shown to be as low as 17°/s for passive movements applied manually, and in such cases, higher forces are recorded once the reflex threshold is attained.11 The latter possibility, however, remains hypothetical because the EMG activity was not monitored during myometry. Nevertheless, in light of our results, with subjects with a high degree of spasticity it might be appropriate to use slower passive movements (about 5°/s) so that the velocity of the muscle stretch remains well below the reflex threshold. This is critical for measuring the nonreflex components of spastic hypertonia.5,7

We believe the choice of a reproducible end position is also very important for reliable measures of force with the myometer, and our results indicate that the 0-degree dorsiflexion angle is as reliable in children as in adults with spasticity.10 The 0-degree dorsiflexion position also has the advantage of being outside the range of the torque overshoot produced at movement initiation can invalidate the measures of the resistive force, especially at high velocity.11 Moreover, because the resistive force at the ankle increases with dorsiflexion (is angle dependent),23,22 the forces recorded at 0 degrees of dorsiflexion are in the range (even during low-velocity muscle stretch) at which changes in the nonreflex components of spastic hypertonia have been detected in children with spastic CP22,23 and in adults with spastic hemiparesis.7,24

One of the main limitations of our study is the small number of subjects, which reduces the power of the statistical analysis. Furthermore, due to the small sample size and the lack of random selection of subjects, the findings cannot be generalized to all children with spasticity. The lack of EMG activity and velocity monitoring during myometry also partly limits the interpretation of the results. Nevertheless, within these limitations, the data reported here suggest that the level of test-retest reliability of the myometer compares favorably to that of the Kin-Com® dynamometer.

Conclusion

The force recorded at 0 degrees of dorsiflexion during passive ankle dorsiflexion with a hand-held dynamometer or a computerized dynamometer are highly reproducible and can be used under standardized conditions as a measure of spastic hypertonia, even in young children. Furthermore, the variation of the measurements taken at a 1-month interval is relatively low (coefficient of variation = 11%–13%), regardless whether a myometer or a Kin-Com® dynamometer is used. From a clinical point of view, it is much simpler and cheaper to use a myometer, given the lower cost of the instrument and the little time required for testing and data analysis. In myometric testing, care should be taken to select two testing velocities: one that is low enough not to evoke a stretch reflex (to measure nonreflex components) and another that is high enough to elicit a reflex response, so that it becomes possible to differentiate the reflex and nonreflex components involved in spasticity. Such a distinction between the contribution of reflex and nonreflex components of spastic hypertonia is important in terms of clinical outcome because the relative contribution of both components is expected to change over time,3,6 whether the central nervous system lesion is present at birth or develops later in adult life, and to influence the choice of therapeutic procedures.
properties of muscle contribute to hypertonia. 


