Development and Evaluation of a New Measure for Muscle Tone of Ankle Plantar Flexors: The Ankle Plantar Flexors Tone Scale

Nobuyuki Takeuchi, RPT, MS, Takeya Kuwabara, RPT, Shigeru Usuda, RPT, PhD


Objective: To develop and evaluate the reliability and concurrent validity of a clinically feasible measure for muscle tone of the ankle plantar flexors.

Design: Cross-sectional reliability and validity study of the Ankle Plantar Flexors Tone Scale.

Setting: Department of rehabilitation in a general hospital.

Participants: Patients (N=74) with cerebrovascular disease.

Interventions: Not applicable.

Main Outcome Measures: Muscle tone of the ankle plantar flexors was measured using the Ankle Plantar Flexors Tone Scale, the Modified Ashworth Scale (MAS), quality of muscle reaction with the Modified Tardieu Scale, and passive resistive joint torque with a handheld dynamometer. Intrarater and interrater reliabilities were assessed using the Cohen kappa coefficient (κ). Internal consistency was assessed using the Cronbach alpha (α). Concurrent validity was assessed with the Spearman rank correlation coefficient (ρ).

Results: The Ankle Plantar Flexors Tone Scale included 3 items: stretch reflex, middle range resistance, and final range resistance. Intrarater and interrater reliabilities and internal consistency of the Ankle Plantar Flexors Tone Scale showed moderate to excellent agreement (κ=.63–.94; α=.81). Concurrent validity of the Ankle Plantar Flexors Tone Scale was low to very high among the 3 items of the Ankle Plantar Flexors Tone Scale and existing measures. The Spearman rank correlation coefficient showed high to very high correlation between stretch reflex and quality of muscle tone as indices of the central component (ρ=.85–.94). Middle range resistance and final range resistance as indices of the peripheral component had low to moderate correlation with passive resistive joint torque using a handheld dynamometer and MAS (ρ=.44–.68).

Conclusions: The Ankle Plantar Flexors Tone Scale allows measurement of ankle plantar flexor tone in greater detail than existing subjective measures and provides a reliable and valid method for research and clinical use.

Key Word: Rehabilitation.

© 2009 by the American Congress of Rehabilitation Medicine

From the Department of Rehabilitation, Honjo General Hospital, Saitama (Takeuchi, Kuwabara); and Graduate School of Health Sciences, Gunma University, Gunma (Takeuchi, Usuda), Japan.

Supported by Grants-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) and the Support Program for Improving Graduate School Education from MEXT.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Reprint requests to Nobuyuki Takeuchi, RPT, MS, Dept of Rehabilitation, Honjo General Hospital, 1780, Kitabori, Hongo-city, Saitama 367-0031, Japan, e-mail: takeuchi_rpt@yahoo.co.jp.

0003-9993/09/0912-00481$36.00/0
doi:10.1016/j.apmr.2009.08.141

List of Abbreviations

CVD cerebrovascular disease
HHD handheld dynamometer
MAS Modified Ashworth Scale
MTS Modified Tardieu Scale
We have already analyzed the characteristics of hypertonia of the ankle plantar flexors in patients with CVD. In 1 report, we measured hypertonia of the ankle plantar flexors with the passive resistive joint torque using an HHD and MTS. The passive resistive joint torque using an HHD measures minimum resistive joint torque within the final range of passive dorsiflexion. The MTS is able to measure central and peripheral components using slow and fast stretch. Results of this study in terms of the Pearson correlation coefficient (r) and Spearman rank correlation coefficient (ρ) showed no or only low correlation between both measures (r = -0.04 to 0.10, ρ = 22–38). In a second report, hypertonia of the ankle plantar flexors was measured using the MAS and quality of muscle reaction, and Spearman rank correlation coefficient showed low correlation between both measures (ρ = 33–38). Quality of muscle reaction mainly measures the central component of hypertonia, while the MAS measures almost the entire range of passive movement, mainly as resistance of the peripheral component, and the passive resistive joint torque using an HHD measures mainly resistive torque as the peripheral component at the final range of passive dorsiflexion rather than any central component. We considered that the MAS measures hypertonia of the ankle plantar flexors from the initial range to the middle range of passive movement (ie, excluding the final range), because passive resistive joint torque using an HHD showed no correlation to the MAS. In addition, we thought that the quality of muscle reaction, MAS, and passive resistive joint torque using an HHD were able to measure different characteristics for hypertonia of the ankle plantar flexors.

The ankle plantar flexors are comprised of the gastrocnemius and soleus muscles. The gastrocnemius is a biarticular muscle influenced by the angles of the knee and ankle. The soleus is a monoarticular muscle affected by the ankle joint. We thus determined that 2 positions of measurement would be needed to evaluate characteristics of tone for both muscles.

Quantification of hypertonia remains a difficult and unresolved problem. In addition, tone of the ankle plantar flexors with these characteristics cannot be evaluated in detail using existing subjective measures. Therefore, the Ankle Plantar Flexors Tone Scale was developed as a new subjective measure to address the limitations of alternative assessment scales by considering these differing characteristics. The Ankle Plantar Flexors Tone Scale is able to measure central and peripheral components of hypertonia and can evaluate characteristics of gastrocnemius and soleus muscle tones separately. This provides useful information that is unavailable with existing subjective measures such as quality of muscle reaction and the Ashworth Scale and MAS. The Ankle Plantar Flexors Tone Scale consists of 3 items: stretch reflex as an index of the central component, and middle range resistance and final range resistance as indices of the peripheral component. Appendix 1 shows Ankle Plantar Flexors Tone Scale. We thus predicted that stretch reflex and quality of muscle reaction, middle range resistance and MAS, and final range resistance and passive resistive joint torque using an HHD would be correlated, respectively. The aim of this study was to develop and evaluate the reliability and validity of the Ankle Plantar Flexors Tone Scale.

METHODS

Development of the Ankle Plantar Flexors Tone Scale

We devised the 3 items of the Ankle Plantar Flexors Tone Scale based on previous studies: stretch reflex as an index of the central component, measuring degrees of overactive stretch reflex; and middle range resistance and final range resistance as indices of the peripheral component, measuring degrees of resistance to passive dorsiflexion within each range. The grading system of the Ankle Plantar Flexors Tone Scale was determined with reference to the results of the previous studies and existing measures.

The velocity of passive movement in the Ankle Plantar Flexors Tone Scale was decided with reference to the MTS. The aim of the MTS is to quantify the presence of dynamic muscle tone by establishing the proportion of change between slow and fast stretch. We determined that the velocity of passive movement for stretch reflex was as fast as possible, while that for middle range resistance and final range resistance was as slow as possible.

The measurement position was set for the above-mentioned reason. We thus determined that 2 positions of measurement would be needed: with knee extended while supine, and with knee flexed at 90° while supine.

Each measurement was repeated 3 times and the highest score was recorded, because a preliminary study confirmed optimal reliability of the Ankle Plantar Flexors Tone Scale using this approach.

Stretch reflex, middle range resistance, and final range resistance evaluate muscle reactions and feelings of resistance to passive movement using each grading system. Score ranges for each item were set from 0 to 4 (5 grades). The stretch reflex grading system was determined referring to quality of muscle reaction, MAS, the spinal cord assessment tool for spastic reflexes, and the ankle clonus test. Stretch reflex evaluates central component in 5 grades according to twitch and clonus. Middle range resistance and final range resistance grading systems were determined referring to quality of muscle reaction and MAS. Middle range resistance and final range resistance evaluate the peripheral component in 5 grades according to resistance to passive movement within the middle and final ranges, respectively. Appendix 2 shows quality of muscle reaction and the MAS, spinal cord assessment tool for spastic reflexes, and ankle clonus test.

Evaluation Reliability and Validity of the Ankle Plantar Flexors Tone Scale

PROCEDURES

We evaluated intrarater and interrater reliabilities, internal consistency, and concurrent validity of the Ankle Plantar Flexors Tone Scale. Concurrent validity was assessed using the quality of muscle reaction, MAS, and passive resistive joint torque measured with an HHD. All indices were measured with the knee extended and with the knee flexed at 90°.

SUBJECTS AND RATERS

Subjects comprised 74 patients with CVD (mean age ± SD, 77.5 ± 10.0y; range, 48–92y). Table 1 shows subject characteristics in detail. All patients were admitted to Honjo General Hospital. Inclusion criteria were admis-

<table>
<thead>
<tr>
<th>Table 1: Subject Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Age (y)</td>
</tr>
<tr>
<td>Sex (men/women)</td>
</tr>
<tr>
<td>Diagnosis</td>
</tr>
<tr>
<td>Cerebral infarction</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
</tr>
<tr>
<td>Duration of illness (d)</td>
</tr>
<tr>
<td>Paretic side (right/left)</td>
</tr>
</tbody>
</table>

NOTE: Values are either n or mean ± SD.
tion for diagnosis of CVD with hemiplegia and starting physical therapy. Exclusion criteria were use of antispastic drugs, history of surgery to control muscle tone, pain during measurement, difficulty maintaining the measurement position during contraction (especially knee and/or hip joints), and inability to provide informed consent.

The raters were physical therapists A and B (experience, 7 years for both raters). Rater A measured the Ankle Plantar Flexors Tone Scale, quality of muscle reaction, MAS, and passive resistive joint torque using an HHD. The Ankle Plantar Flexors Tone Scale was measured twice, while other indices were measured only once. Rater B measured only the Ankle Plantar Flexors Tone Scale twice. The order of measurement between raters was randomized, and no discussion of results between raters occurred during the study, to ensure blinding to each other’s results.

**Measures.** We measured Ankle Plantar Flexors Tone Scale using 2 velocities of passive movement: stretch reflex was as fast as possible, and middle range resistance and final range resistance were as slow as possible. All measurements involved moving from the position of maximum plantarflexion to the position of maximum dorsiflexion. Each measurement of the Ankle Plantar Flexors Tone Scale was repeated 3 times, and the highest score was recorded.

Passive movement of the quality of muscle reaction was as fast as possible, from the position of maximum plantarflexion to the position of maximum dorsiflexion. Quality of muscle reaction was measured 3 times, and the third score was recorded. This protocol was set up using the method of Fosang et al.26

---

**Table 2: Agreement and Kappa Value in Ankle Plantar Flexors Tone Scale for Each Rater (Intrarater) With Knee Extended Position**

<table>
<thead>
<tr>
<th></th>
<th>Rater A</th>
<th></th>
<th>Rater B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First</td>
<td></td>
<td>First</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>0 30 3</td>
<td>0 43 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 4 12 1</td>
<td>1 3 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 3 11</td>
<td>2 1 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 1 1</td>
<td>3 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 1 7</td>
<td>4 1 1</td>
<td></td>
</tr>
</tbody>
</table>

κ=.75*

<table>
<thead>
<tr>
<th></th>
<th>MR First</th>
<th></th>
<th>First</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>0 12 1</td>
<td>0 15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 31 3</td>
<td>1 2 35 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 4 15</td>
<td>2 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 6</td>
<td>3 2 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

κ=.82*

<table>
<thead>
<tr>
<th></th>
<th>FR First</th>
<th></th>
<th>First</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>0 3</td>
<td>0 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 17 2</td>
<td>1 2 20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 29</td>
<td>2 23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 2 19</td>
<td>3 1 17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

κ=.90*
Statistical Analysis

Intrarater reliability was assessed between the first and second scores (test-retest) of 3 items of the Ankle Plantar Flexors Tone Scale by raters A and B. Interrater reliability was assessed between the first score of 3 items of the Ankle Plantar Flexors Tone Scale by both raters. Statistical analysis was conducted using Cohen kappa coefficient (κ). The strength of agreement for the kappa coefficient was determined as described by Landis and Koch32 (0, poor; .01–.20, slight; .21–.40, fair; .41–.60, moderate; .61–.80, substantial; .81–1, almost perfect).

Internal consistency was assessed for 3 items of the Ankle Plantar Flexors Tone Scale in knee extended and knee flexed positions by rater A (ie, a total of 6 items with both positions). We used the first score of the Ankle Plantar Flexors Tone Scale. The Cronbach alpha coefficient (α) and Spearman rank correlation coefficient (ρ) were used. For comparing groups, alpha values of 0.7 to 0.8 are regarded as satisfactory.33

Standards used to describe ρ ranges are as follows: 0 to .25, little, if any, correlation; .26 to .49, low; .50 to .69, moderate; .70 to .89, high; and 0.9 to 1, very high.34

Concurrent validity of the Ankle Plantar Flexors Tone Scale was assessed. Correlations of the quality of muscle reaction, MAS, and passive resistive joint torque using an HHD with the 3 items of the Ankle Plantar Flexors Tone Scale were examined using each score from rater A. The Spearman rank correlation coefficient (ρ) was used.

All statistical analyses were performed using SPSS 17.01 for Windows. Values of P less than .05 were considered statistically significant for all analyses.

Ethics

The ethics committee at Honjo General Hospital approved all study protocols (approval no. 20080119), and written informed consent was obtained from all subjects prior to enrollment.

RESULTS

Reliability of the Ankle Plantar Flexors Tone Scale

Tables 2 through 4 show agreement and kappa values for intrarater and interrater reliabilities of the Ankle Plantar Flexors Tone Scale. Intrarater reliabilities showed substantial to almost perfect agreement with both raters at the knee extended and knee flexed positions (stretch reflex, κ=.72–.79; middle range resistance, κ=.82–.89; final range resistance, κ=.81–.94). Interrater reliabilities showed substantial to almost perfect agreement (stretch reflex, κ=.80–.82; middle range resistance, κ=.74–.76; final range resistance, κ=.63–.72). Each association was significant (P<.001).

Table 5 shows alpha and rho values for internal consistency. The alpha values showed good reliability for the Ankle Plantar Flexors Tone Scale (α=.81). In addition, all correlation coefficients for the 6 items showed positive values (ρ=.22–.79).
Validity of the Ankle Plantar Flexors Tone Scale

Table 6 demonstrates \( \rho \) values for comparisons between the Ankle Plantar Flexors Tone Scale and other indices. The \( \rho \) showed high to very high correlation between stretch reflex and quality of muscle reaction at the knee extended and knee flexed positions (\( \rho = .85–.94 \)). Conversely, no correlation was seen between the stretch reflex and passive resistive joint torque using an HHD (\( \rho = -.07 \) to \( -.05 \)), and only low correlation was noted between the stretch reflex and MAS (\( \rho = .26–.41 \)). The middle range resistance had low to moderate correlation with passive resistive joint torque using an HHD and MAS (\( \rho = .44–.61 \)).

Table 4: Agreement and Kappa Value in Ankle Plantar Flexors Tone Scale Between Raters A and B (Interrater)

|                | Rater A | Rater B | K | K
|----------------|---------|---------|---|---
| Ext SR 0      | 30      | 1       | 4 | .80*
| 1             | 9       | 2       | 15| .76*
| 2             | 1       | 3       | 17| .63*
| 3             | 4       | 1       | 1 | .76*
| Flex SR 0     | 2       | 1       | 1 | .63*
| 1             | 13      | 2       | 1 | 
| 2             | 8       | 23      | 2 | 
| 3             | 5       | 16      |   | 
| 4             | 1       | 1       |   | 

Abbreviations: FR, final range resistance; MR, middle range resistance; SR, stretch reflex.
* \( P < .001 \).

Table 5: Cronbach Alpha Coefficient and Spearman Rank Correlation Coefficients Matrix of the Ankle Plantar Flexors Tone Scale

<table>
<thead>
<tr>
<th>Ext SR</th>
<th>MR .41*</th>
<th>FR .69*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex</td>
<td>.79</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>.27*</td>
<td>.71*</td>
</tr>
<tr>
<td></td>
<td>.22</td>
<td>.53*</td>
</tr>
</tbody>
</table>

Cronbach \( \alpha = .81 \)

Abbreviations: Ext, knee extended position; Flex, knee flexed position; SR, stretch reflex; MR, middle range resistance; FR, final range resistance; * \( P < .05 \); † \( P < .01 \).

Table 6: Spearman Rank Correlation Coefficients Matrix Between the Ankle Plantar Flexors Tone Scale and Others

<table>
<thead>
<tr>
<th>Ankle Plantar Flexors Tone Scale</th>
<th>Ext PRJT-HHD</th>
<th>Ext MAS</th>
<th>Ext QMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR</td>
<td>-.05</td>
<td>.50*</td>
<td>.55*</td>
</tr>
<tr>
<td>MR</td>
<td>.28*</td>
<td>.59*</td>
<td>.67*</td>
</tr>
<tr>
<td>FR</td>
<td>.85*</td>
<td>.42*</td>
<td>.30*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flex PRJT-HHD</th>
<th>Flex MAS</th>
<th>Flex QMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.07</td>
<td>.44*</td>
<td>.55*</td>
</tr>
<tr>
<td>.41*</td>
<td>.62*</td>
<td>.68*</td>
</tr>
<tr>
<td>.94*</td>
<td>.31*</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: Ext, knee extended position; Flex, knee flexed position; SR, stretch reflex; MR, middle range resistance; FR, final range resistance; PRJT-HHD, passive resistive joint torque using an HHD; QMR, quality of muscle reaction; * \( P < .05 \); † \( P < .01 \).
.62) and low correlation with quality of muscle reaction (ρ=.31–.42). Final range resistance was moderately correlated with passive resistive joint torque using an HHD and MAS (ρ=.55–.68), and final range resistance had low correlation with quality of muscle reaction (ρ=.30–.31).

**DISCUSSION**

The overall purpose of this study was to develop and evaluate the Ankle Plantar Flexors Tone Scale. The present results provide support for the reliability and validity of the Ankle Plantar Flexors Tone Scale for participants in this study.

**Reliability and Validity of the Ankle Plantar Flexors Tone Scale**

Intrarater and interrater reliabilities of the Ankle Plantar Flexors Tone Scale suggested substantial to almost perfect reliability.

High internal consistency and positive correlation coefficients of the 6 items (3 items in each position) comprising the Ankle Plantar Flexors Tone Scale were identified. These findings suggest that stretch reflex, middle range resistance, and final range resistance allow measurement of factors affecting hypertonia in the ankle plantar flexors.

Concurrent validity of the Ankle Plantar Flexors Tone Scale was within an acceptable range. Correlation between the stretch reflex and quality of muscle reaction was high. We suggest stretch reflex as a useful parameter for measuring central components of hypertonia. Middle range resistance and final range resistance had low to moderate correlation with passive resistive joint torque using an HHD and MAS, but the correlation between final range resistance and passive resistive joint torque using an HHD was higher than that between the middle range resistance and passive resistive joint torque using an HHD. The passive resistive joint torque using an HHD measured passive resistive joint torque in the final range. Thus, we consider final range resistance as able to evaluate resistance for passive movement in the final range, rather than middle range resistance. Conversely, middle range resistance is able to evaluate resistance in the middle range, rather than final range resistance. This is because the measurement range of middle range resistance does not include the final range.

**Usefulness of the Ankle Plantar Flexors Tone Scale**

Muscle tone conditions change with time after onset. Muscle tone hypertonia with upper motor neuron lesions starts from the overactive stretch reflex. Decreased extensibility of soft tissues such as muscle fibers and fascia, exaggerated sensitivity of muscle spindles, and increased mechanical stimulation of stretch when the condition continues encourage exaggeration of the stretch reflex.1-3,35-37 In total, these changes to muscle tone conditions show the importance of central and peripheral components in hypertonia.

The Ankle Plantar Flexors Tone Scale may offer advantages over existing subjective measures of muscle tone for patients with CVD. The Ankle Plantar Flexors Tone Scale has the possibility of evaluating the 3 characteristics of hypertonia in the ankle plantar flexors: the central component, and resistance as a peripheral component divided into middle and final ranges. Existing subjective measures are insufficient for the evaluation of these characteristics. The Ankle Plantar Flexors Tone Scale offers a more comprehensive subjective measure, and the present research suggests the clinical usefulness of this scale for evaluating hypertonia in the ankle plantar flexors for patients with CVD.

**Study Limitations**

One of the limitations of this study was that only patients with CVD participated. The Ankle Plantar Flexors Tone Scale may be useful for evaluating hypertonia in subjects other than those with CVD. Further investigations are needed to confirm this. If the Ankle Plantar Flexors Tone Scale can be used for subjects with various diseases, then use in wider fields is plausible. The minimum force necessary to maintain maximum dorsiflexion was measured as passive resistive joint torque using an HHD. This may have decreased the reliability of measurement. In addition, passive resistive joint torque using an HHD represents a measurement of passive resistance in a static position, whereas middle range resistance and final range resistance involve movement. Ankle plantar flexor tone will thus differ between these 2 situations. Furthermore, the tone of the ankle plantar flexors was investigated using the passive resistive joint torque using an HHD, MAS, and quality of muscle reaction. The Ankle Plantar Flexors Tone Scale was developed based on these results. In addition to these measures, investigating other indices appears important, such as electrophysiologic measures and use of an accelerometer to assess twitch and clonus during stretch reflex assessment, and dynamic torque of the ankle during middle range resistance and final range resistance assessments. More detailed assessment of the validity of the Ankle Plantar Flexors Tone Scale is needed to investigate measurements using these indices.

**CONCLUSIONS**

Overall findings from this study suggest that the Ankle Plantar Flexors Tone Scale allows measurement of hypertonia of the ankle plantar flexors in greater detail than existing subjective indices. In addition, the Ankle Plantar Flexors Tone Scale provides a reliable and valid method for research and clinical use in patients with CVD.

---

**APPENDIX 1: THE ANKLE PLANTAR FLEXORS TONE SCALE**

**Point of note**

- All tests are measured by passive dorsiflexion from position of maximum plantarflexion to position of maximum dorsiflexion.
- All tests are performed 3 times, and the highest score is recorded.
- Results of measurement are compared with the nonparetic side in the case of hemiplegia.
- Stretch reflex measures neurologic muscle reaction to passive movement.
- Middle range resistance measures resistance with passive movement, not including resistance of the final range.
- Final range resistance measures the resistance necessary to maintain the final position (ie, excluding middle range resistance).
APPENDIX 1: CONTINUED

Velocity of passive dorsiflexion
- Stretch reflex: as fast as possible.
- Middle range resistance: as slow as possible.
- Final range resistance: as slow as possible.

Position of measurement
- All measurements are given for knee extended and knee flexed at 90° in a supine position.
- Beginning position of passive movement is the position of maximum ankle plantarflexion.
- When this method is difficult, the rater must record the difficulty.

Score
- Stretch reflex.
  0: No twitch.
  1: Twitch and no clonus.
  2: Mild clonus, persisting <3s.
  3: Moderate clonus, persisting 3–10s.
  4: Severe clonus, persisting >10s.
- Middle range resistance.
  0: No resistance.
  1: Mild resistance, slight increase in resistance.
  2: Moderate resistance, greater increase in resistance.
  3: Severe resistance, considerable increase in resistance, but able to achieve passive movement.
  4: Passive movement is difficult.
- Final range resistance.
  0: No resistance.
  1: Mild resistance, slight increase in resistance.
  2: Moderate resistance, greater increase in resistance.
  3: Severe resistance, considerable increase in resistance, but able to maintain final position.
  4: Unable to maintain final position or passive movement is difficult.

APPENDIX 2: DESCRIPTIONS OF MEASURES USED IN THIS STUDY

Quality of muscle reaction in MTS\textsuperscript{11-13}

0  No resistance throughout the course of passive movement.
1  Slight resistance throughout the course of passive movement, with no clear catch at a precise angle.
2  Clear catch at a precise angle, interrupting passive movement, followed by release.
3  Fatigable clonus (<10s when maintaining pressure) occurring at a precise angle.
4  Infatigable clonus (>10s when maintaining pressure) occurring at a precise angle.

MAS\textsuperscript{7}

0  No increase in muscle tone.
1  Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the ROM when the affected parts are moved in flexion or extension.
1+ Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remaining ROM (less than half).
2  More marked increase in muscle tone through most of the ROM, but affected parts are easily moved.
3  Considerable increase in muscle tone, passive movement difficult.
4  Affected parts rigid in flexion or extension.

Spinal cord assessment tool for spastic reflexes: clonus\textsuperscript{23}

0  No reaction.
1  Mild, clonus maintained <3s.
2  Moderate, clonus persisting 3–10s.
3  Severe, clonus persisting >10s.

Ankle clonus test\textsuperscript{24,25}

The ankle clonus test is measured as the number of beats of clonus.

Abbreviation: ROM, range of motion.

References

Suppliers
a. Power Track II; Jtech Medical Industry, 470 Lawndale Dr, Ste G, Salt Lake City, UT 84115.