A Review: The Validity and Reliability of the Modified Ashworth Scale as a Measurement Tool for the Evaluation of Spasticity and its Applicability to Children with Cerebral Palsy

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ABSTRACT

Introduction: The modified Ashworth Scale is the most commonly used measurement tool to evaluate spasticity in adults and CP-children. The validity and reliability of the MAS is questionable and therefore critically discussed throughout literature. Due to this reason a review regarding this topic is urgently required.

Methods: In order to retrieve relevant publications the authors performed computerized searches, citation tracking of databases and of bibliographic indexes. All retrieved articles were assessed methodologically on their quality and were summarized in comprehensive tables. Furthermore, interviews with several pediatric physiotherapists were conducted and the handling of the MAS was practised in clinical settings.

Results: 29 articles were found, of them 22 were obtained, 5 were excluded. 17 articles were analyzed, 8 concerning the validity of the MAS, 8 concerning the reliability of the MAS and 1 review. Validity: 3 articles supported the validity of the MAS, 3 rejected it and 2 validated only some grades of the scale. Reliability: both inter-rater and intra-rater reliability varied between little to any and high correlations.

Conclusions: The MAS should be considered as a measure of high tone and not as a measure of spasticity and be regarded as a measure of quality of movement. Therefore, it is recommended to combine it with a quantitative measure of spasticity in every examination. Furthermore, standardization and re-examination of its reliability is particularly necessary.

Key words: modified ashworth scale (MAS), spasticity, tone, measurement tool, reliability, validity, children, Cerebral Palsy

INTRODUCTION

Spasticity is one of the major clinical findings within an upper motor neuron syndrome and is known since ancient times. It is commonly observed in patients with multiple sclerosis, cerebral vascular accident (CVA), brain injury, spinal cord injury and cerebral palsy (CP). Spasticity is “a motor disorder that is characterized by a velocity dependent increase in tonic reflex (muscle tone) with exaggerated tendon reflexes” (Lance 1980 cited: Pandyan et al. 1999). “It can develop following a lesion at any level of the corticofugal pathways: cortex, internal capsule, brainstem or spinal cord” (Burke 1988 cited: Pandyan et al. 1999). “Spastic hypertonia is the exaggeration of the spinal proprioceptive reflexes resulting from a loss of descending inhibitory control” (Burke 1988, Young 1997, Brown 1994 cited: Pandyan et al. 1999). To put this to practical use: “The more rapidly the examiner moves the limb of a patient with spasticity, the greater the increase in muscle tone. Indeed, the resistance to movement may become so great as to stop all movement, the abrupt cessation of movement being described clinically as a
'catch'. If passive flexion of the arm or extension of the leg continues the resistance to movement may disappear rapidly” (Stokes 1998, p. 58).

Cerebral Palsy (CP) is not a disease, but rather a category of disability (Nelson 1988 cited: Tecklin 1998, p.108), which encompasses a wide range of different causative factors and describes an evolving disorder of motor function secondary to a non-progressive pathology of the immature brain. The World Commission of CP defined it in 1988 as “a persistent but not unchanging disorder of posture and movement, caused by damage to the developing nervous system, before or during birth or in the early months of infancy” (Griffiths and Clegg 1988 cited: Stokes 1998, p.229). It is often accompanied by mental retardation, seizures and communication disorders. The prevalence of CP births in the United States is approximately 2 per 1000 and it is reported that there has been a recent rise, probably due to a large increase of the survival rate (Stokes 1998, p.208).

CP can be divided into three categories: Spastic, Athetoid and Ataxic. These categories are not fixed, and the majority of patients have a mixture of symptoms from the three categories. The Spastic form of CP affects 65-75% of patients (Gould 1997, p.493) and is further divided by Molnar into hemiparesis, diplegia and quadriplegia (Molnar 1985 cited: Tecklin 1998, p. 110). Due to the fact that spastic CP is the most common category it is important to have a reliable and valid measurement tool for the evaluation of the level of spasticity, in order to set reasonable treatment goals and continuously assess the treatment development.

For this purpose a number of measurement tools, which measure different aspects of spasticity are described in literature. Theses include the “Tardieu” scale, which measures the stretch-velocity, fast compared to slow, in relation to the moment of muscular reaction (Verschuren et al 2003). Electromyographic (EMG) recordings, which detect the electrical changes, action potentials, that occur when a muscle contracts (Skold et al 1998). The pendulum test, which records the resistance to passive joint movement present while the limb is moving under gravitational control (Bajd and Vodovnik 1984 cited: Smith et al 2002) and the Modified Ashworth Scale (MAS) (Bohannon and Smith 1987).

Of the aforementioned measurement tools this review concentrates on the properties of the MAS for several reasons: (1) It is the most common and frequent used measure of spasticity in adults and children, both in research and in clinical practice (Bakheit et al 2003). (2) It is the most often cited clinical rating scale in literature. (3) It is simple to apply in clinical setting as it does not require any special equipment and as consequence could be used as a handy tool for physicians and physiotherapist working with spastic patients.

The validity and reliability of the MAS is questionable and critically discussed throughout literature. The authors found it necessary to review and scrutinize the topic, since knowledge regarding the acceptability of the tool should be obtained before any recommendations for its use are given.

The original Ashworth Scale (Ashworth 1964 cited: Pandyan et al 1987) presented in table 1, was first developed by Ashworth in 1964 as a 5-point scale, with the purpose of creating a simple clinical tool to test the efficiency of an anti-spastic drug in patients with multiple sclerosis. The scale was later modified (table 2) to
a 6-point scale by Bohannon and Smith (1987) with the aim of increasing the sensitivity of its grades at the lower end of the scale, since their experience showed that most patients demonstrate levels of spasticity at the lower end of the scale (Bohannon and Smith 1987).

Table 1: The Ashworth Scale (Ashworth 1964)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No increase in tone</td>
</tr>
<tr>
<td>1</td>
<td>Slight increase in tone giving a catch when the limb is moved in flexion or extension</td>
</tr>
<tr>
<td>2</td>
<td>More marked increase in tone but limb easily flexed</td>
</tr>
<tr>
<td>3</td>
<td>Considerable increase in tone – passive movement is difficult</td>
</tr>
<tr>
<td>4</td>
<td>Limb rigid in flexion or extension</td>
</tr>
</tbody>
</table>

Table 2: The Modified Ashworth Scale (Bohannon and Smith, 1987)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No increase in muscle tone</td>
</tr>
<tr>
<td>1</td>
<td>Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the ROM when the affected part(s) is moved in flexion or in extension</td>
</tr>
<tr>
<td>1+</td>
<td>Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the reminder (less than half) of the ROM</td>
</tr>
<tr>
<td>2</td>
<td>More marked increase in muscle tone throughout most of the ROM, but affected part(s) easily moved</td>
</tr>
<tr>
<td>3</td>
<td>Considerable increase in muscle tone, passive movement is difficult</td>
</tr>
<tr>
<td>4</td>
<td>Affected part(s) rigid in flexion or extension</td>
</tr>
</tbody>
</table>

While defining the research question, the intention was to carry out a review that explores the validity and reliability of the MAS for the evaluation of spasticity in children between ages 3 and 7 years with CP. As soon as the search for articles began it became clear that very few studies were conducted to investigate the use of the MAS in children with CP, whereas a higher amount of studies have been carried out on adult subjects with different pathologies of the CNS. Because the MAS claims to be a measurement tool for the evaluation of spasticity, the mechanism leading to spasticity or whether the subject is an adult or a child, should not be of any importance. For this reason, studies that were carried out on adults are included in this review in addition to a number of studies that involved children with CP. Since there are some factors that will differ in the examination of spasticity in a child compared to an adult (for example: size, the ability to follow instructions and the ability to relax a limb on command), interviews with a number of
pediatric physiotherapists were carried out and their suggestions and conclusions are taken into account, in later sections of this review.

The purpose of this review is to investigate the validity and reliability of the MAS as a measurement tool for the evaluation of spasticity and explore its applicability on children with CP. This will be done by comparing different outcomes of collected articles and finalized with a conclusion.

**METHODS**

**Literature search**
The authors identified relevant publications, e.g. the validity and/or the reliability of the MAS, by means of computerized searches and citation tracking. The search strategy included four databases; MEDLINE (Pubmed), BMJ journals online, the Cochrane library for systematic reviews and Google for the period 1985-2004. The keywords and phrases used were: modified ashworth scale, reliability, validity, measurement tools, spasticity, children, cerebral palsy and combinations of these.

In addition, all seemingly relevant MEDLINE “related articles” were screened for additional meaningful references and all references of retrieved articles were further examined for additional publications.

**Inclusion / exclusion criteria**
The studies had to meet the following criteria to be included in this review:

1. Publications had to be written in the English, German or Dutch language.
2. The studies had to include human subjects with an upper motor neuron lesion resulting in spasticity.
3. The number of subjects participating in the studies had to be at least 15 or above.
4. The study design had to be descriptive and correlational.
5. Studies that examined the validity, had to compare the MAS with objective measurements such as EMG recordings, or explore the ability of the MAS to detect changes following scientifically proven treatments of spasticity.

For the selection of eligible studies, both authors read all articles and selected those which met the inclusion / exclusion criteria. In cases of disagreement consensus was resolved following extensive discussions between the authors.

**Assessment of methodological quality of the trails**
Preferably, trials should be rated with a “checklist”, which considers two aspects of trial quality, namely the “believability” (internal validity) of the trial and whether the trial contains sufficient statistical information to make it interpretable. A number of computerized lists are available from different scientific databases (e.g. “Pedro-physiotherapy evidence database”), however these lists mostly include items that are characteristically related to randomized controlled trials and therefore do not match the type of studies investigated in this review.

Nevertheless, the authors believe in the importance of assessing the quality of studies. For that reason the following criteria were specified to provide
information, which enables the reader to form an opinion regarding the quality of each article.

1. Information regarding the subjects:
   - Size of study
   - Pathology
   - Age
   - Inclusion/exclusion criteria

2. Information regarding the procedure:
   - Measurement tools
   - Test position
   - Duration of movement
   - Test repetition
   - Number of examiners
   - Blinding
   - Application of training prior to the study or the use of an standardized procedure

3. Information regarding the results:
   - Type of statistical analysis
   - Statistical analysis should be performed using correlation techniques

Content analysis of the articles
To simplify the search for an answer to the research question 3 stages of article content analysis have been taken:
First, the authors developed a table in which they independently documented relevant information found in all articles. The table included a summary of the following: purpose of the study, pathology, method used, results, discussion and additional notes. The purpose of the individual recordings was to increase the reliability of the results and to eliminate the possibility of overlooking significant details.
Second, the information obtained from these tables were analyzed and discussed between the authors. Once agreement was reached regarding all issues and details of each article, the two tables were correlated and divided into two final tables, which drew a difference between the articles that were concerned with validity of the MAS and articles that were concerned with reliability of the MAS.
Third, comprehensive summaries of the final two tables were made in order to provide the reader with the most important aspects of each study. These tables are presented in the result section of this review (tables 6 and 7).
By using this clear procedure, the quality of the final tables and consequently the quality of the results of this review were guaranteed.

Personal Experience
Both authors have carried out interviews with several pediatric physiotherapists in order to explore different approaches and interpretations of the MAS and to achieve different opinions about its practical use.
In addition both authors practiced the handling of the MAS with CP children in clinics in order to familiarize with the practical and to form their own idea regarding the MAS.
RESULTS

The results are divided into four parts. The first 3 parts briefly describe the results of the literature search, inclusion/exclusion criteria and the assessment of methodological quality of articles. The forth part is directly concerned with the results of the selected articles and is further divided into two sub-divisions of validity and reliability.

Literature search
On MEDLINE, the combination “modified ashworth scale AND reliability” produced nine results, “modified ashworth scale AND validity” produced 1 result, “modified ashworth scale AND cerebral palsy” produced 1 result, “spasticity measures AND cerebral palsy” produced 1 result as well and “modified ashworth scale” alone produced 5 results. The combinations “modified ashworth scale AND children”, “spasticity measures AND children” and “spasticity AND measurement tools” offered articles that were already found under the former mentioned combinations.
No articles were found in the Cochrane library for systematic reviews since Cochrane is not publishing reviews on validity and/or reliability of instruments at the moment, but on interventions.
Google and BMJ journals online brought up articles, which were already found in MEDLINE.
Additional two articles were personally handed over by an expert in the field of pediatric physiotherapy. 10 articles were found using references of retrieved articles, however the full text version of 7 of these articles could not be obtained since they were not available in libraries in the surrounding area.
In total twenty-nine articles were found using the different search methods, of these 22 were obtained (Refer to appendix I for the full list of articles).

Inclusion/exclusion criteria
The below listed articles were excluded from answering the research question after applying the inclusion / exclusion criteria, for the following reasons:
In total five articles were excluded, therefore 17 articles remained to be further assessed for methodological quality.

Assessment of methodological quality of the trails
All seventeen articles were assessed for quality according to the criteria specified in the methods. Important issues and points of attention were recorded (tables 6 and 7), no articles were excluded for not complying with all points in the criteria assessment. The authors believe that although a number of studies did not meet all the criteria points, they are still valuable and pointing them out and discussing them critically should be sufficient.
Due to the stated above all 17 articles were used to answer the research question, of these eight are concerned with reliability, 8 with validity and one is a review, which deals with both the validity as well as the reliability of the MAS.

**Articles results**

All results obtained from articles were interpreted according to Munro (p. 235, 1986), and not according to the interpretation given by each article, in order to attain a united interpretation of the results. The interpretation scale is presented in table 3.

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 – 0.25</td>
<td>Little if any</td>
</tr>
<tr>
<td>0.26 – 0.49</td>
<td>Low</td>
</tr>
<tr>
<td>0.50 – 0.69</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.70 – 0.89</td>
<td>High</td>
</tr>
<tr>
<td>0.90 – 1.00</td>
<td>Very high</td>
</tr>
</tbody>
</table>

**Validity**

Articles that investigated the validity of the MAS have used two main methods; comparing MAS scores with objective measures of spasticity and testing the sensitivity of the MAS to detect changes after treatment. The results described in the following section can be found in more details in table 6.

Katz *et al* (1992) correlated MAS scores with four measures, which are considered as objective measures of spasticity throughout literature. For the upper extremity all correlations found were in the range of high to very high, for the lower extremity correlation was only moderate. This research supports the validity of the MAS in the upper extremity but not in the lower extremity. Allison and Abraham (1995) correlated the MAS with 4 objective measures of spasticity, all correlations were found low, thus not supporting the validity of the MAS. Skold *et al* (1998) support the validity of the MAS with 80% correlation between the MAS and EMG recordings. Boyd *et al* (1998) investigated the validity of the MAS by assessing its sensitivity to detect changes resulting after treatment for spasticity. Using a group of placebo to compare the outcomes, no significant difference between the groups was found (p=0.14). Allison and Abraham (2001) used pre and post treatment comparison to detect sensitivity to change in spasticity levels and supported the validity of the MAS with a significant difference of p<0.001. Pandyan *et al* carried out two researches within 3 years and compared MAS scores with resistance to passive movement (RTPM), passive range of motion (PROM) and speed. They demonstrated different results for different MAS grades. In 2001 they found that RTPM was significantly higher in MAS grade 1+ compared to grade 0 and 1, but no significant difference in RTPM between grade 0 and 1, the correlation between MAS and RTPM was low. Speed and PROM were significantly higher in grade 0 compared to grades 1 and 1+, but not significant between grades 1 and 1+. In 2003, their research demonstrated similar results; RTPM was found significantly different between grade 0 and higher grades (higher in grades 1 and 3 compared to grade 0). However, no significant difference was found between grades 1, 1+ and 2. The correlation between
RTPM and the MAS was moderate. Bakheit et al (2003) tried to establish a correlation between MAS scores and the excitability of alpha motor neurons by dividing their subjects into two groups according to MAS scores and taking EMG recordings. No significant difference between the groups was found.

Reliability
The results of the reliability described in the following section are divided into two parts: The first part presents with results of inter-rater reliability, the second part presents with results of intra-rater reliability.
For additional information regarding each research, refer to table 7, which is designed to provide the reader with detailed description of each article; purpose, subjects information, study details and results.

Inter-rater reliability
Eight studies have investigated the inter-rater reliability:
Bohannon and Smith (1987) compared the results of 2 examiners when investigating the elbow flexors of multiple sclerosis and head injury patients and found the Kendall tau correlation to be high. Sloan et al (1992) compared the results of 4 examiners when investigated 3 different muscle groups in stroke and head injury patients using a Spearman’s coefficient. In addition to the usual method of testing they added a special feature of reinforcement, consequently they present with a total of 6 results. The elbow extensors mean correlation presented moderate reliability, reinforcement demonstrated slightly higher results and was high. The elbow flexors mean correlation with or without reinforcement was high. The knee extensors demonstrated low results (with and without reinforcement). Allison et al (1996) investigated the reliability of the plantar flexors in traumatic brain injury patients comparing 2 examiners, they calculated 3 types of correlations, but used the Spearman’s coefficient to present their hypothesis, therefore we chose to present these results, which demonstrated a high correlation. Gregson et al (1999) investigated the elbow flexors of stroke patients comparing 2 examiners and presented their results with a moderate Kappa and a high weighted-kappa. One year later, Gregson et al (2000) investigated the elbow flexors again, but also the wrist, knee and ankle plantar flexors of acute stroke patients, again comparing the results of 2 examiners. The elbow flexors demonstrated a moderate kappa and a high weighted kappa, the wrist flexors and the knee flexors demonstrated a low kappa and a high weighted kappa, and finally the plantar flexors demonstrated with very low results; a little if any correlation using the kappa and a low correlation using the weighted kappa. Blackburn et al (2002) investigated 3 muscle groups of stroke patients comparing results of 2 examiners using a Kendall’s tau-b coefficient. The Gastrocnemius and the Soleus both demonstrated little if any correlation and the Quadriceps demonstrated with a low correlation. Smith et al (2002) compared 3 examiners when investigating the knee extensors of spinal cord injury patient with an ICC and found the correlation to be little if any. Fosang et al (2003) investigated the reliability of 3 muscle groups of children with CP, using ICC correlations to compare the results of 6 examiners. The hamstrings and calf muscles showed a low correlation and the adductors showed a moderate correlation.

For an easier outlook and better understanding of the presented results, table 4 provides with a summary divided according to muscle groups. When combining
the results obtained by all articles a clear result is found regarding the inter-rater reliability of the MAS in the different muscle groups: The elbow flexors and extensors range between moderate and high correlations, the hip adductors demonstrate only moderate correlation, the wrist flexors, knee extensors and Hamstrings are found low. The plantar flexors vary between little if any correlation to high, however the high correlation was found only by one article (Allison et al., 1996).

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Authors</th>
<th>Inter-rater reliability</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexors</td>
<td>Gregson et al, 2000.</td>
<td>0.51 Moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gregson et al, 1999.</td>
<td>0.66 Moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sloan et al, 1992.</td>
<td>0.73 High (+R)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bohannon and Smith, 1987.</td>
<td>0.85 High</td>
<td></td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>Sloan et al, 1992.</td>
<td>0.67 Moderate (+R)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.70 (+R) High (+R)</td>
<td></td>
</tr>
<tr>
<td>Hip Adductors</td>
<td>Sloan et al, 1992.</td>
<td>0.55 Moderate</td>
<td></td>
</tr>
<tr>
<td>Wrist flexors</td>
<td>Gregson et al, 2000.</td>
<td>0.47 Low</td>
<td></td>
</tr>
<tr>
<td>Knee extensors</td>
<td>Sloan et al, 1992.</td>
<td>0.45 Low (+R)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blackburn et al, 2002.</td>
<td>0.29 Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Smith et al, 2002.</td>
<td>0.23 Little if any</td>
<td></td>
</tr>
<tr>
<td>Hamstrings</td>
<td>Fosang et al, 2003.</td>
<td>0.43 Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gregson et al, 2000.</td>
<td>0.29 Low</td>
<td></td>
</tr>
<tr>
<td>Plantar flexors</td>
<td>Allison et al, 1996.</td>
<td>0.73 High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fosang et al, 2003.</td>
<td>0.36 Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blackburn et al, 2002.</td>
<td>0.18 Little if any</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gregson et al, 2000.</td>
<td>0.08 Little if any</td>
<td></td>
</tr>
</tbody>
</table>

*+R= with reinforcement*

**Intra-rater reliability**

Of the eight articles presented under the section of inter-rater reliability, 5 investigated the intra-rater reliability as well, details regarding the number of examiners and pathology of the patients, which were already mentioned under the previous section, are not mentioned again under the following section: Allison et al. (1996) found a Spearman’s correlation ranging between moderate and high for the plantar flexors. Gregson et al. (1999) found in the elbow flexors a mean correlation of a low kappa and a high weighted kappa. In the study they conducted one year later Gregson et al. (2000) found for the elbow flexors a kappa ranging between low and moderate and a high weighted kappa. For the wrist flexors, a low kappa and a high weighted kappa and for the knee flexors a kappa ranging between low and moderate and a weighted kappa ranging between high to very high. Finally, the plantar flexors demonstrated a kappa ranging between little if any correlation and low, and a moderate weighted kappa.

Blackburn et al. (2002) found a Kendall’s tau-b low correlation for the Gastrocnemius and a moderate correlation for the Soleus and Quadriceps. Fosang et al. (2003) found for the Hamstrings and Adductors ICC correlations ranging between moderate and high, for the calf muscles the correlations ranged between little if any and high.

As in the previous section, table 5 provide with a summary of the intra-rater reliability divided according to muscle groups. The elbow flexors demonstrates
low-moderate correlations, the wrist flexors demonstrate low correlations, the knee extensors show a moderate correlation, the correlation in the hamstrings ranges between low to moderate and moderate to high, the hip adductors demonstrate a moderate to high correlation, the plantar flexors range from little if any to low, little if any to high, low to moderate and moderate to high.

Table 5: Intra-rater reliability of the MAS divided into muscle groups

<table>
<thead>
<tr>
<th>Muscle Groups</th>
<th>Authors</th>
<th>Intra-rater reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexors</td>
<td>Gregson et al, 1999.</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Gregson et al, 2000.</td>
<td>0.39-0.53</td>
</tr>
<tr>
<td>Wrist flexors</td>
<td>Gregson et al, 2000.</td>
<td>0.35-0.48</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>Blackburn et al, 2002.</td>
<td>0.66</td>
</tr>
<tr>
<td>Hamstrings</td>
<td>Gregson et al, 2000.</td>
<td>0.27-0.54</td>
</tr>
<tr>
<td></td>
<td>Fosang et al, 2003.</td>
<td>0.66-0.80</td>
</tr>
<tr>
<td>Hip Adductors</td>
<td>Fosang et al, 2003.</td>
<td>0.59-0.72</td>
</tr>
<tr>
<td>Plantar flexors</td>
<td>Gregson et al, 2000.</td>
<td>0.17-0.34</td>
</tr>
<tr>
<td></td>
<td>Fosang et al, 2003.</td>
<td>0.21-0.70</td>
</tr>
<tr>
<td></td>
<td>Blackburn et al, 2002.</td>
<td>0.44-0.59</td>
</tr>
<tr>
<td></td>
<td>Allison et al, 1996.</td>
<td>0.55-0.74</td>
</tr>
</tbody>
</table>

DISCUSSION

Before commencing with a discussion of the results obtained, a brief outline of the characteristics of a measurement tool is provided, and provides the reader with sufficient knowledge for understanding the importance of these characteristics.

Characteristics of measurement tools
A measurement tool must demonstrate validity, reliability, standardization and responsiveness to the obtained results to possess a scientific or objective value. The aforementioned criteria are defined below and provide the reader with sufficient knowledge to ensure adequate understanding of the discussion.

Validity
A test is considered valid if it measures accurately what it aims to measure. There are 3 core types of validity (Wade 1992, Streiner and Norman 1993 cited: Stokes 1998):

1. Construct validity – the extent to which the obtained results using an outcome measure concur with the results predicted from the underlying theoretical knowledge.
2. Content validity – items included in a measure and their validation consists of judgment by experts on whether the items appear appropriate for the intended use.
3. Criteria validity - concerned with external validity or comparison of findings of a new outcome measure with that of an alternative established standardized tool or gold standard.

Reliability
1. Intrarater reliability- the degree to which someone can repeat the measurements he or she has obtained.
Table 6: Validity – Summary of reviewed articles details

<table>
<thead>
<tr>
<th>Authors</th>
<th>Purpose</th>
<th>Correlated measurements</th>
<th>Subjects</th>
<th>Study details</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Katz et al 1992</td>
<td>To develop a reliable and objective technique for quantifying spastic</td>
<td>• MAS</td>
<td>• Number: 10</td>
<td><strong>Method</strong></td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>hypertonia.</td>
<td>• Fugl-Meyer (FM) scale</td>
<td>• Pathology: CVA</td>
<td>• Randomized sequence of tests</td>
<td>P*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pendulum test (PT)</td>
<td>• Mean age: (range: 28-68)</td>
<td>• Procedure of test fully described:</td>
<td>p</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• H-reflex studies</td>
<td>• Mean duration since injury: Not specified</td>
<td>• Test position: Supine</td>
<td>P value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ramp and hold (R&amp;H)</td>
<td>• Inclusion criteria:</td>
<td>• Duration of movement: <strong>not specified</strong></td>
<td>P*</td>
</tr>
<tr>
<td>Allison and</td>
<td>To explore the relationship between the MAS and several objective</td>
<td>• MAS</td>
<td>• Study details</td>
<td><strong>Examiners</strong></td>
<td></td>
</tr>
<tr>
<td>Abraham 1995</td>
<td>quantitative tests in the assessment of plantar flexor spasticity in</td>
<td>• MAS</td>
<td>• Number: 1</td>
<td>• Number: 1</td>
<td></td>
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<tr>
<td></td>
<td>patient with traumatic brain injury (TBI)</td>
<td>• Electrical stimulation</td>
<td>• Blinding: <strong>Not specified</strong></td>
<td><strong>Examiners</strong></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>and EMG recordings to</td>
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<td>• Test repetition: <strong>not specified</strong></td>
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<td>measure:</td>
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<td>• Hvib/Hctrl</td>
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<td>• RTA</td>
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<td>• TTT</td>
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<td></td>
<td></td>
<td>• Mean age: 30.32 (±10.81)</td>
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<td></td>
<td></td>
<td>• Mean duration since</td>
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<td></td>
<td></td>
<td>injury: 3.8 years</td>
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<td>• Inclusion criteria:</td>
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<td></td>
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<td>• Age 18 or above</td>
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<td>• 6 months and above</td>
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<td>post TBI</td>
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<td></td>
<td></td>
<td>• Medically stable</td>
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<td></td>
<td></td>
<td>• Sufficient mobility</td>
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<td>at the ankle joint (0°</td>
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<td>dorsiflexion to 40°</td>
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<td>plantarflexion)</td>
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<td>• Rancho Los Amigos</td>
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<td>cognitive score 7 and</td>
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<td>above</td>
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<td></td>
<td></td>
<td>• Informed consent</td>
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</tbody>
</table>

* P : Pearson’s coefficient

\[
P* = 0.43, \quad P < 0.001
\]

\[
P* = 0.39, \quad P = 0.002
\]

\[
P* = 0.49, \quad P < 0.001
\]

\[
P* = 0.42, \quad P = 0.001
\]

* Sρ : Spearman’s ρ coefficient
<table>
<thead>
<tr>
<th>Authors</th>
<th>Purpose</th>
<th>Correlated measurements</th>
<th>Subjects</th>
<th>Study details</th>
<th>Results</th>
</tr>
</thead>
</table>
| Skold et al 1998 | To investigate whether the MAS is a valid measure of spasticity at the knee joint in flexion and extension for motor complete tetraplegic spinal cord injured (SCI) patients. | • MAS  
• EMG           | • Number: 15  
• Pathology: SCI  
• Mean age: 33 (range: 21-48)  
• Mean duration since injury: 9 years (range: 1-21)  
• Inclusion criteria:  
  - Healthy male  
  - Cervical injury C4 – C8  
  - ASIA grade A or B  
  - At least 1 year post injury | Method  
• Simultaneous MAS testing and EMG recordings  
• Procedure of test fully described: YES  
• MAS:  
• Test position: Supine  
• Duration of movement: 1 second  
• Test repetition: 1  
Examiners  
• Number: 2 (MAS – 1, EMG – 1)  
• Blinding: YES | • Significant correlation between MAS and EMG recordings: 80%, p<0.05 |
| Boyd et al 1998 | To examine the validity of an adapted version of Tardieu's method of spasticity measurements and the Ashworth scale | • Sensitivity of the MAS: Assessing ability to measure changes in spasticity before and after spasticity management | • Number: 16  
• Pathology: Cerebral Palsy (CP)  
• Mean age: 4,6  
• Mean duration since injury: Not specified  
• Inclusion criteria: Not specified | Method  
• The MAS was tested before and after spasticity management in a treatment group and a placebo group.  
• Procedure of test fully described: Yes  
• MAS:  
• Test position: Supine  
• Duration of movement: Not specified  
• Test repetition: Not specified  
Examiners  
• Number: 1  
• Blinding: Yes | Differences between the groups (spasticity treatment and placebo) were compared using the Mann-Whitney test:  
• No significant difference was found, p=0.14 |
<table>
<thead>
<tr>
<th>Authors</th>
<th>Purpose</th>
<th>Correlated measurements</th>
<th>Subjects</th>
<th>Study details</th>
<th>Results</th>
</tr>
</thead>
</table>
| Allison and Abraham 2001 | To detect how far a battery of tests could detect a reduction of plantarflexor spasticity resulting from cryotherapy | • Sensitivity of the MAS: Assessing ability to measure changes in spasticity before and after spasticity management | • Number: 26  
• Pathology: TBI  
• Mean age: 28.15  
• Mean duration since injury: Not specified  
• Inclusion criteria:  
  - Age 18 or above  
  - 6 months and above post TBI  
  - Medically stable  
  - Sufficient mobility at the ankle joint (0° dorsiflexion to 40° plantarflexion)  
  - Ability to follow instructions  
  - Rancho Los Amigos cognitive score 7 and above  
  - Absence of Raynaud's syndrome, peripheral vascular disease and pregnancy.  
  - Informed consent | **Method**  
• The MAS was tested before and after spasticity management  
• Procedure of test fully described: Yes  
• Test position: Sitting  
• Duration of movement: Not specified  
• Test repetition: 5-8 times  
**Examiners**  
• Number: 1  
• Blinding: Not specified | Differences in MAS scores before and after cryotherapy treatment were compared using a Wilcoxon signed-ranks test (alpha level 0.10):  
• Significant difference was found, p<0.001 |
| Pandyan et al. 2001 | To develop a biomechanical non-invasive measure of Resistance To Passive Movement (RTPM).  
Examine validity and reliability of the MAS at the elbow joint. | • MAS  
• Biomechanical device recording Resistance To Passive Movement (RTPM) passive ROM (PROM) and speed: Force transducer and electronic goniometer | • Number: 16  
• Pathology: Stroke  
• Mean age: 67.3 (range: 54-84)  
• Duration since injury: 1 week  
• Inclusion criteria:  
  - Able to comply with study protocol  
  - No previous history of orthopedic problems  
  - Informed consent | **Method**  
• Simultaneous MAS testing and Biomechanical recordings  
• Procedure of test fully described: YES  
• Test position: Not specified  
• Duration of movement: Not specified  
• Test repetition: 3 times  
**Examiners**  
• Number: 1  
• Blinding: YES (to biomechanical) | Differences between MAS and RTPM:  
• RTPM significantly higher in grade 1+ compared to grades 0 and 1 (p<0.05)  
• RTPM not significantly different between grades 0 and 1 (p>0.1).  
• Cohen's kappa correlation: 0.366, poor  
Differences between MAS and Speed:  
• Speed significantly higher in MAS grade 0 than in grades 1 and 1+ (p<0.05).  
• Speed not significantly different between MAS grades1 and 1+  
Differences between MAS and PROM:  
• PROM significantly greater in MAS grade 0 than in grades 1 and 1+ (p<0.05).  
• PROM not significantly different between MAS grades1 and 1+ |
<table>
<thead>
<tr>
<th>Authors</th>
<th>Purpose</th>
<th>Correlated measurements</th>
<th>Subjects</th>
<th>Study details</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pandyan et al</td>
<td>To investigate biomechanically the validity of the MAS at the elbow joint.</td>
<td>MAS</td>
<td>Number: 63</td>
<td><strong>Method</strong></td>
<td>Differences between MAS and RTPM:</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>Biomechanical device recording Resistance To Passive Movement (RTPM): Force transducer and electronic goniometer</td>
<td>Pathology: Stroke</td>
<td>• Simultaneous MAS recordings and Biomechanical recordings</td>
<td>• RTPM significantly different between MAS grade 0 and higher MAS grades. (p&lt;0.01)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean age: Not specified</td>
<td>• Procedure of test fully described: YES MAS:</td>
<td>• RTPM significantly higher in MAS grades 1 and 3 than in MAS grade 0 (p&lt;0.05)</td>
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<tr>
<td></td>
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<td></td>
<td>Mean duration since injury: &lt;26 weeks)</td>
<td>• Test position: Supine</td>
<td>• No significant difference between MAS grades 1, 1+ and 2.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inclusion criteria:</td>
<td>• Duration of movement: 1 second</td>
<td>• Spearman's Correlation: 0.511, moderate</td>
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<td>• First stroke less than 26 weeks previously</td>
<td>• Test repetition: 5-8 times</td>
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<td></td>
<td>• Unilateral clinical signs</td>
<td><strong>Examiners</strong></td>
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<td></td>
<td>• No previous upper limb impairment</td>
<td>• Number: 1</td>
<td>alli <strong>specified</strong></td>
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<td></td>
<td></td>
<td></td>
<td>• Able to understand the study information</td>
<td>• Blinding: YES</td>
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<td></td>
<td>• Informed consent</td>
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<tr>
<td>Bakheit et al</td>
<td>To establish a correlation between MAS and excitability of alpha motor neuron at the ankle joint.</td>
<td>MAS</td>
<td>Number: 25</td>
<td><strong>Method</strong></td>
<td>Two groups was formed according to MAS grades (group A: MAS 1, group B: MAS 2), differences between the groups were calculated using the EMG recordings by a t-test</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>Neuromapper EMG recordings to measure:</td>
<td>Pathology: Stroke</td>
<td>• The MAS was tested first followed by EMG recordings</td>
<td>• H-reflex:</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Mean age:</td>
<td>• Procedure of test fully described: YES</td>
<td>• No significant differences between the groups, p=0.2</td>
</tr>
<tr>
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<td></td>
<td>- Group A – 62.4 (range: 46-72)</td>
<td>• Test position:</td>
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<td>- Group B – 59.1 (range: 46-81)</td>
<td>- MAS – Supine</td>
<td>H/M ratio:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Mean duration since injury:</td>
<td>- EMG – Prone</td>
<td>No significant differences between the groups, p=0.7</td>
</tr>
<tr>
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<td></td>
<td>- Group A – 17.2 months</td>
<td>• Duration of movement: <strong>Not specified</strong></td>
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<td></td>
<td>- Group B – 10.2 months</td>
<td>• Test repetition: <strong>Not specified</strong></td>
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<td>Inclusion criteria:</td>
<td><strong>Examiners</strong></td>
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<td></td>
<td></td>
<td></td>
<td>• Detectable increase in muscle tone</td>
<td>• Number: 1</td>
<td></td>
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<td></td>
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<td></td>
<td>• Not receiving anti-spastic drugs</td>
<td>• Blinding: <strong>Not specified</strong></td>
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<td></td>
<td></td>
<td></td>
<td>• Exclusion criteria:</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Fixed muscle contractures at the ankle joint</td>
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<tr>
<td>Author</td>
<td>Purpose</td>
<td>Subjects</td>
<td>Study details</td>
<td>Tested muscles</td>
<td>Results</td>
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</tbody>
</table>
| Bohannon and Smith 1987 | To determine the inter-rater reliability of a manual test of elbow flexors using a Modified Ashworth Scale (MAS). | • Number: 30  
• Pathology:  
  - Multiple sclerosis (n=1)  
  - Closed head injury (n=5)  
  - CVA (n=24)  
• Mean age: 59.3 (±17.6)  
• Mean duration since injury: Not specified  
• Inclusion criteria:  
  - Able to follow instructions adequately  
  - Informed consent | Method  
• Procedure of test fully described: YES  
• Test position: Supine  
• Duration of movement: 1 second  
• Test repetition: 5-8 times  
Examiners  
• Number: 2  
• Blinding: YES  
• Application of training prior to study: YES | Elbow flexors | Elbow extensors  
+ Reinforcement  
- Elbow flexors  
- Knee extensors | %*  
Kτ**  
* Inter-rater  
86.7  
0.85 |
| Sloan et al 1992 | To test the inter-rater reliability of the MAS at the upper and lower limbs of spastic hemiplegic patients. | • Number: 34  
• Pathology:  
  - Stroke (n=31)  
  - Head injury (n=3)  
• Mean age: 57.8 (±17.8)  
• Mean duration since injury: Not specified  
• Inclusion criteria:  
  - Informed consent | Method  
• Procedure of test fully described: YES  
• Test position:  
  - Elbow: Supine  
  - Knee: Prone  
• Duration of movement: 1 second  
• Test repetition: 4 times  
Examiners  
• Number: 4  
• Blinding: YES  
• Application of training prior to study: YES | Elbow flexors  
Elbow extensors  
Knee extensors | *Inter-rater  
Sp*  
Mean  
| Elbow extensors | 0.56-0.76  
0.67  
+ Reinforcement | 0.63-0.85  
0.70 |
|                   | - Elbow flexors | 0.62-0.90  
0.73 |  
+ Reinforcement | 0.63-0.85  
0.74 |  
- Knee extendors | 0.26-0.62  
0.45 |  
+ Reinforcement | 0.32-0.52  
0.45 |  

* % : Percentage agreement  
**Kτ : Kendall's tau coefficient  
* Sp : Spearman's ρ coefficient
<table>
<thead>
<tr>
<th>Author</th>
<th>Purpose</th>
<th>Subjects</th>
<th>Study details</th>
<th>Tested muscles</th>
<th>Results</th>
</tr>
</thead>
</table>
| Allison et al 1996 | To examine the *inter-rater, intra-rater* and temporal reliability of the MAS at the plantar flexors muscles of patients with traumatic brain injury (TBI). | • Number: 30  
• Pathology: TBI  
• Mean age: 28.3 (±10.8)  
• Mean duration since injury: 56 months (±48.4)  
• Inclusion criteria:  
  - Age 18 or older  
  - History of TBI at least 6 months prior to testing  
  - Adequate ROM at ankle (0° dorsiflexion to 40° plantarflexion)  
  - Ability to follow instructions  
  - Rancho Los Amigos cognitive score of 7 or 8  
  - Informed consent | **Method**  
• Procedure of test fully described: YES  
• Specific training prior to study: YES  
• Test position: Sitting  
• Duration of movement: ½ second  
• Test repetition: 5-8 times  
**Examiners**  
• Number: 2  
• Blinding: YES  
• Application of training prior to study: YES | Plantar flexors | %  | $S_p$  | $C_\kappa$  | $K_\tau b$  |
|                 |                                                                          |                                                                          |                                                                               |                | Inter-rater  | 55  | 0.73  | 0.40  | 0.65  |
|                 |                                                                          |                                                                          |                                                                               |                | Intra-rater  | 53  | 0.74  | 0.69  | 0.67  |
|                 |                                                                          |                                                                          |                                                                               |                | 58  | 0.82  | 0.42  | 0.740  |
| Gregson et al 1999 | To re-evaluate the *inter-rater and intra-rater* reliability of the TAS (Tone Assessment Scale) and MAS at the elbow using an adequate sample size and a standardized procedure. To compare the potential usefulness of the TAS and the MAS as clinical research and assessment tools. | • Number: 32  
• Pathology:  
  - Ischemic stroke (n=27)  
  - Hemorrhagic stroke (n=5)  
• Mean age: 74 (69-80)  
• Mean duration since injury: Not specified  
• Inclusion criteria:  
  - CT diagnosis of stroke  
  - Informed consent  
• Exclusion criteria:  
  - Prescription of tone-modifying drugs  
  - Inability to comply with the conditions of the standardized guideline | **Method**  
• Procedure of test fully described: YES  
• Test position: Supine  
• Duration of movement: 1 second  
• Test repetition: 4 times  
(Average of grades was determined)  
**Examiners**  
• Number: 2  
• Blinding: YES  
• Application of training prior to study: YES | Elbow flexors | $\kappa^*$  | $\kappa^w$  ** |                            |                | Inter-rater  | 0.66  | 0.84  |
|                 |                                                                          |                                                                          |                                                                               |                | Intra-rater  | 0.32  | 0.83  |

---

* % : Percentage agreement  
** $S_p$ : Spearman’s $\rho$ coefficient  
$C_\kappa$ : Cohen’s $\kappa$ coefficient  
$K_\tau b$ : Kendall’s tau-b coefficient  

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** $\kappa^w$ : Weighted quadratic kappa
<table>
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<th>Study details</th>
<th>Tested muscles</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregson et al. 2000.</td>
<td>To assess the inter-rater and intra-rater reliability of the MAS on the elbow, wrist, knee flexors and ankle plantar flexors and of the MRC scale when applied to the same muscles and their antagonists.</td>
<td>Number: 35&lt;br&gt;Pathology: Acute stroke&lt;br&gt;Mean age: 73 (65-80)&lt;br&gt;Mean duration since injury: 40 days (range: 19-78)&lt;br&gt;Inclusion criteria: - Acute stroke - Informed consent</td>
<td>Method&lt;br&gt;Procedure of test fully described: YES&lt;br&gt;Test position: Sitting&lt;br&gt;Duration of movement: 1 second&lt;br&gt;Test repetition: 3 times (Lowest score was chosen)&lt;br&gt;Examiners&lt;br&gt;Number: 2&lt;br&gt;Blinding: YES&lt;br&gt;Application of training prior to study: YES (standardized procedure)</td>
<td>Elbow flexors&lt;br&gt;Wrist flexors&lt;br&gt;Knee flexors&lt;br&gt;Plantar flexors</td>
<td><strong>κ</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
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<td>- Elbow flexors&lt;br&gt;- Wrist flexors&lt;br&gt;- Knee flexors&lt;br&gt;- Plantar flexors</td>
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<td>0.39-0.53&lt;br&gt;0.77-0.83</td>
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<td>0.35-0.48&lt;br&gt;0.80-0.88</td>
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<td>0.27-0.54&lt;br&gt;0.77-0.94</td>
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<td>42.5</td>
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<td>57.5</td>
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<td>85</td>
</tr>
<tr>
<td>Blackburn et al. 2002</td>
<td>To examine the inter-rater and intra-rater reliability of the MAS at the lower limbs of stroke patients using a standardized procedure</td>
<td>Number: 36&lt;br&gt;Pathology: Stroke&lt;br&gt;Mean age: 76.1 (± 7.89)&lt;br&gt;Mean duration since injury: Not specified&lt;br&gt;Inclusion criteria: - Diagnosis of stroke - Reside within 25 km of the ward - Referred to Physiotherapy - Informed consent&lt;br&gt;Exclusion criteria: - Musculoskeletal conditions that prevent testing - Not able to follow simple instructions</td>
<td>Method&lt;br&gt;Procedure of test fully described: YES&lt;br&gt;Test position: Side lying&lt;br&gt;Duration of movement: 1 second&lt;br&gt;Test repetition: 3 times&lt;br&gt;Examiners&lt;br&gt;Number: 2&lt;br&gt;Blinding: YES&lt;br&gt;Application of training prior to study: YES (standardized procedure)</td>
<td>Gastrocnemius&lt;br&gt;Soleus&lt;br&gt;Quadriceps</td>
<td>Gastrocnemius&lt;br&gt;Soleus&lt;br&gt;Quadriceps</td>
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<tr>
<td></td>
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<td>85</td>
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* κ : Kappa<br>** κ<sub>w</sub> : Weighted quadratic kappa<br>% : Percentage agreement<br>**κ<sub>r</sub> : Kendall's tau coefficient
<table>
<thead>
<tr>
<th>Author</th>
<th>Purpose</th>
<th>Subjects</th>
<th>Study details</th>
<th>Tested muscles</th>
<th>Results</th>
</tr>
</thead>
</table>
| Smith et al. 2002 | To develop a new form of the MAS; A combination with velocity (V-MAS) and to compare the inter-rater reliability of both tools. | • Number: 22  
• Pathology: Spinal cord injury  
• Mean age: 33.4 (±12.5)  
• Mean duration since injury: 29.8 months (±43.2)  
• Inclusion criteria:  
  - Informed consent  
  - Muscle strength > grade 3 at the knee extensors  
  - Hip or knee joints abnormalities or trauma  
  - Contractures  
  - External fixation devices  
  - Peripheral neuropathy in lower extremities  
Method  
• Procedure of test fully described: YES  
• Test position: Prone  
• Duration of movement: Not predetermined  
• Test repetition: 3 times (Grade was taken from the 3rd repetition)  
Examiners  
• Number: 3  
• Blinding: Not specified  
• Application of training prior to study: NO  
Inter-rater  
<table>
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<tr>
<th>Knee extensors</th>
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<th><strong>K</strong></th>
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<tr>
<td>- All 3 Raters</td>
<td>--</td>
<td>0.23</td>
</tr>
<tr>
<td>- Rater A vs. Rater B</td>
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</tr>
<tr>
<td>- Rater A vs. Rater C</td>
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<td>0.35</td>
</tr>
<tr>
<td>- Rater B vs. Rater C</td>
<td>32</td>
<td>0.14</td>
</tr>
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</table>

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* % : Percentage agreement  
**K : Kappa  

| Fosang et al 2003 | To investigate the inter-rater and intra-rater reliability of: PROM (Passive Range Of Motion), MAS and MTS (Modified Tardieu Scale) in the lower limbs of children with Cerebral Palsy (CP). To investigate measurement errors of the PROM and MTS. | • Number: 18  
• Pathology: Cerebral Palsy  
• Mean age: 6.4 years (2-10)  
• Mean duration since injury: Not specified  
• Inclusion criteria:  
  - Confirmed diagnosis of CP  
  - Informed consent  
• Exclusion criteria:  
  - Severe fixed contractures  
  - Orthopedic surgery 12 months prior to study  
  - Lower limb botulinum toxin injections/inhibitory plasters 6 months prior to study  
  - Pharmacological managements for spasticity  
Method  
• Procedure of test fully described: YES  
• Test position: Supine  
• Duration of movement: 1 second  
• Test repetition: 3 times (Average of grades was determined)  
Examiners  
• Number of examiners: 6  
• Blinding: YES  
• Application of training prior to study: YES  
Hamstring  
Calf  
Adductors  
Inter-rater  
Intra-rater  
ICC *  
Mean  
<p>| | | | | | |</p>
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<tr>
<td>- Hamstring</td>
<td>0.37-0.48</td>
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<td>0.59-0.72</td>
<td>0.66</td>
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*ICC: Intraclass correlation coefficients
2. Interrater reliability - the degree to which more than one rater obtains measures that match within the same subject.

Standardization is essential for good reliability. A standardized measure should have a manual with explicit instructions for both administering and scoring the measure, so that all assessors use the measure in precisely the same manner.

Responsiveness
Sensitivity of the measurement tool to detect changes.
It can be determined by the intrarater reliability and by the ability to detect actual changes, which occur in a subject over time (Kirschner and Guyatt 1985 cited: Stokes 1998).

Validity
Construct and content validity
The MAS describes the resistance perceived by the examiner when moving a limb through its full ROM, expect for grade 4 in which no movement is possible and the limb is rigid. When looking at the scale one could assume it implies the following:
- Change in the resistance to passive movement is exclusively due to changes in spasticity.
- The response of the muscle to the stretch will be the same during repeated movements.
- Range of movement is unaltered (with the exception of grade 4).
- The velocity in which the movement is performed does not influence the grade.
- Grade 4 imply that the limb is rigid rather than spastic.
- Movements are only performed in flexion and extension.

The authors of this review suggest that the scale should be used with caution as the assumptions stated above are flawed:
Evidence suggest that the resistance to passive movement is not an exclusive measure of spasticity (Pandyan et al, 1999), examining the scale carefully reveals that only grades 1 and 1+ include a clear definition of spasticity, since they contain a ‘catch”, which is a main characteristic of spasticity. The problem lies in the higher grades 2, 3 and 4 that define spasticity with increasing resistance, which could also be a result of viscous-elastic components (e.g. contractures). The scale does not imply a limit of how many movements should be done on one muscle group and therefore, many authors appear to use repeated cycles of passive stretching and make an average of the different grades given, take the lowest grade given or choose the grade of the last movement. It is important to realize that spasticity will decrease with repeated cycles of movement. The assumption that the available ROM is unaltered is disregarding the fact that many patients with spasticity have a limited range of motion. In some of the grades the direction of the movement implies that only flexion and extension are used. By this, a movement such as abduction (e.g. to test the spasticity of hip adductors) is eliminated.
**Level of measurement**

In their review, Pandyan *et al.* (1999) state that it is important to consider what is the level of measure a scale can achieve. Given that the MAS is a subjective measure, the options of ratio and interval levels are excluded. The uncertainty appears to be between the nominal and ordinal levels, and although most researches consider the scale as ordinal, Pandyan *et al.* (1999) believe that by introducing an additional level of measurement (1+), Bohannon and Smith introduced an ambiguity to the scale due to; first, the assumption that the conditions “catch and release” and “minimal resistance at the end of the ROM” are equal since both definitions are graded the same. This assumption is not supported with evidence in literature. Second, the fact that there is no clear clinical or biomechanical definition for the term “catch and release”. We can only assume that the catch and release described in grade 1 represent a lower spastic level than the catch followed by minimal resistance described in grade 1+.

Knowing the level of measurement is important in order to determine the type of statistical analysis used to achieve uniform results. The existing confusion around the MAS is represented through the variety of correlation techniques given in the retrieved articles.

**Criteria validity**

The results of eight articles that examined the validity of the MAS were presented previously. Of these articles, 3 supported the validity, 3 rejected it and 2 have found conflicting results suggesting the scale is valid only for some of its grades but not the others. The first impression observed from the results is that the validity of the MAS is highly controversial.

While Katz *et al.* (1992) supported the validity of the MAS in their research, Pandyan *et al.* (1999) state in their review that in a later study performed by Katz and Rymer it was reported that the resistance to passive movement could be related to changes in the viscous-elastic components of the joint and soft tissue than to spasticity. Bakheit *et al.* (2003) supported this assumption by stating that hypertonia in patients with upper motor neuron lesions results from a combination of spasticity, thixotrophy and changes in the viscous-elastic properties.

In addition, in the article by Katz *et al.* (1992) the duration of the movement, number of repetitions for each movement and whether the examiners were blinded to the results were not specified. Without this information it is impossible to accept their results to answer the research question.

In a research carried out by Bakheit *et al.* (2003) it was concluded that although no statistically significant differences were found between the groups, some EMG measures were higher in group B (MAS 2) compared to group A (MAS 1), suggesting that there is a relation between MAS scores and excitability of alpha motor neuron activity but since the relationship is not linear this suggests that the MAS measures hypertonia rather than spasticity. Again, these results are not acceptable since the same information is lacking as in the article by Katz *et al.* Skold *et al.* (1998) also compared the MAS with EMG recordings and were criticized regarding their method in the review by Pandyan *et al.* (1999). The review claims that although good correlation was found between the MAS and EMG recordings, it is not possible to draw support for the validity of the scale as a measure of spasticity, because of one methodological inconsistency: the actual time to grade
spasticity using the MAS was less than a second while many of the EMG parameters were purely referenced to the same time window and were taken over a period of 7.5 seconds.

Pandyan et al (2001) found in their research that measures of Speed and PROM are not significantly different between grade 1 and 1+. In a later study (2003) they found that RTPM is not significantly different between grade 1, 1+ and 2. These results have led them to the conclusion that the MAS could not be used as a 6-point scale, but could be considered as a valid tool if grades 1, 1+ and 2 will be grouped. In both researches correlations between RTPM were not acceptable (i.e. low and moderate), Pandyan et al state that the low correlations could be due to the poor validity and reliability of the MAS at the lower end of the scale.

One important factor in the method used in both articles that could support the outcome of these studies, is the use of subjects in the early phase after the stroke. This eliminates the possibility for changes in soft tissue and could support their results, since it is more likely that the movement measures spasticity and not other factors of increased muscle tone.

For a measurement tool to be valid it also needs to be able to be sensitive to detect changes following therapy. Two articles have examined this ability and found contrary results (Boyd et al 1998, Allison and Abraham 2001). It is difficult to find the cause for these conflicting results, because in both researches the duration of the movement was not specified, Boyd et al (1998) did not specify the number of repetitions used and Allison and Abraham (2001) did not specify whether the examiner was blinded to the EMG parameters. When these points are not mentioned in the articles it is impossible to compare the method used and therefore difficult to critically examine the results. The authors of this review find these points and especially the duration of movement very important in validation whether the MAS as a measure of spasticity and for this reason do not consider the results of these researches as absolute.

**Reliability**

As stated previously the results were interpreted according to Munro (1986). The authors of this review believe that for a measurement tool to be acceptable and used it should present with high correlations for the reliability. Results beneath 0.69 are therefore not considered to be adequate, since a moderate correlation, is not high enough to establish the reliability of a measurement tool.

The results show a high variety of outcomes within the different articles, this could be due to the following reasons:

- Some researches carried out a period of training for the examiners before the measurements were taken or used a protocol. This could have increased the reliability, due to the fact that the practical handling of the MAS became standardized. The results therefore do not represent the actual situation in practice, since a universal standardization of the MAS does not exist. Bohannon and Smith (1987) support this assumption by stating that it is possible that the high correlations found for the elbow flexors in their research, could be due to in part to their own experience in using the MAS and to the extensive mutual testing and discussions before the investigation was carried out.
• The different muscles groups tested: plantar flexors were considered to be the most difficult muscle group to test and the results show a high amount of articles with poor results. The problem to determine a grade in the plantar flexors would be due the small ROM available in the ankle (Allison et al 1996, Gregson et al 1999).

• The gender factor: it might be that a male examiner will have more muscle power than a female examiner. Therefore, is possible that inter-rater reliability would be decreased, since a male examiner could consider a movement not to be as restricted as a female examiner would consider it (Gregson et al, 1999).

• The amount of spasticity could change within one session and therefore influence the grades given, especially in children who are not following strictly the instructions and are anticipating by holding or pushing (Fosand et al, 2003).

While critically examining each article, certain aspects were noticeable and are consequently discussed in the following section:

Gregson et al (1999, 2000) use in both articles a Kappa and weighted-kappa correlations and consider the results of the reliability according to the weighted-kappa. They state that the reason for choosing the weighted kappa is that a difference of one point on the scale would not be considered clinically significant. It is striking that the weighted kappa was far higher than the kappa, however, the authors of this review disagree with the use of the weighted-kappa since a difference of 1 grade is important in this scale, which only includes 6 possibilities.

Smith et al (2002) intended to develop a new form of the MAS, which is velocity dependent (V-MAS). In their research, they state that the MAS should be performed without a pre-determined velocity for comparing it with the V-MAS. By doing so they eliminated the velocity factor from the test and this could be a reason for the low results of the reliability. The authors of this review disagree with the method used in the article, since spasticity is a velocity dependent phenomenon and is an important feature of the MAS.

Blackburn et al (2002) found that many patients were graded with a 0 during the tests, and therefore decided to exclude it from the statistical analysis, resulting with very low results for reliability of the MAS. The authors of this review disagree with the exclusion, since the grade 0 is part of the scale and agreement regarding it is important. Nevertheless Blackburn et al (2002) state that most agreement was around grade 0 and therefore the scale could be useful to determine if a patient has increased muscle tone or not.

In a review carried-out by Pandyan et al (1999) they suggest that the lower reliability observed when using the MAS, as compared with using the original could be attributed to the fact that Bohannon and Smith by adding an extra level to the classification of the scale, in an attempt to increase its sensitivity might have also increased the probability of errors. Furthermore, Allison et al (1996) state that the terms used in the MAS, such as “slight increase”, “minimal resistance” and “easily moved”, are rich in ambiguity and invite varied interpretations.

**Standardization**

As stated above a measurement tool must have a manual with explicit instructions in order to ensure that all examiners use the same method. Standardization appears to be one of the major problems with the use of the
MAS, as was already mentioned in the section of construct and content validity, a number of important issues are missing: (1) the duration in which the movement has to be performed, (2) the number of repetitions for each movement, (3) the position of the subject during the test.
A Better standardization of the procedure might lead to improved reliability.

Additional remarks
While using the MAS the authors encountered several difficulties regarding the interpretation of certain grades. In practice, a few patients demonstrated a total free movement at the beginning (i.e. first few degrees) of the ROM, up to a point where the examiner felt considerable resistance. The question in these cases was which grade is more appropriate: choosing a grade from the upper end of the scale, (i.e. 2, 3, 4) since the resistance was strong, while ignoring the free movement at the beginning of the ROM, or choosing the grade 0 and note a decreased ROM, since the movement was totally free of at the beginning of the ROM. The problem when following the MAS is to decide whether the grade should be determined by considering the available ROM, or by considering the change in tonus in the affected part.

The authors found, throughout interviews with physiotherapists that this problem is solved in clinical settings by using the MAS in combination with the Tardieu scale (Tardieu et al 1954 cited: Verschuren et al, 2003). Keeping in mind that the main reason to evaluate spasticity is to plan treatment and evaluate its outcome. The Tardieu scale seems to be more useful as it assess the dynamic component of the muscle length; it measures the ROM available by moving the limb in two different velocities, slow (R2) and fast (R1). By deducting R1 from R2, important information reveals: A large difference between R1 and R2 implies there is a large dynamic component, whereas a small difference between R1 and R2 implies there predominantly a fixed contracture. A large dynamic component means there is a large window of opportunity for change in the value of R1 following treatment for spasticity (Boyd and Graham 1999).
Considering the characteristics of the Tardieu, the MAS could therefore draw its attention more to the quality of the tonus changes of the affected part. Both scales together would therefore provide the examiner with valuable and functional information concerning the muscle tone.
In addition, the authors found, that the description of grade 4 is controversial. Some therapists consider the word ‘rigid’ as equal to the medical term ‘rigidity’ while others consider rigid as ‘not bending’, ‘inflexible’ or ‘unchanged into a different shape or position’. The authors suggest the use of the second interpretation, due to the fact that ‘rigidity’ would completely exclude the spastic component from this grade.

The first goal of this review was to find out whether the MAS is a valid and reliable measurement tool for the evaluation of spasticity in children with CP. Only two articles that were carried out with children with CP were found; 1 for validity and 1 for reliability. As stated in the introduction, the mechanism leading to spasticity or whether the subject is an adult or a child should not be of any importance. If a measurement tool is claimed to be valid there should be no difference if the patient is a child or an adult. Therefore, the authors believe that
although most results obtained throughout the researches presented in this review were carried out on adult subjects, they are also applicable for children. However, reliability might be slightly altered since there is a practical difference between doing the MAS on CP children and on adults. Children are less instructable than adults, therefore more time has to be taken and the probability of errors is higher in the measurements taken in children. Additionally, an assessment form should be used where details such as the angle of starting position, pain and any emotions, which influenced the spasticity are recorded.

**Critical view on the used method**
Commonly, in the methods the use of a criteria list is required in order to assess the quality of articles and create a specialized exclusion and inclusion criteria. The purpose of a criteria list is to grade articles according to several important aspects (e.g. size of study, blinding of the examiners etc). The resulting grades represent the qualitative strength and weakness of each article. Furthermore, a criteria list would have been a first step in ensuring that only articles of sufficient methodological quality would have entered this review. The second step would have been the presenting of the results according to levels of strength of the different articles. As mentioned in the method section, in this review a criteria list was not used. This is related to 2 reasons:
First, the fact that a criteria list that evaluates articles, which are concerned with establishing reliability and validity of a measurement tool could not be obtained. Second, creating a criteria list for this review would have involved checking its reliability before any use of it could be continued. Establishing the reliability of a criteria list by only two people would not have been very reliable for itself. Furthermore, the limited amount of time given to write this review was not sufficient to do so.

**CONCLUSIONS**

In conclusion, the validity and reliability of the MAS is highly questionable. It seems as if any practice of it ought to be discouraged, unless the validity of the MAS is proven, but since the MAS it is still the most practical and cheap scale for the use in clinical setting its usage is undeniable. Although it may not be an acceptable tool to quantify spasticity, it does give the examiner important information regarding the quality of the movement. In the previous section the Tardieu scale was introduced, the authors of this review recommend that both scales will be incorporated during the examination since the Tardieu provides more precise information in quantifying the movement. Regarding the questionable reliability of the MAS, the authors suggest that a standardized and precise procedure should be evaluated for reliability under strict conditions, using a large sample of CP-children in an attempt to finally determine the use of the MAS. In addition, it is recommended that the combined practice of the Tardieu and MAS should be tested for validity as well as for reliability before further use of them becomes universal. Furthermore, we recommend the use of a criteria list, which has been proven for its reliability, in further reviews.
REFERENCES


SKOLD, C., HARMS-RINGDAHL, K., HULTING, C., LEVI R., SEIGER A., 1998. Simultaneous Ashworth measurements and electromyographic recordings in
tetraplegic patients. *Archives of Physical Medicine and Rehabilitation, 79 (8), 959-965.*


### Appendix I: Full list of articles search

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<th>Key words combinations</th>
<th>Author</th>
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<th>Name of article</th>
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<td>modified ashworth scale AND reliability</td>
<td>Allison et al.</td>
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<td>Reliability of the Modified Ashworth Scale in the assessment of plantarflexor muscle spasticity in patients with traumatic brain injury</td>
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<td>Blackburn et al.</td>
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<td>Bohannon and Smith</td>
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<td>modified ashworth scale AND validity</td>
<td>Bakheit et al.</td>
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<td>modified ashworth scale AND cerebral palsy</td>
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<td>Measures of muscle and joint performance in the lower limb of children with cerebral palsy</td>
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<td>What does the Ashworth scale really measure and are instrumented measures more valid and précis</td>
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<td>modified ashworth scale</td>
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<td>Objective quantification of spastic hypertonia: correlation with clinical findings</td>
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<td>Pandyan et al.</td>
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<td>A biomechanical investigation into the validity of the modified Ashworth scale as a measure of elbow spasticity</td>
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<td>Waardenburg et al.</td>
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<td>Is Paratonie Betrouwbaar te meten? Een betrouwbaarheid onderzoek voor het meten van paratonie met de MAS en de gemodificeerde toonusschal van Ashworth.</td>
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<td>Haas et al.</td>
<td>1996</td>
<td>The inter rater reliability of the original and the MAS for the assessment of spasticity in patients with spinal cord injury.</td>
<td>Not obtained</td>
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<td>Worely</td>
<td>1993</td>
<td>Relationship among three clinical measures of muscle tone in shoulders and wrists of patients with post stroke condition.</td>
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<td></td>
<td>Lehmann et al.</td>
<td>1989</td>
<td>Spasticity: quantitative measurements as a basis for passing effectiveness of therapeutic interventionist.</td>
<td>Not obtained</td>
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<td>Burry</td>
<td>1972</td>
<td>Objective measurements of spasticity.</td>
<td>Not obtained</td>
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<td></td>
<td>Rovai et al.</td>
<td>1992</td>
<td>Objective quantification of spastic hypertonia: correlation with clinical findings.</td>
<td>Not obtained</td>
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<td></td>
<td>Price et al.</td>
<td>1991</td>
<td>Quantitative measurements of spasticity in children with CP.</td>
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<td>Handed by expert</td>
<td>Engsberg et al.</td>
<td>1996</td>
<td>Quantitative Clinical Measure of spasticity in children with Cerebral Palsy.</td>
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<td></td>
<td>Verschuren et al.</td>
<td>2003</td>
<td>Het meten van spasticiteit bij jonge kinderen met een cerebrale parese.</td>
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