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Velocity dependent measure of spasticity: Reliability in children and juveniles with neuromotor disorders

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Abstract: Purpose: The purpose of this study was to create a clear, standardized test description to rate spasticity severity into four categories according to the definition given by Lance [1], referred to as the Velocity Dependent Measure of Spasticity (VDMS). Method: Muscle groups of the upper and lower limbs of children with neuromotor disorders were evaluated on their response to passive movement in a fast-versus slow-velocity test condition. The interrater and test-retest reliability were assessed using Gwet's alpha one (95%-CI) and the percentage agreement. Results: Two physiotherapists independently assessed 45 children and youths (age 4-19 years). The interrater reliability of the VDMS was substantial to almost perfect (Gwet's alpha one: 0.66-0.99, n= 45) while the test-retest reliability was almost perfect as well (Gwet's alpha one: 0.83-1.00, n= 42). Conclusion: The VDMS can be recommended as a reliable assessment with a standardized procedure to assess spasticity of the extremities in children with neuromotor disorders.

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Velocity Dependent Measure of Spasticity (VDMS): reliability in children with neuromotor disorders

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Short Title:

Velocity Dependent Measure of Spasticity

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Abstract

Purpose: The purpose of this study was to adapt existing rating scales to improve clarity of the test instructions and standardization to rate the severity of spasticity into four categories entitled the Velocity Dependent Measure of Spasticity (VDMS).

Method: Muscle groups of the upper and lower limbs of children with neuromotor disorder were evaluated on their ability to react to passive movement in a fast versus low-velocity test condition. The interrater and test-retest reliability was assessed using Gwet's alpha one (95% CI) and the percentage agreement.

Results: Two physiotherapists tested independently 45 children and youths (age <19 years). The interrater reliability of the VDMS was substantial to almost perfect (Gwet's alpha one: 0.66-0.99, n=45) while the test-retest reliability was almost perfect (Gwet's alpha one: 0.83-1.00, n=42).

Conclusion: The VDMS can be recommended as a reliable assessment with a standardised procedure to assess spasticity of the extremities in children with neuromotor disorders.

Keywords

Cerebral palsy, hypertonia, spasticity, assessment, psychometric properties

1. Introduction

In clinical practice, we need assessments with clear descriptions how to conduct and rate them. Especially in children, they should be practical and cost relatively little time to perform so that the test situation does not burden the children. With the Hypertonia Assessment Tool (HAT), an assessment exists to discriminate between the hypertonia subtypes spasticity, dystonia or rigidity in children with neuromotor disorders.[1] The validity to detect spasticity in all four extremities in children with cerebral palsy (CP) and in children with other neuromotor disorders was considered moderate to good.[1, 2] For the HAT, the authors followed the definition of Lance for spasticity as a velocity-dependent resistance of a muscle to stretch.[3] Further, they highlighted that other factors such as a child's state of alertness, activity, posture, pain, surface contact, or other non-noxious sensory inputs have to be considered when assessing spasticity. The HAT lacks, though, a scale for rating the severity of the spasticity. In a recent review about spasticity measures in children and adolescences with CP,[4] three groups of assessments were included: 1) clinical assessment tools (Ashworth, and the modified Ashworth Scale, Tardieu and modified Tardieu Scale, HAT, the Composite Spasticity Scale). 2) Biomechanical assessment tools (Myotonometer, Wartenberg pendulum test, three-dimensional pendulum test, dynamometry, measures using goniometry, inertial sensor, stiffness tool with robotic- assisted gait orthosis). 3) Neurophysiological assessment tools (electromyography, tonic stretch reflex testing, Hoffmann reflex of soleus muscle). None of the included assessment achieved good reliability. While the authors stated that neurophysiological tools provided the most promising results, they questioned the accuracy of the information deriving from ordinal scaled clinical assessments.[4]

While ordinal-scaled assessment might from a theoretical point of view be less sensitive to detect change over time, for example, due to an intervention (i.e., responsiveness), such assessments provide often a quick and easy testing in clinical practise. In comparison, implementing neurophysiological measures like electromyography in clinical practice is time consuming, needs special equipment and knowledge, and there are still various factors influencing reliability.[5] Another study done by Scholtes et al., (2006) reviewed the clinical assessment of spasticity in children with cerebral palsy.[6] In their review, thirteen different clinical spasticity assessment instruments were evaluated. One group of assessments used non-specific velocity to observe spasticity with a grading system accordingly to Ashworth. Another group of assessments used the joint-angle measurement of the onset of resistance to measure spasticity like the Tardieu scale. A third group can be described as a combination of Ashworth and Tardieu-liked classification. They concluded that only the original Tardieu Scale, which compares the joint angles by passive moving in three different described velocity and defines the angle where resistance started, included the definition of different velocities and, therefore, provides an appropriate assessment to grade spasticity in children with CP. However, they also mentioned some of the weaknesses of the Tardieu Scale, such as time-consuming, and lack of standardisation.[7] Further, the absolute measurement errors of the joint angles are high for test-retest, and interrater reliability.[8] Concerning the psychometric properties, the original and modified Ashworth Scales have a low content validity, as they do not test velocity related change of resistance,[11] and the reliability is weak.[9] Both the Ashworth and Tardieu have an insufficient description of the test procedures, rating scale, and the instructions.[10] Hence, they were applied in many different ways, which affected their reliability negatively and, finally, questioned their clinical benefit.[5]

As a consequence of this literature review, we decided that we need, first, a clear standardised description of the testing procedure and consecutive rating, and, second, a test procedure that requires a slow and fast passive applied movement to be in line with the definition of spasticity.

This study we adapted and combined the MAS and the HAT to a scale quantifying spasticity of the upper and lower extremity with an improved standardisation of the assessment and scoring procedure. We named it the Velocity Dependent Measure of Spasticity (VDMS). In a first step we determined the interrater and test-retest reliability of the VDMS.

2. Methods

The VDMS is composed of the test procedure as described in the test manual of the HAT to test spasticity [2] and a rating scale that is a modification of the Modified Ashworth Scale.[12] In according to the definition of Lance, we defined a slow and fast movement velocity. First, the tested limb should be moved slowly two times until the end range of motion (= slow stretch). One slow stretch lasted 3 to 4 seconds, depending the degree of range of motion. Second, the tested limb should be moved two times at a fast speed until the end of the range of motion (= fast stretch). Two fast stretches lasted less than one second and were repeated after a pause to feel the resistance of the antagonists. Then, the rater has to rate the difference in perception of resistance between the slow and fast passive stretches. For example, if a rater would perceive resistance in the slow passive stretch, and the same resistance was perceived in the fast passive stretch, spasticity would be rated as zero, meaning no spasticity. The first and second author defined four categories: 0) no spasticity; 1) mild spasticity; 2) moderate spasticity; 3) severe spasticity (table 1). A clear definition of the categories and a supplementary description of the

perceived resistance by the assessor, supports the assessors to rate the spasticity. The categories were first described in German and then translated into the English language.

The study was conducted in the same study sample as the previous work of this group investigating the psychometric properties of the HAT.[1]

<table 1>

2.1. Study Design

This was a cross-sectional psychometrical study with repeated assessments. The test was performed three times in each child. At day one, rater A (second author) and B (first author) performed the test in a random order. The tests were performed during a one-hour time-window, after the lunch break, with at least a ten-minute break between the two tests. One of the raters repeated the test one week later at the same time of the day in the same room. Twenty minutes were scheduled to perform this third test to determine the test-retest reliability. This procedure ensured that the measurements were performed independently from each other. Each physiotherapist had more than five years and more than 10 years of practical experience, respectively, in treating children with neuro-motor disorders.

2.2. Participants

Children were recruited from the Rehabilitation Centre for Children and Adolescents of the University Children's Hospital Zurich in Affoltern am Albis. Inclusion criteria were: diagnosed as having a neuro-motor disorder, aged four to 19 years, able to follow simple instructions (such as closing and opening the eyes), and able to lie in supine position for 20 minutes. Participants were excluded from the study if they had received surgery within the last three months, changed

medication (muscle relaxants) during the measurement period or were not allowed to be moved passively. The COSMIN guidelines for psychometric studies considered sample sizes less than 30 as poor.[13] Therefore, we aimed to recruit more than 30 children, with various neuro-motor disorders.

2.3. Assessment Procedure

The VDMS was applied in the same test situation as the HAT. The patients were lying in supine position. The head was supported by a pillow and the legs were positioned on a knee role or a convolved towel. The extremities were tested in a random order. Seven muscle groups were tested per limb, starting proximal to distal, in the following order: for the upper extremity: shoulder adductors, elbow flexors, elbow extensors, forearm pronators, forearm supinators, wrist flexors, and wrist extensors. For the lower extremity: hip flexors, hip extensors, hip adductors, knee flexors, knee extensors, ankle plantar flexors, and dorsal extensors.

We followed the test procedure defined by Jethwa et al.: “Support the limb against gravity. Move the joints of the limb through the child’s full range starting with the joint in full flexion or adduction, moving to full extension or abduction, and then returning to flexion or adduction, twice slowly and twice as quickly as possible.”[2] For the upper extremity: “shoulder adduction and abduction – begin with shoulder in full adduction; elbow flexion and extension – begin with elbow in full flexion; forearm pronation and supination – begin with forearm in full pronation; wrist flexion and extension – begin with wrist in full flexion.”[2] For the lower extremity: “hip adduction and abduction – begin with hip in full adduction; hip flexion and extension – begin with full extension; knee flexion and extension – begin with knee flexed with the hip in 90° flexion; ankle dorsiflexion and plantarflexion – begin with ankle in full plantarflexion.”[2] The

position of the tested limb is depicted on the assessment sheet (see user manual VDMS, appendix I). The tested limb has to be supported carefully against gravity, without touching the target muscle groups. Rating was done after testing each muscle group according to the defined VDMS categories. An example of a rating of the left knee flexors with VDMS mild, moderate, and severe is shown in Figure 1.

<figure 1>

2.4. Statistical Analysis

Statistical calculations were performed with RStudio, using the ‘rel’ and ‘irr’ Package. For the reliability statistics we presented the percentage agreement, and linear Gwet’s first-order agreement coefficient (Gwet’s AC1) with 95 confidence interval (95% CI).[14] Gwet’s AC1 is less influenced by the prevalence of an occurrence than Kappa, and therefore recommended.[15] Gwet’s AC 1 were interpreted as follows: <0=poor, 0.00-0.20=slight, 0.21-0.40=fair, 0.41-0.60=moderate, 0.61-0.80=substantial, and 0.81-1.00=almost perfect.[16]

As mentioned in the first part, we included children with different neuromotor disorder, similar to those treated in our rehabilitation centre. As we noticed in our previous study, the children showed signs of spasticity in at least one muscle group in 57% of the left upper limbs, 42% of the right upper limbs, 76% of the left lower limbs, and 59% of the right lower limbs.¹ We expect to find low occurrence of spasticity in certain muscle groups and higher occurrence in others.

3. Results

3.1. Participants

Forty-six children (32 boys, 16 girls) were recruited from August 2013 to July 2015 for this study. One child (GMFCS Level IV; spastic cerebral palsy) performed just one measurement,

due to illness of one of the raters. Data of this child was excluded from the analysis. The age ranged from 4y 2mo to 18y 10mo. Twenty-seven of the children used a wheelchair for mobility and 19 were walkers. Further patient characteristics of all 46 children were presented table 2. The GMFCS Levels of the included 22 children with spastic CP were; level I, n=2; level II, n=3; level III, n=9; level IV, n=8 and level V, n=0.

<table 2>

The VDMS could be applied to all children. Overall it took 7-12 minutes to test all four extremities in one child. No pain or adverse event occurred during the VDMS testing. Fig. 2 shows the frequencies of the VDMS categories (no, mild, moderate, severe) per tested muscle group and participant (x-axis) from rater A (second author) and rater B (first author).

<figure 2>

3.2. Interrater reliability

The interrater reliability results are based on data from 45 children who were tested at the same day by rater A and B. The Gwet's AC1 including the 95 CI were 'almost perfect' for all muscle groups of the upper extremity excepting the elbow flexors which were rated as 'moderate' and the wrist flexors which were 'substantial' (Table 3a). The percentage agreements laid in line with the Gwet's AC1.

A comparable picture was found for the lower extremity with 'almost perfect agreement' for all muscle groups excepting the knee extensors which were rated as 'substantial' and the plantar flexors as 'moderate' (Table 3a).

3.3. Test-retest reliability

Due to practical circumstances, two children could not be measured a second time. Rater A tested 28 children twice, rater B 15. One child had to be excluded due to change of medication and, therefore, 42 children were included in this analysis.

The percentage agreement and the Gwet's AC1 including the 95CI showed 'almost perfect agreement' for all muscle groups of the upper extremity, except for the wrist flexors of the left side which showed 'substantial' agreement (Table 3b). Likewise, we found for the lower extremity in all muscle groups 'almost perfect' agreement except for the plantar flexors which showed on both sides 'substantial' agreement (Table 3b).

4. Discussion

The aim of this study was to determine the reliability of the VDMS, which we consider a standardised clearly described ordinal scale to rate spasticity in children with neuromotor disorders. The precise test procedure followed the description of velocity-dependence increase in muscle resistance to passive stretch. The interrater as well as the test-retest reliability showed 'substantial' to 'almost perfect' agreement for most muscle groups included in the test protocol. One explanation for these good results could be that we provided a clear description of the testing procedure and the interpretation of the results to rate the spasticity severity level.

As previous studies used different statistical analyses for quantifying the reliability of the various spasticity assessments, a comparison of the results is difficult, because the results are dependent on the distribution of the data and the applied statistical method. Previous studies often used Intraclass correlation coefficients (ICC), even for ordinally scaled spasticity assessments. Flamand and colleagues compared the interrater reliability of spasticity measurement

tools applied in children and youths with cerebral palsy: the interrater ICCs of the Ashworth Scale varied between 0.54-0.80 and for the modified Ashworth scale between 0.27-0.87. For the Tardieu scale, the percentage agreement of the measured angles (elbow, knee, and ankle) was 42%-100%. For the modified Tardieu scale, the ICC lied between 0.22-0.74. The interrater reliability of the Australian Spasticity Assessment Scale (ASAS), another ordinal scale to assess spasticity, was quantified with the weighted kappa and percentage agreement and showed comparable results compared to our findings.[17]

While in our previous study the agreement between the two assessors for the occurrence of a spastic catch (item 4 of the HAT) was low,[1] in the actual analysis of the VDMS the agreement was high. In the recent VDMS study we followed the description to assess spasticity following item 3 of the HAT: “Velocity Dependent Resistance to Stretch”. We assume that differentiating between a ‘spastic catch’ is more challenging than rating the difference in resistance occurring by applying slow versus fast passive stretch. In the descriptions of the VDMS categories, the term ‘catch’ is not included, in contrast to the definitions of the Modified Ashworth Scale or the ASAS.[12, 17]

The agreement between the two assessors testing a child on the same day was for some muscle groups (elbow flexors, wrist flexors, plantar flexors) lower than the test-retest reliability (testing the child by the same rater with one week in between). Several reasons could account for this. As both raters used the VDMS for the first time in this study, some experience and discussions with each other might be needed to increase the agreement. Another reason could be the influence of the first test on the findings of the second test that followed ten-minutes later. Namely, the assessment itself could already induce a reduction of the spasticity level due to

mobilisation of the muscle groups during the first test procedure. Indeed, we found in three muscle groups, the elbow extensors, the knee flexors and the knee extensors of the left side, a significantly lower VDMS score at the second compared to the first test occasion (Bland-Altman test with Wilcoxon signed rank test; bias (i.e., systematic difference) of 0.05, 0.21 and 0.24, respectively, see supplementary data, appendix II). For the other muscle groups, the biases were low and not significant. The most disagreement between rater A and B could be found between VDMS categories “mild” and “moderate” in the elbow flexors and plantar flexors (Fig. 2). We assume that in these children the tested resistance was closed to the one-third of the passive range of motion.

Despite that we included a relative heterogeneous group of patients, reflecting the patients in our rehabilitations centre well, we did not find spasticity in several muscle groups (e.g. shoulder adductors, forearm pronators, forearm supinators, dorsal extensors). From a statistical point of view, this could be considered a limitation and it would be desirable to include a sample of children with higher levels of spasticity in these muscles. From a clinical point of view, though, it is important to discriminate between the hypertonia subtypes (spasticity, dystonia, and rigidity) and to exclude whether high resistance to passive stretch is caused by non-contractile structures. [18-21] Therefore, finding a good agreement of the absence of spasticity is also valuable to avoid an overestimation of the prevalence of the diagnosis of spasticity.

We experienced that the VDMS can be easily integrated when using the HAT, which is advantageous to determine not only the category of hypertonia but additionally also the severity of spasticity in the different muscle groups.

5. Conclusion

With the VDMS a well-described and reliable assessment procedure became available to score spasticity in various muscle groups. The VDMS is easy to apply in children from the age of four years with various neuromotor disorders and a heterogeneous presentation of sensory-motor and cognitive impairments.

6. Funding

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8. Declaration of Conflict of Interest

The authors alone are responsible for the content and writing of the paper. The authors declare no conflict of interest.

9. Ethical Approval

The study was approved by the ethics committee of the Canton of Zurich, complied with the Declaration of Helsinki and followed the guidelines of good clinical practice. All children (and caregivers) agreed to participate. Parents and adolescents aged 15 years and above signed the informed consent form.

10. Author Contributions

PM collaborated in designing the study. She tested participants, performed the analyses and interpreted the results. PM wrote the first draft of the manuscript and incorporated the feedbacks from the other authors. VFW collaborated in designing the study, tested participants and assisted with writing the manuscript. HvH provided senior mentorship in designing the study, advised with statistical analyses and interpretation of results and provided feedback on the manuscript. All authors approved the final version of the manuscript.

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List of Tables & Figures

Table 1: Interpretation of the Velocity Dependent Measure of Spasticity

Figure 1: Example of interpretation of the Velocity Dependent Measure of Spasticity categories

If passive range of motion (pROM) of knee extension is 120° , Velocity Dependent Measure of Spasticity of the Knee flexors would be rated as:

Mild – as a mild increase in resistance by applied fast passive stretch

compared to slow applied stretch through less than one-third ($<40^\circ$) of the pROM

Moderate – as a moderate increase in resistance by applied fast passive stretch compared to slow applied through more than one-third, and less than two-third (40° - 80°) of the pROM

Severe – as a severe increase resistance by applied fast passive stretch compared to slow applied stretch through more than two-third ($>80^\circ$) of the pROM

Table 2: Patient characteristics

Figure 2: Frequencies of Velocity Dependent Measure of Spasticity categories per participants (n=45)

Frequencies of no, mild, moderate, and severe spasticity rated with the Velocity Dependent Measure of Spasticity per limb according to the participants (x-axis)

Table 3: Inter- and test-retest reliability Velocity Dependent Measure of Spasticity results

Table 1. Velocity Dependent Measure of Spasticity: Definitions of categories in comparison to the modified Ashworth Scale

Categories VDMS	Definition VDMS	Categories MAS	Definition MAS*[12]
No	The assessor perceives no increase in resistance through the whole passive range of motion when applying fast passive stretch compared to slow passive stretch. <i>'No' means the perceived resistance is the same as for fast passive stretch and slow passive stretch.</i>	0	No increased resistance
Mild	The assessor perceives a slightly increased resistance through less than one-third of the passive range of motion when applying fast passive stretch compared to slow passive stretch. <i>'Mild' means fast passive stretch can be applied easily, but an increased resistance compared to slow passive stretch is perceived.</i>	1	Slightly increased resistance (catch followed by relaxation or minimal resistance at the end of range of motion)
		1+	Slightly increased resistance (catch followed by minimal resistance throughout less than half of the range of motion)
Moderate	The assessor perceives a moderate increased resistance through more than one-third, and less than two-third of the passive range of motion when applying a fast passive stretch compared to slow passive stretch. <i>'Moderate' means fast passive stretch can be applied only with more effort; a clear increased resistance compared to the slow passive stretch is perceived.</i>	2	Clear resistance throughout most of the range of motion
Severe	The assessor perceives a severe increased resistance through more than two-third of the passive range of motion by applying a fast passive stretch compared to slow passive stretch. <i>'Severe' means fast passive stretch is difficult to perform, the perceived resistance is high.</i>	3	Strong resistance; passive movement is difficult
		4	Rigid flexion or extension

Abbreviations: VDMS – velocity dependence measure of spasticity; MAS – modified Ashworth scale

Table 2. Patient characteristics				
Diagnosis	Number (n)	Age (SD)	weeFIM mobility (SD)	WeeFim total (SD)
Spastic CP	22	11y 7mo (4y 4mo)	18.5 (10.3)	71.3 (32.6)
Mixed CP	9	10y 6mo (3y 4mo)	12.6 (10.6)	47.7 (31.8)
Acquired brain injuries	11	11y 4mo (4y 4mo)	19.8 (11.9)	79.3 (42.3)
Different syndromes	4	11y 4mo (6y 3mo)	29.3 (6.9)	103.5 (13.9)
Total	46	11y 6mo (4y 4mo)	18.6 (11.1)	71.4 (36.1)

Number, age and WeeFIM values apportioned by the four categories of diagnosis. WeeFIM mobility maximal score is 35 points; the maximal WeeFIM total score is 126 points.

Abbreviations: CP- cerebral palsy; n- numbers; y – years; mo – months; SD – standard deviation; WeeFIM- functional independence measure for children

	Extremity	Muscle group	Left side		Right side	
			% Agr.	AC1 (95% CI)	% Agr.	AC1 (95% CI)
a) Interrater reliability	Upper Extremity	Shoulder adductors	96	0.98 (0.96-1.00)	91	0.96 (0.92-1.00)
		Elbow flexors	49	0.66 (0.51-0.81)	67	0.76 (0.62-0.90)
		Elbow extensors	78	0.90 (0.84-0.97)	80	0.90 (0.82-0.98)
		Forearm pronators	100	0.95 (0.91-0.99)	100	0.97 (0.94-1.00)
		Forearm supinators	100	0.97 (0.93-1.00)	100	1.00 (1.00-1.00)
		Wrist flexors	67	0.81 (0.71-0.92)	78	0.87 (0.81-0.96)
		Wrist extensors	87	0.95 (0.91-0.99)	96	0.99 (0.96-1.00)
	Lower Extremity	Hip flexors	87	0.94 (0.89-0.99)	89	0.93 (0.87-0.99)
		Hip extensors	76	0.89 (0.82-0.96)	82	0.92 (0.85-0.98)
		Hip adductors	78	0.89 (0.82-0.97)	78	0.91 (0.85-0.97)
		Knee flexors	78	0.89 (0.82-0.97)	87	0.94 (0.89-0.99)
		Knee extensors	71	0.83 (0.73-0.94)	78	0.87 (0.77-0.96)
		Plantar flexors	42	0.64 (0.54-0.74)	69	0.77 (0.69-0.90)
		Dorsal extensors	93	0.97 (0.93-1.00)	96	0.98 (0.94-1.00)
b) Test-retest reliability	Upper Extremity	Shoulder adductors	98	0.99 (0.95-0.99)	95	0.98 (0.96-1.00)
		Elbow flexors	81	0.88 (0.80-0.97)	84	0.92 (0.87-0.98)
		Elbow extensors	84	0.92 (0.86-0.97)	100	0.96 (0.92-1.00)
		Forearm pronators	93	0.98 (0.95-1.00)	98	0.99 (0.91-1.00)
		Forearm supinators	91	0.97 (0.93-1.00)	98	0.99 (0.98-1.00)
		Wrist flexors	74	0.85 (0.74-0.95)	91	0.95 (0.90-1.00)
		Wrist extensors	98	0.99 (0.97-1.00)	98	0.99 (0.98-1.00)
	Lower Extremity	Hip flexors	93	0.96 (0.92-1.00)	91	0.95 (0.90-1.00)
		Hip extensors	88	0.96 (0.92-1.00)	83	0.94 (0.89-0.99)
		Hip adductors	83	0.92 (0.85-0.99)	86	0.93 (0.86-0.99)
		Knee flexors	86	0.94 (0.88-0.99)	86	0.93 (0.87-0.99)
		Knee extensors	83	0.93 (0.87-0.96)	83	0.93 (0.84-0.99)
		Plantar flexors	76	0.83 (0.73-0.94)	76	0.84 (0.74-0.94)
		Dorsal extensors	100	1.00 (1.00-1.00)	98	0.99 (0.98-1.00)

a) % Agreement, and Gwet's alpha one coefficient between raters A and rater B, of two assessments following each other; n=45

b) % Agreement, Gwet's alpha one coefficient of two tests of the same rater with one week in between; n=42

Abbreviations: Agr. - Agreement; CI - Confidence Interval

Appendix

I. User Manual and Score Sheet for the Velocity Dependence Measure of Spasticity (VDMS)

II. Wilcoxon signed rank test of the first versus the second measurement and the bias with upper limit of agreement and lower limit of agreement

mild VDMS

moderate VDMS

severe VDMS

Upper Limb left side

Upper Limb right side

Lower Limb left side

Lower Limb ride side