

Reliability of the Modified Ashworth Scale in post-stroke spasticity assessment: cross-sectional study

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Abstract

Introduction. Spasticity evaluation in stroke survivors is crucial for effective rehabilitation. The Modified Ashworth Scale (MAS) is commonly used for this purpose, but its reliability when administered by less experienced individuals like physiotherapy students remains understudied. Therefore, our objective is to assess the inter-observer reliability of the MAS among physiotherapy students for evaluating post-stroke lower limb spasticity.

Methods. Thirty-two patients (24 males, 65.2 ± 13.9 years) with hemiplegia/hemiparesis at least six months post-stroke were enrolled. Extensors and flexors in the hip, knee, and ankle of each participant were assessed independently by two trained final-year physiotherapy students, approximately 5 min apart. The Weighted Cohen's Kappa Index (K_w) was calculated.

Results. The MAS showed substantial agreement for hip extensors ($K_w = 0.78$) and flexors ($K_w = 0.70$), knee flexors ($K_w = 0.77$), dorsiflexors ($K_w = 0.64$), and plantar flexors ($K_w = 0.63$), and fair agreement for knee extensors ($K_w = 0.54$).

Conclusions. Novice physiotherapy students demonstrated reliable application of the MAS when evaluating spasticity in the lower limbs of individuals recovering from strokes. Substantial agreement in most muscle groups examined supports the use of the MAS as a valid tool for assessment, even during the initial phases of clinical education.

Key words: cerebrovascular accident, lower extremity, measurement, outcome assessment (healthcare), reproducibility of results, stroke

Introduction

Spasticity, a defining feature of central motor neuron disorder, is a complex motor disturbance predominantly identified by a velocity-dependent enhancement of myotatic reflexes, leading to exaggerated tendon jerks and enhanced muscle tone [1]. Lance's widely disseminated definition describes spasticity as 'a velocity-dependent increase in the tonic stretch reflex'. However, researchers such as Pandyan et al. [2] argue that this understanding is limited and propose a broader definition, describing spasticity as 'a disorder of sensorimotor control resulting from an upper motor neuron lesion, characterised by intermittent or sustained involuntary activation of muscles'. This revised definition emphasises the multifaceted nature of spasticity, which extends beyond increased muscle tone and reflects a broader spectrum of motor dysfunction.

Spasticity is commonly observed in several major neurological disorders such as stroke, multiple sclerosis, traumatic brain injury, and spinal cord injury [3]. Unlike hypertonus or generalised increased muscle tone, spasticity specifically relates to the rate of muscle stretching: quicker stretches result in more significant resistance. This phenomenon may originate from intrinsic muscle rigidity or an amplification of the myotonic reflex [4]. The repercussions of spasticity extend beyond mere alterations in muscle tone, affecting joint mobility, coordination of movement, and overall functional capability [5]. It varies in severity among individuals, potentially causing discomfort, pain, and restricted motion, thus significantly affecting daily life activities. Effective management

of spasticity is crucial for enhancing mobility and quality of life, especially considering that, twelve months post-stroke, the occurrence rate of spasticity can vary between 17% and 38% in those affected [6–8].

Quantifying the severity of spasticity requires reliable and valid methods of assessment [3]. Although electromyography and electrophysiological tests are objective methods to assess spasticity; in clinical settings, scales are usually used because they are less expensive, less time consuming and more practical [3, 9, 10]. Among the subjective methods for assessing spasticity, the Modified Ashworth Scale (MAS) is the most frequently applied scale in clinical practice [11]. Several studies have demonstrated that the MAS has good reliability between and within raters, particularly when the assessment focuses on the elbow and wrist [11]. However, the reliability in the lower limbs has been questioned as it may be difficult to perceive rigidity mediated by reflex responses in the lower extremities, which are heavy and difficult to mobilise [12, 13]. Moreover, limited research has evaluated the inter-observer reliability of the MAS in the lower extremities of stroke patients [11, 14–18], and only one has included physiotherapy students, but it did not exclusively include stroke survivors [19]. Recent research has demonstrated that the MAS exhibits varying degrees of reliability across different muscle groups in stroke patients [18]. Specifically, the inter-observer reliability ranged from poor to good for upper extremities (Kappa = 0.25 to 0.66) and was moderate for lower extremities (Kappa = 0.41 to 0.54) [18]. Moderate intra-observer reliability was detected in the assessment of the hip flexors, underscoring the importance of cautious interpreta-

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tion of MAS outcomes, especially when considering its lower reliability in assessing certain muscle groups in stroke patients. Additionally, a Spanish version of the MAS is available, as referenced in the Rehabilitation Measures Database. A validation study conducted by physiotherapists in Cali, Colombia, further supports its cultural adaptation and suitability for Spanish-speaking populations [20].

This research innovatively assesses the reliability of the MAS when utilised by novice physiotherapists, a scarcely explored area in the existing literature. It emphasises the importance of reliable tools for neurorehabilitation, aiding clinical decision-making in stroke survivor care. These insights are crucial for enhancing spasticity assessment accuracy in clinical settings, especially for early-career professionals. Addressing both a knowledge gap and the impact of practitioner experience on assessment reliability, the objective of this investigation is to assess the inter-observer reliability of physiotherapy students in evaluating lower limb spasticity post-stroke using the MAS.

Subjects and methods

Study design

We conducted an observational cross-sectional study.

Participants

A total of 32 participants selected by convenience sampling were assessed between March and May 2016. Nine participants were recruited from two geriatric homes, eight through an advertisement placed in local media, and 15 were recruited using different methods such as physiotherapist referral, contact on the streets, and referral by a health institution. People over 40 with hemiplegia or hemiparesis, minimum 6 months after their stroke, volunteers, being able to follow simple commands and living in Bucaramanga were included.

Participants with additional lower limb disorders, including orthopaedic, musculoskeletal, vascular, or integumentary conditions that could interfere with the mobilisation of the affected limb (e.g., fractures, severe arthritis, peripheral arterial disease, or skin ulcers) were excluded. Additionally, individuals presenting dyspnoea, abdominal pain, chest pain, uncontrolled hypertension, congestive heart failure, acute chest trauma, or pulmonary thromboembolism were also excluded to ensure participant safety and the reliability of the assessments.

All participants were undergoing physiotherapy as part of a clinical trial titled Effects of Lower Limb Muscle Strengthening on Spasticity, Gait, and Functionality in Post-Stroke Patients. The intervention included conventional therapy consisting of motor sequence exercises, balance activities, and functional training tailored to initial assessment findings. Additionally, participants in the experimental group received lower-limb resistance training over a 4-month period.

Evaluators

Two final-year physiotherapy students from the University of Santander (UDES) with prior academic training in neurological evaluation and intervention conducted all assessments. To ensure consistency and reliability, they received 12 hours of specialised training from a physiotherapist with over 10 years of experience in neurorehabilitation (ICGD). This training included theoretical instruction, practical exercises, and the use of a standardised checklist to ensure uni-

formity in the application of the MAS [19]. As part of their preparation, the students performed practice assessments on participants from UDES and a local geriatric care facility. Additionally, a pilot test was conducted in which each student assessed six participants under conditions identical to the main study. This process made it possible to refine the study protocol and ensured consistency in applying the MAS, a widely used tool for measuring spasticity on a six-point scale ranging from 0 to 4 [21]. All procedures, including the use of the checklist, were standardised during the pilot phase to maintain methodological rigour throughout the study.

Procedure

A general information questionnaire was completed to assess patients' socio-demographic characteristics, medical history, and affected side.

Each evaluator performed a single attempt to assess spasticity per participant, with the second evaluator conducting the assessment approximately 5 min after the first. This approach was chosen to minimise variability caused by changes in participants' muscle tone due to fatigue, emotional status, or environmental factors. Moreover, previous studies [22] have demonstrated that the effects of passive mobilisation on spasticity are short-lived, as they primarily influence the biomechanical properties of the muscle without significantly affecting other aspects of spasticity. Therefore, the first evaluation was unlikely to impact the subsequent results. To ensure consistency and minimise external influences, all assessments were conducted in a controlled environment. Patients were evaluated either on a stretcher or bed in a space designed to provide a fresh and pleasant atmosphere, allowing them to remain relaxed during the examination. Participants recruited from geriatric homes were assessed in their own beds within the institution, while other participants were evaluated at the 'Neurotrauma Center SAS', a facility specialising in neurorehabilitation and research in Bucaramanga. The order of evaluation between the two assessors was randomised to prevent systematic bias. Additionally, the evaluators were blinded to each other's results to maintain objectivity. Testing sessions were conducted between 8 AM and 12 PM to account for consistency in circadian variations that could affect muscle tone.

Each participant was positioned supine with the head in the midline, and the upper limbs were aligned with the trunk. The mobilisation was performed with manual contacts on the bony prominences of the segment that was mobilised to prevent pressure or stimulation on the muscle or tendon that could facilitate or inhibit muscle tone. The passive mobilisation was done in flexion and extension, with rhythmic and successive displacements of the segment, varying the speed so as not to facilitate adaptation. The evaluator moved the joints three times, with each movement lasting less than one second, as determined by counting 'one thousand and one' ('mil uno' in Spanish). One score was assigned based on the three movements. The muscle testing sequence advanced systematically through assessments of the hip, knee, and ankle joints, wherein extensors and flexors were evaluated sequentially for each joint. The passive mobilisation was done first on the unaffected muscle group to develop a sense of a normal movement, and afterward, the affected muscle group was tested. The spasticity assessment on the affected side was carried out as described in the supplementary file. Prior to assessing spasticity, ankle mobility was evaluated to identify any potential retraction or fixed contractures. This was done by performing mobilisations at varying speeds. Changes in the speed of movement help differentiate the cause of re-

sistance: spasticity-related resistance varies with the movement speed due to hyperexcitability of the muscle spindle, whereas resistance from contractures remains constant regardless of the speed [22]. This step ensured accurate differentiation between spasticity and fixed contractures and enhanced the reliability of the assessment process.

Statistical analysis

Age was reported as the mean value accompanied by the standard deviation, and time with the stroke was conveyed by the median alongside the 25th and 75th percentiles (inter-quartile range – IQR). Nominal variables were expressed using both counts and percentages. The inter-observer reliability was assessed using the quadratic weighted Cohen’s Kappa Index (K_w). Also, the 95% confidence intervals (95% CI) were calculated. The interpretation of the results followed the Landis and Koch criteria, which categorise agreement as follows: poor (< 0), slight (0–0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80), and almost perfect (0.81–1) [23]. Approval for the study was obtained from the Research Ethics Board at the UDES Prior to the assessment, informed consent was obtained from all participants. Statistical significance was set at a *p*-value of less than 0.05, and data analysis was conducted using the Stata 16.1 software.

Results

Out of the 32 recruited participants, 75% (*n* = 24) were male. The mean ± SD age was 65.2 ± 13.9 years, and 53.1% (*n* = 17) had a stable partner. The right side was the main dominant side (75%, *n* = 24) and the most affected one (53.1%, *n* = 17). A medical history of heart disease was reported by 53.1% (*n* = 17) of participants. Only one participant was taking antispastic drugs (baclofen). The median time since the stroke was 60 months (IQR 25.3–110.3). The general MAS scores for both evaluators have been summarised in Table 1. All muscle groups evidenced substantial agreement,

Table 1. Participants’ characteristics (*n* = 32)

Variable		<i>n</i>	%
Sex	female	8	25.0
	male	24	75.0
Age (years)	mean (<i>SD</i>)	65.2 (13.9)	
Marital status	without a stable partner	15	46.9
	with a stable partner	17	53.1
Laterality	right	24	75.0
	left	8	25.0
Medical history of heart disease	yes	17	53.1
	no	14	43.8
	do not know	1	3.1
Affected side	right	17	53.1
	left	15	46.9
Variable		Median	(IQR)
Time since the stroke (months)		60	(25.3–110.3)
General MAS score, evaluator 1		8	(5–12.5)
General MAS score, evaluator 2		9	(5–17)

Table 2. Inter-observer reliability of the Modified Ashworth Scale for lower limb muscle groups

Muscle group	Kappa (K_w)	95% CI
Hip flexors	0.70	0.50, 0.83
Hip extensors	0.78	0.59, 0.92
Knee flexors	0.78	0.60, 0.88
Knee extensors	0.54	0.30, 0.76
Dorsiflexors	0.65	0.42, 0.83
Plantar flexors	0.64	0.39, 0.84

with the exception of the knee extensors, which presented a moderate level of agreement (Table 2).

Discussion

The study explored the MAS’s inter-observer reliability in assessing lower limb spasticity in patients six months post-stroke, particularly when administered by physiotherapy students. Our findings revealed substantial agreement across most of the muscle groups assessed. The moderate reliability observed in the knee extensors highlights a need for cautious interpretation in certain muscle groups. These results are significant as they demonstrate that novice physiotherapists, even with limited clinical experience but adequate training, can reliably utilise the MAS in a clinical setting. This implies that the MAS could be considered a viable instrument for evaluating spasticity when used by emerging healthcare professionals, reinforcing its applicability in diverse clinical environments and among varied practitioner skill levels. To the best of our knowledge, there are no other studies that have assessed the reliability of the lower limb MAS between novice physiotherapists, nor have they examined inter-observer reliability in hip extensors and dorsiflexors (Table 3).

In the study by Sloan et al. [16], which adopted a methodology similar to ours in terms of sample size, participants’ position, time between evaluators, ordering between evaluators, blinding results between evaluators, and training, the Spearman’s rank correlation coefficient indicated slight to moderate inter-observer agreement, which was lower than our findings. The differences could be partly attributed to the higher number of evaluators (*n* = 4) and the increased number of movements performed during the test in the Sloan et al. [16] study. Repeated passive stretching could affect spasticity and this aspect makes the classifying problematic for evaluators. Conversely, Gregson et al. [17] found a similar agreement in the knee flexors. However, in their study, the position of the participants was seated, the time between evaluators’ assessments was 5 min longer, and the time since stroke was lower.

While the agreement of the knee extensors was higher in the current study compared with Blackburn et al. [14], the knee extensors obtained the lowest agreement, which may be related to the participants’ position during the test and posture. Fleuren et al. [24] found that elongated muscles such as knee extensors in the supine position increased stretch reflex activity when contrasted with contracted muscles such as knee flexors in a seating position. In addition, in Blackburn et al. [14], the participants were positioned in a side-lying posture, with the affected leg placed on top, presenting a challenge for the evaluator to simultaneously control the knee, hip, and pelvis.

Regarding the dorsiflexors and plantar flexors, although there was substantial agreement in our study, it was lower

Table 3. Inter-observer reliability of the Modified Ashworth Scale for lower limb muscle groups

Variable	Gomez et al. (our study)	Sloan et al. (1992) [16]	Gregson et al. (1999) [17]	Blackburn et al. (2002) [14]	Li et al. (2014) [15]	Vidmar (2023) [18]
General characteristics						
Males/Total (n)	24/32	26/34	20/35	17/36	36/51	20/30
Age (years)	65.2 ± 13.9	57.8 ± 17.8	73 ± (NR)	76.1 ± 7.9	59 ± 14	55.1 ± 13.5
Population	stroke	stroke n = 31 head injury n = 3	stroke	stroke infarct n = 33 unclassified n = 3	stroke ischemic n = 37 haemorrhagic n = 14	stroke
Evolution time	60 (R: 6–288) months	NR	40 (R: 19–78) days	R: 2–12 weeks	3.7±4.3 months	R: 1–19 months
Aspects of the MAS						
time resting before the test	5 min	NR	NR	5 min	10 min	10 min
verbal instruction to start	yes	NR	NR	NR	NR	NR
extremities – position	supine	supine	seated	side lying	supine	supine
movements	3	4	3*	3	2	up to 3
Methodological aspects						
number of evaluations per rater	1	1	2 (two consecutive days)	1	1	2 (1 day in between)
time between raters' assessments	5 min	5 min	10 min	1 h	30 min	15 min
time between muscle groups	0 min	not applicable	NR	NR	NA	NR
evaluator independent registration (blind)	yes	yes	yes	yes	yes	NR
Aspects of the evaluators						
number of raters	(2): PT students	(4): 2 PT 2 doctors	(2): 1 medical specialist 1 PT	(2): both PT	(2): 1 physiatrist 1 PT	(3): 2 PT 1 physiatrist
order between raters	random	random	counter balanced	counter balanced	physiatrist then PT	random
experience	final year student	NR	NR	>10 years	NR	one rater = 2 years two raters > 10 years
rater training	yes	yes, not specified	nr	not extensive	yes	no additional
results	K ω (95% CI)	rho	K ω	Kb	K	K (95% CI)
HF	0.70 (0.50–0.82)	NA	NA	NA	NA	A1–B 0.15 (–0.39,0.68) A1–C 0.48 (0.10,0.85) B–C 0.59 (0.21,0.97)
KF	0.77 (0.59–0.88)	MD1 vs MD2: 0.37 MD1 vs PT1: 0.57 MD1 vs PT2: 0.44 PT1 vs MD2: 0.40 PT1 vs PT2: 0.62 PT2 vs MD2: 0.26	day 1: 0.79 day 2: 0.73	NA	NA	A1–B 0.43 (0.10,0.76) A1–C 0.67 (0.44,0.89) B–C 0.24 (–0.10,0.59)
KE	0.54 (0.29–0.76)	NA	NA	0.28 $p = 0.06$	NA	A1–B 0.45 (0.20,0.71) A1–C 0.71 (0.53,0.90) B–C 0.36 (0.06,0.65)
plant flexors	0.63 (0.38–0.83)	NA	day 1: K $\omega = 0.51$ day 2: K $\omega = 0.45$	G: 0.15 $p = 0.21$ S: 0.19 $p = 0.10$	K: 0.48 $p < 0.001$	S: A1–B 0.53 (0.34,0.72) S: A1–C 0.71 (0.52,0.90) S: B–C 0.39 (0.20,0.59) G: A1–B 0.42 (0.25,0.59) G: A1–C 0.64 (0.44,0.84) G: B–C 0.34 (0.14,0.54)

PT – physiotherapist, MD – doctor of medicine, HF – hip flexors, HE – hip extensors, KF – knee flexors, KE – knee extensors, G – gastrocnemius, S – soleus, R – range, IQR – interquartile rank, K ω – weighted Kappa, K – Kappa, Kb – Kendall tau-b, rho – Spearman's rank correlation coefficient, 95% CI – confidence interval of the 95%, NA – not assessed, NR – not reported

* Three measurements each time, 30 s apart, the lowest value was selected.

compared with the hip extensors and flexors and knee flexors. This might be associated with the constrained ankle range of motion and the contraction of the plantar flexors, complicating classification [25]. However, in the current study, we did not assess the range of motion to confirm this statement. Also, the dorsiflexors and plantar flexors were the last muscle group that the evaluators tested, and there was no break between muscle groups, which could affect spasticity differently in the two evaluations of the same participants.

Overall, the high level of reliability found in the current study could be primarily explained by the rater training and the standardisation of the test procedure. This means that the MAS is reliable for an inexperienced rater (final year physiotherapy student) with a training period in the MAS evaluation and following a pre-established evaluation protocol. This protocol included a rest period prior to the first evaluation to obtain a basal state of patient conditions; three movements by counting 'one thousand and one' ('mil uno' in Spanish) following the Bohannon and Smith [21] procedure, which allows the same stretch speed during the test. This counting tried to reduce inconsistency in the movement velocities used by the evaluators during the assessment. A study of 14 patients (10 post-stroke participants) [19] incorporated a metronome in the MAS evaluation to obtain consistent movement velocities. However, the findings indicated low reliability, with a Kappa coefficient classified as poor for the ankle plantar flexors [19]. Also, the manual contacts were standardised mainly using bony prominences as the contact point of the tester's hand on the patient avoiding the pressure over the muscle so as not to facilitate the response of the myotatic reflex and avoiding the pressure over the tendon so as not to stimulate the tendinous organ of Golgi with the consequent relaxation. In addition, in this reliability study, the protocol involved a resting time of 5 min between evaluators to prevent a carry-over effect. Another aspect that may have increased the reliability was the time since stroke (6 months and over), which allows reflex stability. The variability of reflex responses in stroke patients is known to be higher during acute stages than in chronic stages [26], and the muscle's mechanical properties can also evolve over time [27].

Questions have been asked regarding whether the MAS serves as a valid assessment tool for spasticity. Concurrent criterion validity studies of the MAS have been carried out using electrophysiological and biomechanical measurements. While some studies have shown low-to-moderate validity [28–32], previous research has demonstrated a low correlation between MAS scores and electrophysiological or biomechanical measures of spasticity [33–37]. The inconclusive results of the concurrent criterion validity could be explained due to the MAS not being able to exclusively evaluate spasticity. Spasticity is typified by an elevation in resistance to passive movement that is dependent on velocity, stemming from an increase in excitability of tonic stretch reflexes, referred to as neural stiffness [38]. However, augmented resistance to passive movement may result from non-neural factors, such as modifications in the muscle or joint properties, notably changes in extracellular matrix viscosity (non-neural stiffness) [38, 39].

Contractures are another non-neural factor that can increase the resistance to passive movement. Changes in soft tissue, including a reduced number of sarcomeres in series, restructuring of connective tissue, and diminished extensibility, are associated with contractures [36]. According to Kwah et al. [40], 52% of patients developed at least one contracture at 6 months post-stroke. In our study, the median of time since the stroke was 60 months; thus, the participants in this study had a high probability of having soft tissue and joint property changes during the evaluation due to their underlying con-

dition. Therefore, the MAS evaluated both spasticity (neural stiffness) and non-neural stiffness.

In addition, electrophysiological measures (i.e., H-reflex and F-waves) are frequently applied to monitor muscle neural activities [28, 29], while biomechanical measures (i.e., Myotonometry and Sonoelastography) evaluate non-neural stiffness [41]. Other combined electrophysiological and biomechanical measurements (i.e., NeuroFlexor) evaluate both non-neural and neural stiffness [42]. Therefore, the MAS's validity results, as a measure of stiffness rather than spasticity, depend on the criterion used in the validity study.

Another point of controversy is whether the MAS is an ordinal measure of stiffness. Two studies have demonstrated that the resistance to passive movement using a biomechanical device was not significantly different among grades 1, 1+, and 2 [37] or 0, 1, 1+, and 2 of the MAS [35]. Both studies concluded that the MAS does not fulfil the criteria for a valid ordinal-level measure of resistance to passive movement. However, despite these limitations, the MAS remains the most frequently applied clinical measure of spasticity in post-stroke patients [4, 43].

Limitations

The current study is subject to limitations, including a small sample size, which may impact the calculation of Kappa statistics. Specifically, a larger sample size is necessary to compute the Kappa index if the prevalence of the outcome is low [44]. Previous studies of reliability have shown a low prevalence of high levels of spasticity in people with stroke [13, 14]. In addition, the results are restricted to a sample of stroke survivors in the chronic stage due to the reflex stability; although in clinical settings, clinicians need to assess spasticity in patients in acute stages. The agreement was assessed by two physiotherapy students with little experience, who mainly scored spasticity between 0 and 2 according to the MAS. Also, their main disagreements were in the knee extensor, dorsiflexors and plantar flexors; the second rater tended to assign 1 while the first rater tended to assign 0 (see supplementary file Appendix 2). Because some uncontrolled factors could alter the spasticity in the second assessment, the evaluators carried out the assessments in random order. Other factors that were not evaluated in the current study and could influence the scoring of the two evaluators were pain and the angle of the rater's joints during measurements, which could influence the speed of the movement of the limb and the pressure exerted by the rater at the point of contact with the participant.

Further studies need to be carried out in people with acute stroke, using more than two evaluators and evaluators from diverse disciplines. Regarding the methodology of the reliability study, for future studies, we suggest a random order between muscle groups instead of the cephalocaudal order and giving breaks between muscle groups.

Conclusions

In conclusion, the MAS shows substantial agreement using K_{ω} in non-experienced but trained evaluators for five out of the six lower limb muscle groups assessed. This supports its utilisation in assessing spasticity in individuals who have experienced a stroke. The implementation of this type of study contributes to the body of scientific evidence for health professionals working in rehabilitation. Rehabilitation workers require scales with adequate psychometric properties that provide objectivity to the evaluation to address the intervention plans according to the problems detected.

Data availability statement

Data from this study are available upon request from the corresponding author.

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Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Institutional Review Board of the University of Santander (UDES).

Informed consent

Informed consent was obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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References

- [1] Lance JW. The control of muscle tone, reflexes, and movement: Robert Wartenberg Lecture. *Neurology*. 1980;30(12):1303–13; doi: 10.1212/wnl.30.12.1303.
- [2] Pandyan AD, Gregoric M, Barnes MP, Wood D, Van Wijck F, Burridge J, Hermens H, Johnson GR. Spasticity: clinical perceptions, neurological realities and meaningful measurement. *Disabil Rehabil*. 2005;27(1–2):2–6; doi: 10.1080/09638280400014576.
- [3] Aloraini SM, Gäverth J, Yeung E, MacKay-Lyons M. Assessment of spasticity after stroke using clinical measures: a systematic review. *Disabil Rehabil*. 2015;37(25):2313–23; doi: 10.3109/09638288.2015.1014933.
- [4] Trompetto C, Marinelli L, Mori L, Pelosin E, Currà A, Mol-fetta L, Abbruzzese G. Pathophysiology of spasticity: implications for neurorehabilitation. *Biomed Res Int*. 2014;2014:354906; doi: 10.1155/2014/354906.
- [5] Li S, Francisco GE. New insights into the pathophysiology of post-stroke spasticity. *Front Hum Neurosci*. 2015; 9:192; doi: 10.3389/fnhum.2015.00192.
- [6] Leathley MJ, Gregson JM, Moore AP, Smith TL, Sharma AK, Watkins CL. Predicting spasticity after stroke in those surviving to 12 months. *Clin Rehabil*. 2004;18(4): 438–43; doi: 10.1191/0269215504cr727oa.
- [7] Lundström E, Terént A, Borg J. Prevalence of disabling spasticity 1 year after first-ever stroke. *Eur J Neurol*. 2008; 15(6):533–9; doi: 10.1111/j.1468-1331.2008.02114.x.
- [8] Watkins CL, Leathley MJ, Gregson JM, Moore AP, Smith TL, Sharma AK. Prevalence of spasticity post stroke. *Clin Rehabil*. 2002;16(5):515–22; doi: 10.1191/026921 5502cr512oa.
- [9] Rekan T. Clinical assessment and management of spasticity: a review. *Acta Neurol Scand Suppl*. 2010; (190):62–6; doi: 10.1111/j.1600-0404.2010.01378.x.

- [10] Platz T, Eickhof C, Nuyens G, Vuadens P. Clinical scales for the assessment of spasticity, associated phenomena, and function: a systematic review of the literature. *Disabil Rehabil*. 2005;27(1–2):7–18; doi: 10.1080/096 38280400014634.
- [11] Meseguer-Henarejos AB, Sánchez-Meca J, López-Pi-na JA, Carles-Hernández R. Inter- and intra-rater reliability of the Modified Ashworth Scale: a systematic review and meta-analysis. *Eur J Phys Rehabil Med*. 2018; 54(4):576–90; doi: 10.23736/S1973-9087.17.04796-7.
- [12] Ansari NN, Naghdi S, Arab TK, Jalaie S. The interrater and intrarater reliability of the Modified Ashworth Scale in the assessment of muscle spasticity: limb and muscle group effect. *NeuroRehabilitation*. 2008;23(3):231–7.
- [13] Biering-Sørensen F, Nielsen JB, Klinge K. Spasticity-assessment: a review. *Spinal Cord*. 2006;44(12):708–22; doi: 10.1038/sj.sc.3101928.
- [14] Blackburn M, van Vliet P, Mockett SP. Reliability of measurements obtained with the modified Ashworth scale in the lower extremities of people with stroke. *Phys Ther*. 2002;82(1):25–34; doi: 10.1093/ptj/82.1.25.
- [15] Li F, Wu Y, Li X. Test-retest reliability and inter-rater reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in hemiplegic patients with stroke. *Eur J Phys Rehabil Med*. 2014;50(1):9–15.
- [16] Sloan RL, Sinclair E, Thompson J, Taylor S, Pentland B. Inter-rater reliability of the modified Ashworth Scale for spasticity in hemiplegic patients. *Int J Rehabil Res*. 1992; 15(2):158–61; doi: 10.1097/00004356-199206000-00 009.
- [17] Gregson JM, Leathley M, Moore AP, Sharma AK, Smith TL, Watkins CL. Reliability of the Tone Assessment Scale and the modified Ashworth scale as clinical tools for assessing poststroke spasticity. *Arch Phys Med Rehabil*. 1999;80(9):1013–6; doi: 10.1016/s0003-9993(99)90053-9.
- [18] Vidmar T, Goljar Kregar N, Puh U. Reliability of the Modified Ashworth Scale after stroke for 13 muscle groups. *Arch Phys Med Rehabil*. 2023;104(10):1606–11; doi: 10.1016/j.apmr.2023.04.008.
- [19] Zurawski E, Behm K, Dunlap C, Koo J, Ismail F, Boulias C, Reid S, Phadke CP. Interrater reliability of the modified ashworth scale with standardized movement speeds: a pilot study. *Physiother Can*. 2019;71(4):348–54; doi: 10.3138/ptc-2018-0086.
- [20] García Correa HR, Sánchez DP, Ordoñez Mora LT. Validated scales for neurorehabilitation in Hispanics: scoping review [in Spanish]. *Rehabilitacion*. 2021;55(4):301–11; doi: 10.1016/j.rh.2021.02.005.
- [21] Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther Rehabil J*. 1987;67(2):206–7; doi: 10.1093/ptj/67.2.206.
- [22] Gómez-Soriano J, Taylor J. Spasticity after a spinal cord injury: review of the pathophysiology mechanisms, diagnostic techniques and current physiotherapy treatments [in Spanish]. *Fisioterapia*. 2010;32(2):89–98; doi: 10.1016/ j.ft.2009.09.002.
- [23] Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1): 159–74.
- [24] Fleuren JF, Nederhand MJ, Hermens HJ. Influence of posture and muscle length on stretch reflex activity in poststroke patients with spasticity. *Arch Phys Med Rehabil*. 2006;87(7):981–8; doi: 10.1016/j.apmr.2006.03. 018.
- [25] Mehrholz J, Major Y, Meissner D, Sandi-Gahun S, Koch R, Pohl M. The influence of contractures and variation in measurement stretching velocity on the reliability of

- the Modified Ashworth Scale in patients with severe brain injury. *Clin Rehabil.* 2005;19(1):63–72; doi: 10.1191/0269215505cr824oa.
- [26] Muslumanoglu L, Aki S, Turkdogan D, Us O, Akyuz G. Involvement of sympathetic reflex activity in patients with acute and chronic stroke: a comparison with functional motor capacity. *Arch Phys Med Rehabil.* 2004; 85(3):470–3; doi: 10.1016/j.apmr.2003.03.009.
- [27] Lee SSM, Spear S, Rymer WZ. Quantifying changes in material properties of stroke-impaired muscle. *Clin Biomech.* 2015;30(3):269–75; doi: 10.1016/j.clinbiomech.2015.01.004.
- [28] Allison SC, Abraham LD. Correlation of quantitative measures with the modified Ashworth scale in the assessment of plantar flexor spasticity in patients with traumatic brain injury. *J Neurol.* 1995;242(10):699–706; doi: 10.1007/BF00866923.
- [29] Hu B, Zhang X, Mu J, Wu M, Zhu Z, Liu Z, Wang Y. Spasticity measurement based on the HHT marginal spectrum entropy of sEMG using a portable system: a preliminary study. *IEEE Trans Neural Syst Rehabil Eng.* 2018;26(7):1424–34; doi: 10.1109/TNSRE.2018.2838767.
- [30] Katz RT, Rovai GP, Brait C, Rymer WZ. Objective quantification of spastic hypertonia: Correlation with clinical findings. *Arch Phys Med Rehabil.* 1992;73(4):339–47; doi: 10.1016/0003-9993(92)90007-j.
- [31] Pizzi A, Carlucci G, Falsini C, Verdesca S, Grippo A. Evaluation of upper-limb spasticity after stroke: a clinical and neurophysiologic study. *Arch Phys Med Rehabil.* 2005; 86(3):410–5; doi: 10.1016/j.apmr.2004.10.022.
- [32] Cooper A, Musa IM, van Deursen R, Wiles CM. Electromyography characterization of stretch responses in hemiparetic stroke patients and their relationship with the Modified Ashworth scale. *Clin Rehabil.* 2005;19(7):760–6; doi: 10.1191/0269215505cr888oa.
- [33] Bakheit AMO, Maynard VA, Curnow J, Hudson N, Kodapala S. The relation between Ashworth scale scores and the excitability of the alpha motor neurones in patients with post-stroke muscle spasticity. *J Neurol Neurosurg Psychiatry.* 2003;74(5):646–8; doi: 10.1136/jnnp.74.5.646.
- [34] Ghotbi N, Olyaei GR, Hadian MR, Ansari NN, Bagheri H. Is there any relationship between the Modified Ashworth Scale scores and alpha motoneuron excitability indicators?. *Electromyogr Clin Neurophysiol.* 2006;46(5): 279–84.
- [35] Kumar RTS, Pandyan AD, Sharma AK. Biomechanical measurement of post-stroke spasticity. *Age Ageing.* 2006; 35(4):371–5.
- [36] Pandyan AD, Price CIM, Rodgers H, Barnes MP, Johnson GR. Biomechanical examination of a commonly used measure of spasticity. *Clin Biomech.* 2001;16(10): 859–65.
- [37] Pandyan AD, Price CI, Barnes MP, Johnson GR. A biomechanical investigation into the validity of the modified Ashworth Scale as a measure of elbow spasticity. *Clin Rehabil.* 2003;17(3):290–4; doi: 10.1191/0269215503cr610oa.
- [38] Luo Z, Lo WLA, Bian R, Wong S, Li L. Advanced quantitative estimation methods for spasticity: a literature review. *J Int Med Res.* 2020;48(3):0300060519888425; doi: 10.1177/0300060519888425.
- [39] Stecco A, Stecco C, Raghavan P. Peripheral mechanisms contributing to spasticity and implications for treatment. *Curr Phys Med Rehabil Rep.* 2014;2(2):121–7; doi: 10.1007/s40141-014-0052-3.
- [40] Kwah LK, Harvey LA, Diong JHL, Herbert RD. Half of the adults who present to hospital with stroke develop at least one contracture within six months: an observational study. *J Physiother.* 2012;58(1):41–7; doi: 10.1016/S1836-9553(12)70071-1.
- [41] Lo WLA, Zhao JL, Li L, Mao YR, Huang DF. Relative and absolute interrater reliabilities of a hand-held myotonometer to quantify mechanical muscle properties in patients with acute stroke in an inpatient ward. *Bio-med Res Int.* 2017;2017:4294028; doi: 10.1155/2017/4294028.
- [42] Lindberg PG, Gäverth J, Islam M, Fagergren A, Borg J, Forssberg H. Validation of a new biomechanical model to measure muscle tone in spastic muscles. *Neurorehabil Neural Repair.* 2011;25(7):617–25; doi: 10.1177/1545968311403494.
- [43] Plantin J, Pennati GV, Roca P, Baron JC, Laurencikas E, Weber K, Godbolt AK, Borg J, Lindberg PG. Quantitative assessment of hand spasticity after stroke: imaging correlates and impact on motor recovery. *Front Neurol.* 2019;10:836; doi: 10.3389/fneur.2019.00836.
- [44] Sim J, Wright CC. The Kappa statistic in reliability studies: use, interpretation, and sample size requirements. *Phys Ther.* 2005;85(3):257–68.

Appendix 1. MAS assessment description in the affected side of post-stroke patients

Hip extensors: Standing next to the affected side of the patient, the rater placed one hand under the knee on the medial and lateral femoral condyles, and the other on the internal and external malleoli. The participant was asked to relax as much as possible. The lower limb was moved from maximum hip and knee extension to maximum hip flexion and 90° of knee flexion [1].

Hip flexors: Standing next to the affected side of the patient, the rater placed one hand over the knee on the medial and lateral femoral condyles, and the other hand under the heel. The patient was asked to relax as much as possible. The lower limb was moved from maximum hip flexion and 90° of knee flexion to maximum hip and knee extension [1].

Knee extensors and flexors: Standing next to the affected side of the patient, the rater placed one hand near the knee on the lateral surface of the thigh to stabilise the femur, and the other hand proximal to the ankle. To assess the knee extensor, with the hip fixed between 45° and 60° of flexion, depending on the contractures of the participant, the knee was moved from maximum extension to maximum flexion. To assess the knee flexor, with the hip fixed in the previous position, the knee was moved from maximum flexion to maximum extension.

Dorsiflexors and plantarflexors: Standing next to the affected side of the patient, the rater placed one hand under the patient's sole on the metatarsals, and one hand on the malleoli of the ankle joint. To assess the dorsiflexors, the ankle was moved from maximum dorsiflexion to maximum plantarflexion. To assess the plantarflexors, the ankle was moved from maximum plantarflexion to maximum dorsiflexion. The movement was performed in both muscle groups.

Appendix 2. Distribution of evaluators' responses

Appendix 2a. Hip muscle groups						
Hip flexors	Evaluator 2					
Evaluator 1	0	1	1+	2	3	Total
0	2	4	1	0	0	7
1	4	3	1	0	0	8
1+	0	1	5	1	1	8
2	0	2	1	1	0	4
3	0	0	0	3	2	5
Total	6	10	8	5	3	32
Hip extensors	Evaluator 2					
Evaluator 1	0	1	1+	2	3	Total
0	4	1	0	0	0	5
1	4	3	0	1	1	9
1+	0	3	4	1	0	8
2	0	0	2	1	1	4
3	0	0	0	2	4	6
Total	8	7	6	5	6	32

Appendix 2b. Knee muscle groups							
Knee flexors	Evaluator 2						
Evaluator 1	0	1	1+	2	3	4	Total
0	1	3	0	0	0	0	4
1	1	3	1	1	0	0	6
1+	0	1	6	1	1	0	9
2	0	1	1	5	2	0	9
3	0	0	0	1	1	0	2
4	0	0	0	0	1	1	2
Total	2	8	8	8	5	1	32
Knee extensors	Evaluator 2						
Evaluator 1	0	1	1+	2	3	4	Total
0	0	5	1	1	0	0	7
1	0	1	2	2	1	0	6
1+	1	1	3	4	0	0	9
2	0	0	1	1	2	0	4
3	0	0	1	2	2	0	5
4	0	0	0	0	0	1	1
Total	1	7	8	10	5	1	32

Appendix 2c. Ankle muscle groups							
Dorsiflexors	Evaluator 2						
Evaluator 1	0	1	1+	2	3	4	Total
0	9	6	0	0	0	0	15
1	1	6	1	0	2	0	10
1+	0	0	2	1	1	1	5
2	0	0	0	0	0	0	0
3	0	0	1	0	0	0	1
4	0	0	0	0	0	1	1
Total	10	12	4	1	3	2	32
Plantarflexors	Evaluator 2						
Evaluator 1	0	1	1+	2	3	4	Total
0	6	6	0	0	0	0	12
1	3	4	1	2	2	0	12
1+	0	1	3	0	1	0	5
2	0	0	0	0	0	1	1
3	0	0	0	1	0	0	1
4	0	0	0	0	0	1	1
Total	9	11	4	3	3	2	32