REVIEW

Clinical Outcome Assessments for Spasticity: Review, Critique, and Recommendations

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ABSTRACT: Background: Spasticity is a common feature in patients with disruptions in corticospinal pathways. However, the term is used ambiguously. Here, spasticity is defined as enhanced velocity-dependent stretch reflexes and placed within the context of deforming spastic paresis encompassing other forms of muscle overactivity.

Objective: This scoping review aims at evaluating the clinimetric quality of clinical outcome assessments (COAs) for spasticity across different pathologies and to make recommendations for their use.

Methods: A literature search was conducted to identify COAs used to assess spasticity. An international expert panel evaluated the measurement properties in the included COAs. Recommendations were based on the MDS-COA program methodology based on three criteria: if the COA was (1) applied to patients with spastic paresis, (2) used by others beyond the developers, and (3)

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determined to be reliable, valid, and sensitive to change in patients with spasticity.

Results: We identified 72 COAs of which 17 clinician-reported outcomes (ClinROs) and 6 patient-reported outcomes (PROs) were reviewed. The Tardieu Scale was the only ClinRO recommended for assessing spasticity. One ClinRO—Composite Spasticity Index—and two PROs—Spasticity 0–10 Numeric Rating Scale and 88-Item Multiple Sclerosis Spasticity Scale—were recommended with caveats. The Ashworth-derived COAs were excluded after evaluation due to their focus on muscle tone rather than spasticity, as defined in this review.

Conclusions: The Tardieu Scale is recommended for assessing spasticity, and two PROs are recommended with caveats. Consistent terminology about the various types of muscle overactivity is necessary to facilitate their assessment and treatment.

Key Words: muscle spasticity; spastic paresis; muscle overactivity; muscle hypertonia; rating scales; psychometrics; review

Spasticity is seen in patients with subacute or chronic disruption of the central execution of motor command involving corticospinal pathways.[1,2] However, the use of the term spasticity is equivocal in the vast amount of literature on this topic[3] ranging from an understanding of spasticity simply as a phenomenon of increased resistance to passive stretch, whichever the mechanisms of the resistance, that is, muscle tone,[4-7] to a specific type of muscle overactivity related to hyperexcitability of the velocity-dependent stretch reflexes, which characterizes the syndrome of spastic paresis.[1,2] In parallel, an expansion of the concept of spasticity has been proposed, defining it as a disorder of sensorimotor control manifesting as any intermittent or sustained involuntary activation of muscles of neurogenic origin.[8] Following Lance[9] and, more recently, Gracies,[2] Li,[10] and the recent viewpoint by the International Parkinson and Movement Disorder Society (MDS) Spasticity Study Group,[11] the definition of spasticity used in this review is an enhancement of velocity-dependent stretch reflexes. From the phenomenological perspective relevant to clinicians, this particular definition distinguishes spasticity from other types of muscle overactivity present in patients with deforming spastic paresis (eg, spastic dystonia and spastic cocontraction[2]) or from types of muscle overactivity encountered in other neurological conditions (eg, tremors or rigidity classifiable as "spasticity" based on less specific definitions[8]). This definition integrates spasticity into the broader concept of deforming spastic paresis involving spastic myopathy,[1] a term used to describe the muscle disorder present in these patients, and a neurologic disorder comprising stretch-sensitive paresis (ie, decreased access of the central command to the agonist motoneuron, aggravated by antagonist stretch) and three main types of muscle overactivity (defined as increased involuntary motor unit recruitment): spastic dystonia (chronic tonic muscle activation at rest), spastic cocontraction (involuntary antagonist muscle activation during an agonist-directed voluntary effort), and spasticity (Table 1).[2] Such framing clears the way for a balanced evaluation of spasticity: *per se*, its disabling level is low (with the possible exception of fast, ballistic movements), and it has no deforming capacity, but it can serve as a useful clinical parameter quantifiable at the bedside, which may be correlated with more disabling forms of spastic muscle overactivity because they may all partially reflect both enhanced motoneuronal excitability and spindle responsiveness.[3] Of course, such an evaluation requires a valid, reliable, and easy-to-use clinical assessment outcome (COA).

However, the reality of the commonly used "spasticity" COAs parallels the term's ambiguity. Currently, the most widely used assessment tool is the Ashworth Scale (AS) or its modified version (MAS), which rather quantifies general resistance to passive stretch at rest (ie, muscle tone[6,7,12]) velocity-dependence of the stretch-reflexes.[3,13-17] Nevertheless, it has often been considered the gold standard of "spasticity" assessment, particularly by regulatory agencies, which has confused several spasticity-related fields, especially when aiming to validate pharmacological, (neuro)surgical, and rehabilitation treatments. Thus, the main goals of this review were to evaluate COAs aiming to assess spasticity, to critically appraise them from the viewpoint of the concept of deforming spastic paresis, and to make recommendations regarding their use based on highly standardized MDS COA methodology.

Methods

Organization and Review Process

The MDS COA Scientific Evaluation Committee (COA-SEC) invited R.J. to form and chair an international group of experts on spasticity to perform a scoping review of COAs assessing spasticity across different pathologies. Based on the number of COAs identified, 11 specialists in spasticity were invited to participate. These experts included neurologists, physiatrists, physiotherapists, and clinimetricians from Europe, Asia, and the Americas. Two panel members evaluated each COA

TABLE 1 *Terminology table: for further details, see Baude et al.*[3]

Term	Definition
(Deforming) Spastic paresis	Clinical syndrome caused by lesions involving corticospinal pathways, comprising spastic myopathy, stretch-sensitive paresis, and muscle overactivity.
Spastic myopathy	Evolving muscle disorder following immobilization in short or neutral position in the context of spastic paresis, clinically manifested by hypo-extensibility, then deformity.
Stretch-sensitive paresis	Decreased access of the central command to the agonist motoneuron, aggravated by antagonist stretch.
Muscle overactivity	Increased involuntary motor unit recruitment.
—Spastic dystonia	Chronic tonic muscle activation at rest, in the absence of phasic stretch or voluntary effort; sensitive to the degree of tonic stretch.
—Spastic cocontraction	Involuntary antagonist muscle activation during agonist-directed voluntary effort, regardless of any phasic stretch imposed on the antagonist; sensitive to the degree of tonic stretch.
—Spasticity	Enhancement of velocity-dependent stretch reflexes.

independently, and potential discrepancies were resolved by O.G. and C.R.-B., who also reviewed their methodology. Data were entered into a template provided by the MDS-COA-SEC and adapted for this review (see Appendix S1). Information on each COA included its description, use, measurement properties, and overall impression for its use in patients with spastic paresis.

Literature Search

The methodology for this scoping review was based on a previously published methodology for critical appraisal and recommendation of COA by the MDS-COA program.[18] A literature search was performed using MEDLINE and Scopus for all publications from inception to December 2023. Keywords used in the search included the truncate terms "spastic*" OR "hyperton*" OR "tone*" as well as the terms "index" OR "measure" OR "questionnaire" OR "assessment" OR "scale." Only published or in-press peer-reviewed articles and relevant conference abstracts containing information on measurement property data (ie, validity, reliability, and responsiveness) were used (Fig. 1).

COA Selection

COAs that were used at least once in a sample of patients with spastic paresis (eg, after stroke, multiple sclerosis, brain trauma) were included only if they were clinician-reported outcome (ClinRO) or patient-reported outcome (PRO) measures designed to assess spasticity. A COA was qualified based on its stated intention to assess spasticity, its use of the term "spasticity," or its common application in clinical practice or research (eg, the Ashworth scales).

For PROs, however, strict compliance with the definition of spasticity posed challenges as patients may not report changes in their stretch reflexes. Instead, they often interpret "spasticity" as a combination of various forms of muscle overactivity or disorders, including spastic dystonia and spastic myopathy. Because these symptoms are interrelated, the authors decided to include them in the review with revised recommendation levels, as detailed in the subsequent section.

For composite COAs covering multiple constructs, some components had to focus on spasticity to be included. Electrophysiological assessments and assessments using technical devices were excluded. However, they were used for the assessment of validity of the selected COAs (see below). Additionally, COAs were excluded if they were unavailable in English; did not aim to measure spasticity but focused on other spasticity-related domains such as pain, function, or QoL; were used only in animals; were unpublished, or completely lacked data on their measurement properties. Although the Wartenberg Pendulum Test lacked measurement property data, it was reviewed for its use in clinical practice.

Evaluation of Measurement Properties

When the COA measurement properties were assessed, the following general criteria were used. As for reliability, we followed a strict approach to distinguishing test–retest from intra-rater reliability. The latter is the agreement between repeated observations within the same test session, typically using a videotape. On the contrary, the former involves the agreement between repeated observations across separate test sessions, always considering intra-rater error.[19] The intraclass correlation coefficient (ICC) and the kappa index were standard reliability assessment methods. The values ≥0.7 for ICC and ≥0.6 for kappa indicated good reliability.[20,21]

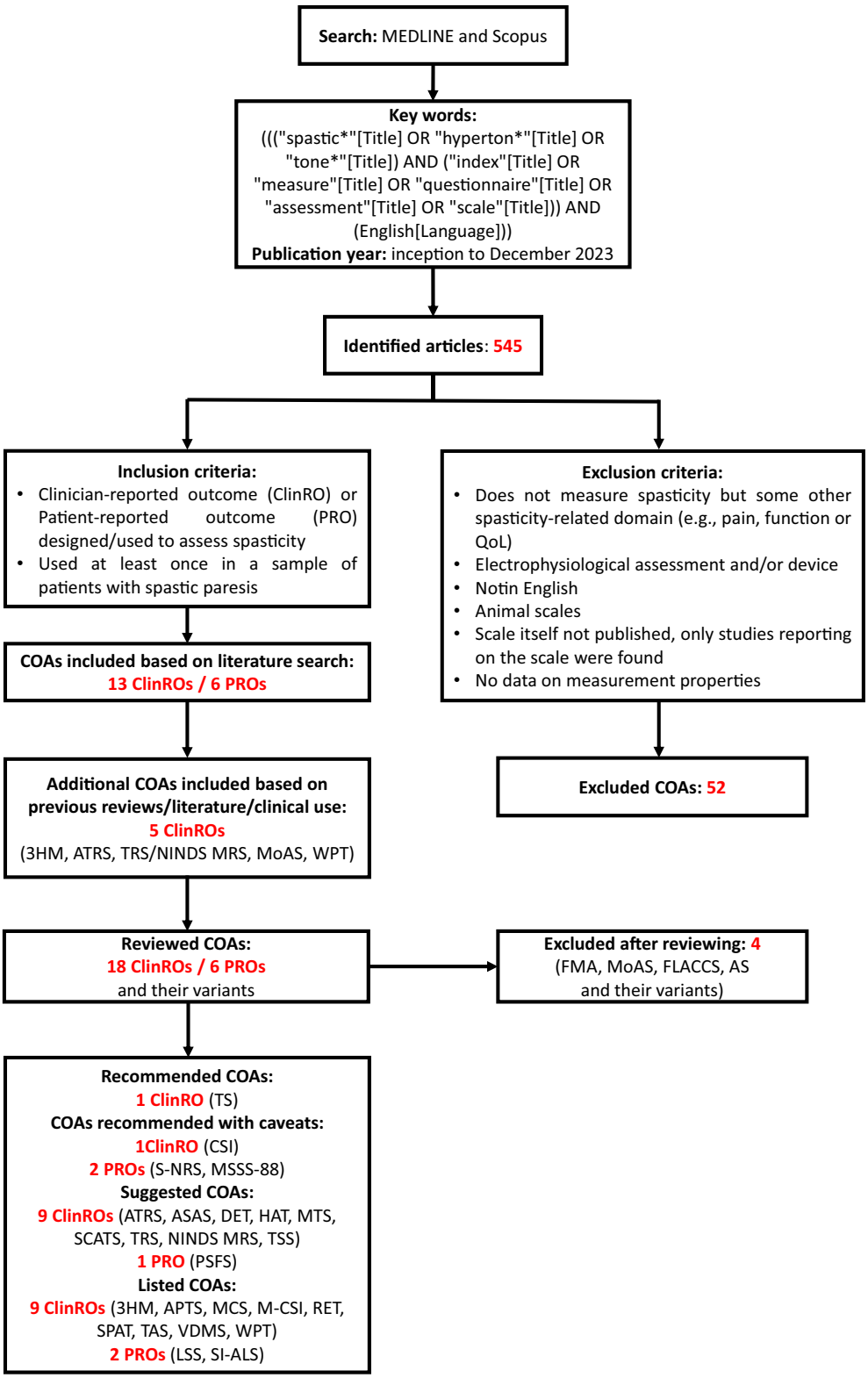

FIG. 1. Flow diagram: Search results, study selection, inclusion process, and recommendation levels. [Color figure can be viewed at wileyonlinelibrary.com]

Criterion validity was assessed by evaluating a correlation of COAs with objective measurements, such as various electromyography (EMG) variables. Correlations with related COAs were categorized as convergent or divergent construct validity. Content validity, that is, the extent to which a measure covers

the important parts of the domain to be measured, and, when available, criterion validity were emphasized in the validity section of the evaluation template, as they had the most impact on the overall assessment.

For responsiveness, the reviewers focused on specific statistics outlined by Husted et al,[22] including effect sizes for internal responsiveness, correlation of change analyses, and regression models for external responsiveness.

Recommendation Levels

Using the standardized MDS-COA program appraisal scheme, a ClinRO was "recommended" if all of the following requirements were met[1]: it was applied to patients with spastic paresis,[2] there were data on its use beyond the developers, and[3] it was found to be reliable, valid, and sensitive to change in patients with spasticity. It was "recommended with caveats" if it met these criteria but with some limitations, for example, in low number of studies, in studies with small sample size, and limited statistics. (the reasoning for each individual COA is in Appendix S1). It was "suggested" if[1] it was applied to populations with spastic paresis and only one of the other two criteria applied. It was "listed" if it was used in samples with spastic paresis, but none of the other criteria was met. In the case of PROs, the same criteria were used. Still, it could only reach the "recommended with caveats" level as the construct assessed did not fully correspond to the strict definition of spasticity.

Results

Identified COAs and their Use in Clinical Research

The original search identified 545 papers reporting on 76 COAs. Of these, 52 were excluded because they did not meet inclusion criteria or were identified as variants of a single scale. A total of 18 ClinROs and 6 PROs (and their variants) were included for evaluation and are listed in Tables 2 and 3.

After the evaluation process, the Motor Assessment Scale (MoAS),[23] Fugl-Meyer Assessment (FMA),[24] the Face, Legs, Activity, Cry and Consolability Scale (FLACC),[25] AS,[12] and their variants were excluded because they either have an unclear construct (MoAS) or focus on different constructs: impairment and recovery in the case of the FMA, pain in the case of the FLACC, and muscle tone in the case of the Ashworth COAs (Fig. 1).

Only the Tardieu Scale (TS)[26] met the criteria for "recommended." One ClinRO and two PROs were recommended with caveats: the Composite Spasticity Index,[27] Spasticity 0–10 Numeric Rating Scale,[28] and 88-Item Multiple Sclerosis Spasticity Scale.[29]

Nine ClinROs and one PRO were "suggested": the Adductor Tone Rating Scale,[30] Australian Spasticity Assessment Scale,[31] Duncan-Ely Test,[32] Hypertonia Assessment Tool,[33] Modified Tardieu Scale,[34,35] Spinal Cord Assessment Tool for Spastic Reflexes,[36] Tendon Reflex Scale,[37] National Institute of Neurological Disorders and Stroke Myotatic Reflex Scale,[38] Triple Spasticity Scale,[39] and Penn Spasm Frequency Scale.[40]

Nine ClinROs and two PROs were "listed": 3-item Hypertonus Measure,[41] Ankle Plantarflexors Tone Scale,[42] Mayo Clinic Scale,[43] Modified Composite Spasticity Index,[44] Root-Ely Test,[45] Spasticity Test,[46] Tone Assessment Scale,[47] Velocity Dependent Measure of Spasticity,[48] Wartenberg Pendulum Test,[49] Leeds Spasticity Scale,[50] and Spasticity Index-Amyotrophic Lateral Sclerosis (Tables 4 and 5).[51]

Appendix S1 contains a detailed description of all the reviewed COAs.

Recommended COAs

Tardieu Scale

Description. The Tardieu Scale (TS) measures the threshold of muscle reaction to stretch at slow and fast speeds, using two angular values: X_{V1} for the angle of arrest at a slow speed of stretch and X_{V3} for the angle of catch at a fast speed of stretch, to yield the spasticity angle $X = X_{V1}\text{-}X_{V3}$. In addition, one ordinal value (spasticity grade or Y) indicates the presence or absence of a catch or (in)fatigable clonus.[26] Several variables may be derived from these, including the spasticity and shortening coefficients.[1,52] For the construct assessed, the X_{V1} value primarily reflects histological muscle damage leading to muscle hypo-extensibility and shortening and partly spastic dystonia. In contrast, the X_{V3} value primarily reflects spasticity as the enhancement of velocity-dependent stretch reflexes alongside spastic dystonia and muscle shortening.[53,54]

A modified version of the TS exists, the Modified Tardieu Scale (MTS).[34,35] However, it is less reliable in terms of test–retest and inter-rater reliability and was thus only classified as suggested in this review. Also, several instrumented versions exist (see Appendix S1), which were not assessed due to the clinical nature of this review.

The TS is publicly available for free in English and French. In general, the administration of the TS is brief (less than 1 minute for one muscle/muscle group). However, the assessment duration depends on the number of muscles/muscle groups tested and the rater's experience, affecting the COA reliability.[55-59] Some parts of the assessment are standardized.[55,60,61] However, a complete guideline for testing all muscles/muscle groups has not been published. The TS has been used by many groups worldwide in a broad spectrum of patients with spastic paresis.

TABLE 2 *Characteristics of the reviewed spasticity clinician-reported outcomes*

Scale	Target population	Available languages	Time to administer	UL/LL/Other	Equipment	Training
Tardieu Scales • Tardieu Scale (TS) • Modified Tardieu Scale (MTS)	Stroke, TBI, CP, MS, chronic SCI, and various other spasticity aetiologies, eg, tumor, cerebral hypoxia, cerebrovasculitis	TS: English, French MTS: English, Russian, and Brazilian Portuguese	Less than a minute for 1 muscle/muscle group (not formally assessed)	TS/MTS: UL/LL	Goniometer, chair (UL) or plinth (LL)	Inconclusive data but some training seems to be beneficial
Composite Spasticity Index (CSI) Modified Composite Spasticity Index (M-CSI)	CSI: Developed for adults with hemiplegia; used in SCI and stroke M-CSI: Not specified but used in CP	English	Max. 10 min (not formally assessed)	UL (elbow, wrist)/LL (triceps surae)	Reflex hammer	Not reported but some training seems to be beneficial
Adductor Tone Rating Scale (ATRS)	Spasticity of spinal and cerebral origin incl. MS, CP, and ALS	English	1 min (not formally assessed)	LL (hip adductors)	Plinth or wheelchair. Two examiners for grade 5	Not reported
Australian Spasticity Assessment Scale (ASAS)	Developed for CP, used also in ABI incl. stroke	English	Depending on the number of evaluated muscles, but short for 1 muscle	UL/LL	No	No specific training formally required but performed anyway in the original study
Duncan-Ely Test (DET) Root-Ely Modified Test (RET)	Mainly CP but also used in stroke and TBI with quadriceps spasticity	English	Approx. 1 min (not formally assessed)	LL (rectus femoris)	Plinth, goniometer if angle is measured	Not reported, only short instruction about standardized position and scoring system
Hypertonia Assessment Tool (HAT)	Children	English	Max. 10 min (not formally assessed)	UL/LL	No	None reported but some training seems to be beneficial
Spinal Cord Assessment Tool for Spastic Reflexes (SCATS)	Developed for SCI	English	Few minutes (not formally assessed)	LL	Plinth, reflex hammer to apply pinprick stimulus	Yes, instructional video, and practicing assessment
Tendon Reflex Scale (TRS)	All neurologic patients	English	A few minutes (not formally assessed)	UL/LL	Reflex hammer	None reported except for

(Continues)

TABLE 2 *Continued*

Scale	Target population	Available languages	Time to administer	UL/LL/Other	Equipment	Training
NINDS Myotatic Reflex Scale (NINDS MRS) Mayo Clinic Scale (MCS)						NINDS-MRS where no training effect was observed
Triple Spasticity Scale (TSS)	Not specified but used only in stroke	English, Portuguese also likely Chinese	10 min resting period + few minutes assessment (not formally assessed)	UL (elbow)/LL (triceps surae)	Plinth and goniometer	Not reported but some training seems to be beneficial
3-Item Hypertonus Measure (3HM)	Developed for stroke	English	A few minutes (not formally assessed)	UL (shoulder, elbow, wrist)	Deltoid aid and an adapted suspension arm sling, goniometer	Not reported but some training seems to be beneficial
Ankle Plantarflexors Tone Scale (APTS)	Stroke	English, Japanese	A few minutes (not formally assessed)	LL (gastrocnemii, soleus)	Plinth	Not reported but some training seems to be beneficial
Spasticity Test (SPAT)	Developed for CP children	English, probably Dutch	Max. 15 min	LL	No	The author suggests a special training program
Tone Assessment Scale (TAS)	Not specified but used only in stroke	English	Short, max. 10 min (not formally assessed)	UL/LL	Not specified but goniometer may be needed for associated reactions scoring	Recommended by the authors
Velocity Dependent Measure of Spasticity (VDMS)	Developed for children with neuromotor disorders	German, English	7–12 min	UL/LL	No	Not reported but some training seems to be beneficial
Wartenberg Pendulum Test (WPT)	Not specified	English	Less than a minute (Some centers recommend doing 4 trials 1 min apart)	LL (rectus femoris) UL (elbow/wrist?)	Plinth without any crossboard or any other construction that might interfere with the free swinging of the legs	Not reported but some training seems to be beneficial
Ashworth Scales • Ashworth Scale (AS)	AS, REPAS, MAS, MMAS, PS-M(M) AS: used in patients with increased	AS: English REPAS: English and German	AS, MAS, MMAS, PS-M(M)AS, SPRS 7 and 8: Short,	AS, REPAS, MAS, MMAS, PS-M(M) AS: UL/LL SPRS: LL	Plinth, chair	AS, REPAS, MAS, MMAS, PS-M(M) AS: recommended by many authors.

(Continues)

TABLE 2 *Continued*

Scale	Target population	Available languages	Time to administer	UL/LL/Other	Equipment	Training
• REsistance to PASsive movement scale (REPAS) • Modified Ashworth Scale (MAS) • Modified Modified Ashworth Scale (MMAS) • Peacock-Staudt Modified (Modified) Ashworth Scale (PS-M(M)AS) • Spastic Paraplegia Rating Scale (SPRS)	muscle tone of various etiologies SPRS: spastic paraplegia	MAS: English, French, German, Italian, Japanese, Korean, Spanish, and probably others MMAS: English, Persian PS-M(M)AS: English SPRS: English, Brazilian Portuguese	approx. 1 s per muscle SPRS: Short, max. 15 min			SPRS: Not reported
Fugl-Meyer Assessment (FMA)	Developed for stroke but also occasionally used in MS and TBI	English, Colombian-Spanish, French, Japanese, Romanian, Italian, Danish, Brazilian-Portuguese, Korean, French Canadian, Urdu	Whole FMA: 30–110 min Motor Function Section: 20 min Reflex section: Few min (not formally assessed)	UL/LL	A chair, bedside table, reflex hammer, cotton ball, pencil, small piece of cardboard or paper, cylindrical object, tennis ball, stop-watch, and blindfold depending on FMA protocol	Training is required
Motor Assessment Scale (MoAS)	Stroke	English, Norwegian, Brazilian	15–60 min	Not defined, could be UL and/or LL	None for item 9 (general tonus). Various ADL objects for other items as well as stopwatch and table	Not reported but some training seems to be beneficial

Abbreviations: ABI, acquired brain injury; TBI, traumatic brain injury; MS, multiple sclerosis; CP, cerebral palsy; SCI, spinal cord injury; ALS, amyotrophic lateral sclerosis; UL, upper limb; LL, lower limb.

TABLE 3 *Characteristics of the reviewed "spasticity" patient-reported outcomes*

Scale	Target population	Available languages	Time to administer	UL/LL/other	Respondent	Specific Requirements
88-Item Multiple Sclerosis Spasticity Scale (MSSS-88)	MS	English, Italian, Serbian, German	45 min	Global rating (UL+LL +trunk)	Patient	Non-demented without major neuropsychological deficits
Spasticity 0–10 Numeric Rating Scale (S-NRS)	Not specified but used in MS, CP, SCI	English	<1 min	Global rating (UL+LL +trunk)	Patient	Patient has to understand that 0 = no spasticity and 10 = most severe and bothering spasticity
Penn Spasm Frequency Scale (PSFS)	Developed for spasticity of spinal origin and used in SCI and MS	English	A few minutes	LL	Patient	Able to read and/or understand the questions
Leeds Spasticity Scale (LSS)	Stroke	English	Max. 10 min (not formally assessed)	Global rating and UL and LL individually	Patient	Understanding questions and reversed scoring in items 7 and 8
Spasticity Index-Amyotrophic Lateral Sclerosis (SI-ALS)	ALS	English	Max. 10 min (not formally assessed)	UL, LL, trunk, neck, and throat	Patient or caregiver (assistance with page turning/writing)	Able to read and/or understand the questions
Face, Legs, Activity, Cry, and Consolability Scale (FLACC) Revised Face, Legs, Activity, Cry, and Consolability Scale (r-FLACC)	CP	FLACC: English, Thai, Swedish, Brazilian Portuguese, Chinese, Korean, Japanese, Arabic r-FLACC: English, Danish	FLACC: <5 min r-FLACC: 2–5 min	Global rating of pain	The clinician observes the patient's behavior and scores it to assess patient's own non-verbal expression of the severity of the symptoms.	Clarification of the defining characteristics of observed behavior

Abbreviations: MS, multiple sclerosis; CP, cerebral palsy; SCI, spinal cord injury; ALS, amyotrophic lateral sclerosis; UL, upper limb; LL, lower limb.

TABLE 4 *Summary of "use recommendations" of spasticity clinician-reported outcomes*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
Tardieu Scales • Tardieu Scale (TS) • Modified Tardieu Scale (MTS)	TS: Good with limitations MTS: Not good	TS: Good MTS: Good	TS: Good MTS: Good	Yes	TS: Recommended MTS: Suggested	• Better standardization needed for both versions
Composite Spasticity Index (CSI) Modified Composite Spasticity Index (M-CSI)	CSI: Good with limitations M-CSI: Not good	CSI: Good with limitations M-CSI: Not good	CSI: Good with limitations M-CSI: Not assessed	CSI: Yes M-CSI: No	CSI: Recommended with caveats M-CSI: Listed	• Unclear assessment position and instructions • Targets only elbow flexors and extensors, quadriceps and triceps surae
Adductor Tone Rating Scale (ATRS)	Not assessed	Not good	Good	Yes	Suggested	• Patient position and speed of passive mobilization are not clearly stated • Poor clinimetric profile
Australian Spasticity Assessment Scale (ASAS)	Good with limitations	Not assessed	Not assessed	Yes	Suggested	• Incomplete clinimetric data • Mix between MAS and TS with unclear benefits • Unclear test procedure • R1 and R2 are not recorded despite being clinically essential
Duncan-Ely Test (DET) Root-Ely Modified Test (RET)	DET: Inconclusive RET: Good with limitations	DET: Not good RET: Not assessed	DET: Inconclusive RET: Not assessed	DET: Yes RET: No	DET: Suggested RET: Listed	DET • Binary measure (positive/negative) • Prone to confusing spasticity and contracture • Does not really specify stretch velocity • Incomplete clinimetric data • Only applicable for rectus femoris RET • Good reliability in experienced clinicians only • Incomplete clinimetric data • Not used by groups other than developers

(Continues)

TABLE 4 *Continued*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
						• Only applicable for rectus femoris
Hypertonia Assessment Tool (HAT)	Good	Not assessed	Not assessed	Yes	Suggested	• Some items would not be adequate for non-verbal or cognitively impaired patients • Incomplete clinimetric data
Spinal Cord Assessment Tool for Spastic Reflexes (SCATS)	Good with limitations (only 1 study)	Good	Good with limitations (2 studies without responsiveness statistics)	Yes	Suggested	• Incomplete clinimetric data • Focuses only on the most severe type of spasticity, that is, clonus (ignoring non-clonic catch)
Tendon Reflex Scale (TRS) NINDS Myotatic Reflex Scale (NINDS MRS) Mayo Clinic Scale (MCS)	TRS: Not assessed NINDS MRS: Inconclusive MCS: Inconclusive	Good	Not assessed	Yes	TRS: Suggested NINDS MRS: Suggested MCS: Listed	• Incomplete clinimetric data • Severity evaluated only partly • Can be used only for some muscles/muscle groups
Triple Spasticity Scale (TSS)	Good	Good with limitations (only a few studies)	Inconclusive	Yes	Suggested	• Better standardization needed. • Incomplete clinimetric data • Use only described in elbow and ankle
3-Item Hypertonus Measure (3HM)	Not good	Not assessed	Not assessed	No	Listed	• Confounds spasticity and muscle shortening by using too slow of a stretch • Applicable only in the shoulder (only for internal rotators), elbow (only for flexors) and wrist (only for flexors) • Requires adapted overhead suspension device for shoulder and wrist assessment • Clinimetric properties not properly assessed

(Continues)

TABLE 4 *Continued*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
						• Only used by the developers.
Ankle Plantarflexors Tone Scale (APTS)	Good with limitations (only 1 study)	Good with limitations (only a few studies by one group)	Not assessed	No	Listed	• Lacks quantitative evaluation of slow passive stretch • Can be used only for triceps surae • Used only by developers • Incomplete clinimetric data and only tested in stroke patients
Spasticity Test (SPAT)	Not good	Not assessed	Not assessed	Disputably	Listed	• Incomplete clinimetric data • Only evaluated in the Netherlands by an interconnected group of researchers
Tone Assessment Scale (TAS)	Not good	Not assessed	Not assessed	No	Listed	• Poor clinimetric profile • Does not assess spastic co-contractions • Applicable only to some UL/LL muscles/muscle groups
Velocity Dependent Measure of Spasticity (VDMS)	Good with limitations (only 1 study)	Not assessed	Not assessed	No	Listed	• Redundant repetition of stretches • Potentially ambiguous rating anchors and instructions • Incomplete clinimetric data • Only used by developers
Wartenberg Pendulum Test (WPT)	Not assessed	Not assessed	Not assessed	No	Listed	• No data on clinimetric properties • Assesses presence of spasticity only (severity may be only roughly estimated) • Results completely affected by the level of relaxation and the form of sitting • Qualitative abnormalities are difficult to evaluate

(Continues)

TABLE 4 *Continued*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
						• No useful information in severe spasticity. • Used only by developers • It is not possible with the test to dissociate increased resistance in the muscle due to viscoelastic changes from the velocity-dependent resistance due to spasticity
Ashworth Scales • Ashworth Scale (AS) • REsistance to PASsive movement scale (REPAS) • Modified Ashworth Scale (MAS) • Modified Modified Ashworth Scale (MMAS) • Peacock-Staudt Modified (Modified) Ashworth Scale (PS-M(M)AS) • Spastic Paraplegia Rating Scale (SPRS)	AS: Not good REPAS: Good MAS: Conflicting MMAS: Good PS-M(M)AS: Not assessed SPRS: Inconclusive	AS: Not good REPAS: Not good MAS: Not good MMAS: Inconclusive PS-M(M)AS: Not good SPRS: Not assessed	AS: Good REPAS: Good MAS: Good MMAS: Good PS-M(M)AS: Good with limitations SPRS items 7 and 8: Not assessed	AS: Yes REPAS: Yes MAS: Yes MMAS: Disputably PS-M(M)AS: Yes SPRS: Yes	AS, REPAS, MAS, MMAS, PS-M(M)AS, SPRS: Suggested for muscle tone, excluded after evaluation for spasticity	AS, REPAS, MAS, MMAS, PS-M(M)AS, SPRS 7 and 8: • Valid as measures of tone, but not of spasticity • No distinction between muscle changes (contracture) and muscle overactivity AS, MAS, PS-M(M)AS, SPRS 7 and 8: • Low levels of standardization in the procedure (speed, amplitude, posture), as explored velocities and ranges of motion (onset and end) may markedly affect perceived resistance SPRS: • Does not represent a spasticity measurement tool as a whole
Fugl-Meyer Assessment (FMA)	FM1975: Good P2005: Good with limitations G2010: Good S2011: Good with limitations S2013: Good for UE only	Not good for spasticity	FM1975: Good P2005: Good G2010: Not assessed S2011: Not assessed S2013: Good	Yes	Excluded after evaluation for spasticity	• Evaluates impairment and not specifically spasticity • Extensive redundancy • Lengthy administration • Other protocol-specific caveats

(Continues)

TABLE 4 *Continued*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
Motor Assessment Scale (MoAS)	Good for items 1–8 Not good for item 9 (general tonus)	Good for motor function (items 1–8) Not assessed for item 9 (general tonus)	Inconclusive for motor function (items 1–8) Not assessed for item 9 (general tonus)	Yes	Excluded after evaluation for spasticity	• Lack of clear construct with respect to spasticity in item 9 (general tone). • No instructions for item 9 (general tone) • Incomplete clinimetric data for item 9 (general tone)

Measurement properties. The reliability of the TS was considered good. Still, it had limitations because positive test–retest and inter-rater reliability results were found in most muscles but only in two studies with rather small sample sizes and some statistical shortcomings. The TS has good face validity for spasticity assessment.[2,10] In one study, the TS had 100% Percentage of Exact Agreement (PEA) between the Y TS component and the EMG ($r = 0.86$ for elbow flexors; 0.62 for ankle plantar flexors) and 94% PEA between the X_{V1} TS component and laboratory measures of contracture ($r = 0.89$ for elbow flexors; 0.84 for plantar flexors), suggesting good criterion validity.[16] Another study showed similar positive results for the TS Y component compared to instrumented biomechanical assessment.[62] The COA appears sensitive to change after various interventions (botulinum toxin, anesthetic nerve blocks, selective neurotomy, physiotherapy interventions), and its responsiveness has been specifically evaluated after a long-term stretch program with good results.[63]

Strengths and weaknesses. The TS closely follows the definition of spasticity as an enhancement of velocity-dependent stretch reflexes and can differentiate between spasticity and contracture as opposed to the Ashworth-derived COAs.[16] Generally, it has good validity, reliability, and responsiveness, and does not require extensive equipment. Of clinical utility is the fact that the COA is fast, simple, and easily administered and that both the X and the Y components may reflect other types of muscle overactivity, that is, spastic dystonia[64] and spastic cocontraction.[1] The key limitation of the TS is the lack of a publicly available practical standardization for the whole assessment procedure, muscle by muscle.

Recommendation level. TS is recommended as a ClinRO of spasticity. It is suitable for screening, prevalence, clinical trials, intervention studies, and clinical practice. It should be used as a gold standard to validate other spasticity COAs.

COAs Recommended with Caveats

Composite Spasticity Index

Description. The Composite Spasticity Index (CSI) is a clinical measure of spasticity reflected by the magnitude of the stretch reflex response evaluated in both its phasic (tendon jerk, clonus) and tonic (resistance to stretch) aspects.[27,65,66] It combines the assessment of tendon jerks, MAS, and clonus elicited in the wrist and/or ankle with a rapid stretch. A total score is calculated as the sum of the three scores, but the MAS part is double-weighted. Nevertheless, the tendon jerk and clonus parts assess spasticity in a strict sense. The CSI

TABLE 5 *Summary of "use recommendations" of "spasticity" patient-reported outcomes*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
88-Item Multiple Sclerosis Spasticity Scale (MSSS-88)	Good	Good with limitations (rates "spasticity" perceived by patient as muscle stiffness)	Good	Yes	Recommended with caveats as a patient reported measure of "spasticity" perceived by the patient as muscle stiffness and its impact in adolescent or adult MS patient	• Reflects muscle stiffness rather than spasticity in the strict sense • Lengthy administration • Disease specific
Spasticity 0–10 Numeric Rating Scale (S-NRS)	Good	Good with limitations (rates "spasticity" perceived by patient as muscle stiffness)	Good	Yes	Recommended with caveats as a self-reported instrument to gather/monitor changes in subjective severity of "spasticity" perceived by the patient as muscle stiffness	• Reflects muscle stiffness rather than spasticity in the strict sense • No definition of severity of "spasticity"
Penn Spasm Frequency Scale (PSFS)	Good with limitations	Not good	Good	Yes	Suggested as a patient-reported measure of spasm frequency and severity	• Considers only spasm frequency and severity • Validity assessment is missing • Time context not standardized • Does not adequately record flexor and extensor spasms
Leeds Spasticity Scale (LSS)	Inconclusive	Good	Not assessed	No	Listed	• Sole existing validation study • Only used by developers • Only used in stroke • Responsiveness not tested

(Continues)

TABLE 5 *Continued*

Scale	Reliability	Validity	Sensitivity to change	Used beyond original developers	Recommendation level	Major caveats and clinimetric limitations of the scales
Spasticity Index-Amyotrophic Lateral Sclerosis (SI-ALS)	Inconclusive	Inconclusive	Not assessed	No	Listed	• Accessibility • Poor clinimetric profile
Face, Legs, Activity, Cry, and Consolability Scale (FLACC) Revised Face, Legs, Activity, Cry, and Consolability Scale (r-FLACC)	FLACC: Conflicting r-FLACC: Good	FLACC/r-FLACC: Good for pain FLACC/r-FLACC: Not assessed for spasticity	FLACC/r-FLACC: Not good for pain FLACC/r-FLACC: Not assessed for spasticity	Yes	Suggested for pain assessment Excluded after evaluation for spasticity (with the exception of children that for some reason cannot be assessed using spasticity scales; in such cases FLACC/r-FLACC might be clinically useful to get a rough observational estimate of muscle overactivity)	• Has been used more to evaluate pain management success, but not so much as a stand-alone tool to assess the severity of pain. This would require more validations of the different grades of pain severity. • FLACC: conflicting data on reliability • Insufficient data on responsiveness • Does not really assess spasticity and differentiate between various types of muscle overactivity and between these and contracture

is an ordinal COA that scores the presence and severity of spasticity.

A modified version of the COA exists, the modified CSI (M-CSI),[44] which eliminated the clonus section. However, because the COA has not been used beyond its developers and has a poor measurement property profile, the level of recommendation for this modified version is only listed.

The CSI is publicly available in English only with no fee. The time to perform the CSI should be less than 10 minutes, and the examination requires a reflex hammer. Instructions on how to perform the tasks need to be clarified. For instance, it needs to be clarified which joint to select and what the standardized position is when assessing. Also, Items I (tendon jerk) and II (resistance to stretch) scores 2–4 are liable to subjective interpretation. The developers and other groups used the CSI in patients with a spinal cord injury (SCI)[67] and stroke.[68]

Measurement properties. Several studies support the reliability of the CSI in terms of test–retest reliability[69,70] and internal consistency,[67,69,71] but inter-rater reliability was not assessed. In general, validity was considered good, but it had limitations because part of the COA utilizes MAS, and the validity of AS and its variants as a measure of spasticity has been repeatedly questioned (eg,[13-17]; see *Discussion* below). Two studies indicated the responsiveness of the COA with transcutaneous electrical nerve stimulation,[27,67] but responsiveness statistics were not used.

Strengths and weaknesses. The CSI has the advantage of using several velocities, which should be used in the assessment of spasticity, as well as combining three items (reflexes, stretch-induced resistance, and clonus), although the "stretch-induced resistance" could be due to muscle hypo-extensibility or spastic dystonia as well. Key caveats relate to the lack of standardization (which joint to choose, assessment position, imprecise description of some scores) and the fact that the COA can be used only to assess elbow flexors and extensors, quadriceps, and triceps surae.

Recommendation level. CSI is recommended with caveats as a ClinRO of spasticity because the resistance to stretch assessment may be contaminated by phenomena other than spasticity (spastic myopathy, spastic dystonia), the measurement property profile is good with limitations, and there are several feasibility issues. The CSI is suitable for screening, prevalence, treatment trials, correlation with other COAs, including validations, and clinical practice with caveats.

Spasticity 0–10 Numeric Rating Scale

Description. The Numeric Rating Scale (NRS) is a self-reported instrument originally designed to assess the perceived pain level. It has been adapted to assess "spasticity" perception (S-NRS), where the patient scores the presence and severity of perceived muscle stiffness—over the last 24 hours on a scale of 0 to 10.[28] Importantly, "spasticity" is explained to the patient as experienced muscle stiffness, which can be considered accurate in the case of a PRO. However, both neurological and non-neurological factors may cause muscle stiffness, and even among the neurological causes, spastic dystonia rather than spasticity likely plays a key role.

S-NRS is publicly available with no fee for the English version. However, as the NRS is utilized to assess pain worldwide, it can also be easily used for "spasticity" assessment in any language. The tool is fast to use as it rests on one simple question. However, in case of severe cognitive or language impairment, it may still be impractical to use. It has been used by developers in multiple sclerosis (MS) patients and by other groups in SCI adults and cerebral palsy (CP) children.

Measurement properties. Test–retest reliability of S-NRS was good in two studies with MS-related spasticity.[28,72] Because the COA only substitutes the word *spasticity* for *pain* as the anchor endpoint, its face and content validity are supported by the well-documented validity of the 0–10 NRS for measuring changes in pain. The S-NRS strongly correlates with the Spasm Frequency Scale,[28] MTS,[72,73] MAS,[72,73] and Spasticity Index-Amyotrophic Lateral Sclerosis,[51] suggesting good convergent validity. S-NRS responsiveness was rated as good based on the results of two cannabinoid studies in MS[28,74] and one rehabilitation treatment trial in SCI patients.[75] Also, the values of 30% clinically important difference and 18% minimal clinically important difference are available.[28]

Strengths and weaknesses. The NRS is widespread in pain and can easily be adapted for clinical practice in spasticity. It is simple and easy to report and has good measurement properties. A limitation is that the severity of "spasticity" is not defined and explained in detail.

Recommendation level. NRS is recommended with caveats as a PRO to gather/monitor changes in patient-reported severity of "spasticity" perceived by the patient as muscle stiffness. S-NRS is suitable for clinical trials, intervention studies, and clinical practice with caveats relating to the ambiguous use of "spasticity." For this reason, this COA is not suitable for validation studies of COAs that use the term spasticity in a strict sense.

88-Item Multiple Sclerosis Spasticity Scale

Description. The 88-Item Multiple Sclerosis Spasticity Scale (MSSS-88) is designed to capture the impact of "spasticity" as perceived by an MS patient over the past 2 weeks in eight clinically relevant areas: three symptoms interpreted as spasticity-related, three areas of physical functioning, and emotional health and social functioning.[29] Using a 1–4 Likert-type rating scale, the tool scores the presence and severity of symptoms and the physical and psychosocial impact of "spasticity" in a multidimensional way. The respondent should be non-demented without major neuropsychological deficits, able to read, hear, and understand questions, and respond to the 88 questions (concentration span).

The MSSS-88 is free for the English, German, Italian, and Serbian versions. The patient must exert effort to fill in the 88 items. In high-functioning patients, a minimum of 45 minutes is estimated to complete the full questionnaire. In patients with sensorial, cognitive, communication, or motor difficulties, it may take up to 2 hours to complete the full MSSS-88 questionnaire or it may not be feasible to use this PRO in the clinic. Developers and other groups have been using this COA.

Measurement properties. The MSSS-88 is internally consistent and has good item-total correlations. Test–retest validity was good in one study[76] and good for some subsections in another.[77] Although no formal content validity testing was made, it can be deemed acceptable as the COA was developed based on a conceptual model, a literature review, and the participation of patients and experts.[29] The MSSS-88 has good criterion validity (compared to a laboratory measure of ankle plantar flexor responses to stretch[78]). It correlates with other relevant COAs, that is, AS as a tone-related COA,[77-80] NRS or Patient-Reported Impact of Spasticity Measure as "spasticity" PRO,[79] and Expanded Disability Status Scale as an MS-specific scale.[80] The good responsiveness of the MSSS-88 has been shown in two studies[77,78] and considered comparable to a laboratory-based measure of ankle plantar flexor responses to stretch.[78]

Strengths and weaknesses. The MSSS-88 is easy for the clinician, although its lengthy administration can burden the patient. It has complete validation studies and is available in several languages. Except for the extensiveness of the COA, the main weaknesses are linked to the fact that it is a PRO lacking true, objective measurement of spasticity as well as to the fact that it is a disease-specific measure.

Recommendation level. The MSSS-88 is recommended with caveats as a PRO of "spasticity" and its impact in adolescent or adult patients with MS. The MSSS-88 is suitable for epidemiological studies and treatment trials with caveats relating to the ambiguous use of "spasticity." For this reason, this COA is not suitable for validation studies of COAs that use the term spasticity in a strict sense.

Discussion and Recommendations

In this review, the TS was the only ClinRO recommended to assess spasticity, followed by the CSI, S-NRS, and the MSSS-88, all recommended with caveats. The latter two evaluate "spasticity" from the patient's perspective, that is, as perceived tone. As such, however, they can only be recommended with caveats. These recommendations are not based solely on the measurement properties of the COA but also on their critical appreciation from the viewpoint of the concept of spastic paresis comprising not only spasticity but also other forms of muscle overactivity. These COAs are recommended for patients with spastic paresis regardless of the cause with the exception of MSSS-88, which is a disease-specific PRO.

The TS closely follows the definition of spasticity as an enhancement of velocity-dependent stretch reflexes. To make full use of its potential, it should be used as one component of the Five-Step Assessment (FSA) of spastic paresis[1,52] specifically designed to evaluate the most important components of spastic paresis. In brief, as the first step, the FSA identifies key muscle groups that contribute to function impairment. These muscles are subsequently evaluated technically using the TS to obtain information about their shortening and spasticity as an indicator of more disabling forms of muscle overactivity, that is, spastic dystonia and spastic cocontraction. Subsequently, active and rapid alternating movements against the resistance of the evaluated muscles are assessed. Several coefficients can be derived from these measurements, reflecting shortening, spasticity, weakness, and fatigability.[1] These have high clinical relevance as they guide the treatment process. Although precise cutoff scores are not yet available for these coefficients, their significance in the decision-making process can be—in simple terms—described the following way. Patients with a high coefficient of shortening should be primarily prescribed an intensive stretching regimen[63,81] or be sent to surgical lengthening procedures.[82] Similarly, patients with a high coefficient of spasticity, if a bothersome clonus is present and/or if spastic dystonia is and/or if the coefficients of weakness and fatigability suggest the presence of spastic cocontraction, might be primarily treated with neuromuscular agents such as botulinum toxin.[1,83-86] At the same time, intensive, specific, and long-term training of active movements against the overactive muscles should

be prescribed.[87-89] Finally, patients with a low coefficient of spasticity, no clonus, and/or without spastic dystonia or cocontraction—which may be objectified using diagnostic nerve blocks—should primarily undergo the aforementioned active training in combination with various adjunct therapies. Functional electrical stimulation or orthotic devices are two examples.[83] Of course, various other treatments are available, but stretching, active training, and possibly botulinum toxin injections should be the basic ones focusing specifically on deforming spastic paresis. On a worldwide scale, this is often not done. Our recommendation to use the TS might change this, paving the way for establishing a more transparent decision-making process and utilizing efficient treatment methods.

Regarding the two patient-reported COAs recommended with caveats—the S-NRS and MSSS-88—the choice between the two is rather simple. The main strength of the S-NRS is the wide use of similar ratings in the pain field (NRS) and its simplicity of use. On the contrary, caution is advised in interpreting these results as the COAs ask about the level of spasticity, which the patient with spastic paresis will probably interpret as a combination of various forms of muscle overactivity, especially spastic dystonia and spastic myopathy. The term "spasticity" in these COAs makes sense given the general understanding of the word and its use by clinicians who influence the patient's perception of it. However, it barely reflects the enhancement level of velocity-dependent stretch reflexes. In fact, the not-yet-validated Global Subjective Self-Assessment incorporated into the first step of the FSA comprises three NRS-based questions about pain, function, and *stiffness*, which is more precise compared to "spasticity" in S-NRS as it relates rather to the combination of muscle overactivity and spastic myopathy. As for the MSSS-88, the COA is recommended for use under two specific conditions, namely that the patient has MS-related "spasticity" and that there is enough time to complete this rather extensive survey. Regarding the use of the word "spasticity," the same caution is advised as in the case of the S-NRS. The MSSS-88 combines "spasticity" with stiffness, tightness, feeling the muscles pulling, being rigid, restricted, and other descriptions of stiffness. In this sense, it approaches the construct in question using patient-relevant descriptions. For a clinician, however, it is impossible to ascribe the scores strictly to spasticity.

The exclusion of some of the scales after evaluation requires an explanation, especially in the case of the Ashworth scales—that is, AS, REsistance to PASsive movement (REPAS), MAS, Modified MAS (MMAS), Peacock-Staudt Modified (Modified) Ashworth Scale (PS-M(M)AS), and Spastic Paraplegia Rating Scale (SPRS). Then again, this may not be surprising because Ashworth himself stopped short of claiming that his COA was measuring "spasticity" in his original publication.[12] Indeed, the Ashworth Scales rate a superordinate construct, that is, muscle tone defined as resistance to passive movement,[12] and not spasticity, which can be assessed only using at least two velocities of stretch as it is defined as an enhancement of the velocity-dependent stretch reflexes.[2,9,10] Besides failing to specify the *speed* of the passive stretch performed by the examiner, Ashworth remained silent about the *starting position* of the movement—which will also impact the reference range of motion (ROM) and the moment of perceiving the first abnormal resistance—and the *end of the actual ROM* for which the first point of abnormal resistance should be evaluated. In effect, was this the full theoretical range of the joint involved or the practically available range left by contracture? Of these three missing pieces of information, only *speed* and *onset of range* are occasionally considered an issue by some of the later authors who produced the Ashworth-derived COAs. These shortcomings led to rating the feasibility as not good in the case of the AS, MAS, PS-M(M)AS, and SPRS items 7 and 8.

Regarding the speed of the stretch, the Ashworth-derived COAs and some studies using the original AS erroneously address it by fixing the time of the stretch to 1 second[90-93] instead of fixing the speed. Because, however, the available ROM and the resistance one encounters markedly differ for various muscles, the speed of stretch will vary between them. Thus, if spasticity is defined as a velocity-related phenomenon, the ability of the AS/REPAS/MAS/MMAS to detect spasticity will vary in different segments. In addition, ROM is commonly limited by contractures in patients with chronic deforming spastic paresis. Therefore, even in segments with a physiologically large ROM where the AS/REPAS/MAS/MMAS might theoretically stretch fast enough to elicit some spastic response, in clinical practice this is usually not the case because those muscles are shortened, which in turn—due to the 1-second instruction—leads to a decrease in the speed of the stretch. Also, because the contrast between passive ROM using a slow and a fast stretch is not considered, the Ashworth-derived COAs mix contracture with "spasticity."[16]

Thus, although they are valid measures of muscle tone, the validity of AS and AS-derived COAs could not be considered good for spasticity. Regarding other measurement properties, the reliability was rated as good only in the cases of REPAS and MMAS; however, these conclusions should be treated with caution as they are derived from scarce data. Only responsiveness can be considered good in the cases of the AS, MAS, MMAS, and REPAS.

In conclusion, the expert panel recommends using the TS for spasticity assessment optimally within the framework of the FSA. Future efforts should focus on

publishing official muscle-by-muscle assessment guidelines and potentially also on developing web-based training to achieve standardized practices. Additionally, a further review—already commissioned by the MDS COA-SEC—should address the pressing need to evaluate functional COAs in patients with spastic paresis. The authors of this review urge clinicians and researchers to use the TS and adopt the terminology described within the framework of deforming spastic paresis. This approach could enhance understanding of the efficacy of various (non-)pharmacological treatments and address current research questions, such as the recurrence of "spasticity" following various neurosurgical procedures.[94]

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Data Availability Statement

The data that supports the findings of this study are available in the supplementary material of this article.

References

1. Gracies JM. Coefficients of impairment in deforming spastic paresis. Ann Phys Rehabil Med 2015;58(3):173–178.
2. Gracies JM. Pathophysiology of spastic paresis. II: emergence of muscle overactivity. Muscle Nerve 2005;31(5):552–571.
3. Baude M, Nielsen JB, Gracies JM. The neurophysiology of deforming spastic paresis: a revised taxonomy. Ann Phys Rehabil Med 2019;62(6):426–430.
4. Katz RT. Rymer WZJAopm, rehabilitation. Spastic hypertonia: Mech Meas 1989;70(2):144–155.
5. Li S, Francisco GE. Current concepts in assessment and management of spasticity. In: Wilson RRP, ed. Stroke Rehabilitation. St. Louis, Missouri: Elsevier; 2019:133–154.
6. Mosso A. Description d'un myotonomètre pour étudier la tonicité des muscles chez l'hommne. Arch ital de biol 1896;3:1–36.
7. Smith AE, Martin DS, Garvey PH, Fenn WO. A dynamic method for measurement of muscle tonus in man. J Clin Invest 1930;8(4):597–622.
8. Pandyan AD, Gregoric M, Barnes MP, Wood D, Van Wijck F, Burridge J, et al. Spasticity: clinical perceptions, neurological realities and meaningful measurement. Disabil Rehabil 2005;27(1–2):2–6.
9. Lance JWFR, Young RR, Koeller C. Spasticity: Disorder of Motor Control. Chicago, IL: Year Book Medical; 1980:485–494.
10. Li S, Francisco GE, Rymer WZ. A new definition of poststroke spasticity and the interference of spasticity with motor recovery from acute to chronic stages. Neurorehabil Neural Repair 2021;35(7):601–610.
11. Gracies J-MA K, Biering-Sørensen B, Dewald JPA, et al. For the Spasticity Study Group of the International Movement Disorders Society. Spastic Paresis: Treatable Movement Disorder. Submitted to Movement Disorders Journal; 2024.
12. Ashworth B. Preliminary trial of Carisoprodol in multiple sclerosis. Practitioner 1964;192:540–542.
13. 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):290–293.
14. Pandyan AD, Price CI, Rodgers H, Barnes MP, Johnson GR. Biomechanical examination of a commonly used measure of spasticity. Clin Biomech (Bristol, Avon) 2001;16(10):859–865.
15. Bakheit AM, 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):646–648.
16. Patrick E, Ada L. The Tardieu scale differentiates contracture from spasticity whereas the Ashworth scale is confounded by it. Clin Rehabil 2006;20(2):173–182.
17. Fleuren JF, Voerman GE, Erren-Wolters CV, Snoek GJ, Rietman JS, Hermens HJ, et al. Stop using the Ashworth scale for the assessment of spasticity. J Neurol Neurosurg Psychiatry 2010;81(1):46–52.
18. Skorvanek M, Goldman JG, Jahanshahi M, Marras C, Rektorova I, Schmand B, et al. Global scales for cognitive screening in Parkinson's disease: critique and recommendations. Mov Disord 2018;33(2):208–218.
19. Holmefur M, Aarts P, Hoare B, Krumlinde-Sundholm L. Test-retest and alternate forms reliability of the assisting hand assessment. J Rehabil Med 2009;41(11):886–891.
20. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33(1):159–174.
21. Terwee CB, Bot SD, de Boer MR, van der Windt DA, Knol DL, Dekker J, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol 2007;60(1):34–42.
22. Husted JA, Cook RJ, Farewell VT, Gladman DD. Methods for assessing responsiveness: a critical review and recommendations. J Clin Epidemiol 2000;53(5):459–468.
23. Carr JH, Shepherd RB, Nordholm L, Lynne D. Investigation of a new motor assessment scale for stroke patients. Phys Ther 1985;65(2):175–180.
24. Fugl-Meyer AR, Jääskö L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient. 1. A method for evaluation of physical performance. Scand J Rehabil Med 1975;7(1):13–31.
25. Merkel SI, Voepel-Lewis T, Shayevitz JR, Malviya S. The FLACC: a behavioral scale for scoring postoperative pain in young children. Pediatr Nurs 1997;23(3):293–297.
26. Gracies JM, Marosszeky JE, Renton R, Sandanam J, Gandevia SC, Burke D. Short-term effects of dynamic lycra splints on upper limb in hemiplegic patients. Arch Phys Med Rehabil 2000;81(12):1547–1555.
27. Levin MF, Hui-Chan CW. Relief of hemiparetic spasticity by TENS is associated with improvement in reflex and voluntary motor functions. Electroencephalogr Clin Neurophysiol 1992;85(2):131–142.
28. Farrar JT, Troxel AB, Stott C, Duncombe P, Jensen MP. Validity, reliability, and clinical importance of change in a 0-10 numeric rating scale measure of spasticity: a post hoc analysis of a randomized, double-blind, placebo-controlled trial. Clin Ther 2008;30(5):974–985.
29. Hobart JC, Riazi A, Thompson AJ, Styles IM, Ingram W, Vickery PJ, et al. Getting the measure of spasticity in multiple sclerosis: the multiple sclerosis spasticity scale (MSSS-88). Brain 2006;129(Pt 1):224–234.
30. Snow BJ, Tsui JK, Bhatt MH, Varelas M, Hashimoto SA, Calne DB. Treatment of spasticity with botulinum toxin: a double-blind study. Ann Neurol 1990;28(4):512–515.
31. Love S, Gibson N, Smith N, Bear N, Blair E. Interobserver reliability of the Australian spasticity assessment scale (ASAS). Dev Med Child Neurol 2016;58(Suppl 2):18–24.
32. Bleck EE. Orthopaedic Management in Cerebral Palsy. London: Mac Keith; 1987.
33. Jethwa A, Mink J, Macarthur C, Knights S, Fehlings T, Fehlings D. Development of the hypertonia assessment tool (HAT): a discriminative tool for hypertonia in children. Dev Med Child Neurol 2010;52(5):e83–e87.
34. Boyd RN, Graham HK. Objective measurement of clinical findings in the use of botulinum toxin type A for the management of children with cerebral palsy. Eur J Neurol 1999;6(S4):s23–s35.

35. Boyd RNBS, Ballieu CE, Graham HK. Validity of a clinical measure of spasticity in children with cerebral palsy in a double-blinded randomized controlled clinical trial, abstract. Dev Med Child Neurol 1998;40:7.
36. Benz EN, Hornby TG, Bode RK, Scheidt RA, Schmit BD. A physiologically based clinical measure for spastic reflexes in spinal cord injury. Arch Phys Med Rehabil 2005;86(1):52–59.
37. Bates B. A Guide to Physical Examination and History Taking. 5th ed. Philadelphia: Lippincott; 1991.
38. Hallett M. NINDS myotatic reflex scale. Neurology 1993;43(12): 2723.
39. Li F, Wu Y, Xiong L. Reliability of a new scale for measurement of spasticity in stroke patients. J Rehabil Med 2014;46(8):746–753.
40. Priebe MM, Sherwood AM, Thornby JI, Kharas NF, Markowski J. Clinical assessment of spasticity in spinal cord injury: a multidimensional problem. Arch Phys Med Rehabil 1996;77(7):713–716.
41. Worley JS, Bennett W, Miller G, Miller M, Walker B, Harmon C. Reliability of three clinical measures of muscle tone in the shoulders and wrists of poststroke patients. Am J Occup Ther 1991;45(1): 50–58.
42. Takeuchi N, Kuwabara T, Usuda S. Development and evaluation of a new measure for muscle tone of ankle plantar flexors: the ankle plantar flexors tone scale. Arch Phys Med Rehabil 2009;90(12): 2054–2061.
43. Stam J, van Crevel H. Reliability of the clinical and electromyographic examination of tendon reflexes. J Neurol 1990;237(7): 427–431.
44. Jobin A, Levin MF. Regulation of stretch reflex threshold in elbow flexors in children with cerebral palsy: a new measure of spasticity. Dev Med Child Neurol 2000;42(8):531–540.
45. Drefus LC, Clarke S, Resnik K, Koltsov J, Dodwell ER, Scher DM. The root-Ely modified test of rectus Femoris spasticity has reliability in individuals with cerebral palsy. HSS J: Musculoskeletal J Hospital Special Surg 2018;14(2):143–147.
46. Scholtes VA, Dallmeijer AJ, Knol DL, Speth LA, Maathuis CG, Jongerius PH, et al. Effect of multilevel botulinum toxin a and comprehensive rehabilitation on gait in cerebral palsy. Pediatr Neurol 2007;36(1):30–39.
47. Barnes S, Gregson J, Leathley M, Smith T, Sharma A, Watkins C. Development and inter-rater reliability of an assessment tool for measuring muscle tone in people with hemiplegia after a stroke. Physiotherapy 1999;85(8):405–409.
48. Marsico P, Frontzek-Weps V, van Hedel HJA. Velocity dependent measure of spasticity: reliability in children and juveniles with neuromotor disorders. J Pediatr Rehabil Med 2021;14(2):219–226.
49. Wartenberg R. Pendulousness of the legs as a diagnostic test. Neurology 1951;1(1):18–24.
50. Barker S, Horton M, Kent RM, Tennant A. Development of a self-report scale of spasticity. Top Stroke Rehabil 2013;20(6):485–492.
51. Milinis K, Tennant A, Mills RJ, Al-Chalabi A, Burke G, Dick DJ, et al. Development and validation of spasticity index-amyotrophic lateral sclerosis. Acta Neurol Scand 2018;138(1):47–54.
52. Gracies JM, Bayle N, Vinti M, Alkandari S, Vu P, Loche CM, et al. Five-step clinical assessment in spastic paresis. Eur J Phys Rehabil Med 2010;46(3):411–421.
53. Gracies JM, Esquenazi A, Brashear A, Banach M, Kocer S, Jech R, et al. Efficacy and safety of abobotulinumtoxinA in spastic lower limb: randomized trial and extension. Neurology 2017;89(22): 2245–2253.
54. Winston P, Mills PB, Reebye R, Vincent D. Cryoneurotomy as a percutaneous mini-invasive therapy for the treatment of the spastic limb: case presentation, review of the literature, and proposed approach for use. Arch Rehab Res Clin Transl 2019;1(3–4):100030.
55. Gracies JM, Burke K, Clegg NJ, Browne R, Rushing C, Fehlings D, et al. Reliability of the Tardieu scale for assessing spasticity in children with cerebral palsy. Arch Phys Med Rehabil 2010;91(3): 421–428.
56. Baude M, Loche CM, Gault-Colas C, Pradines M, Gracies JM. Intra- and inter-raters reliabilities of a stepped clinical assessment of chronic spastic paresis in adults. Ann Phys Rehabil Med 2015;58: e4–e5.
57. Singh P, Joshua AM, Ganeshan S, Suresh S. Intra-rater reliability of the modified Tardieu scale to quantify spasticity in elbow flexors and ankle plantar flexors in adult stroke subjects. Ann Indian Acad Neurol 2011;14(1):23–26.
58. Akpinar P, Atici A, Ozkan FU, Aktas I, Kulcu DG, Sarı A, et al. Reliability of the modified Ashworth scale and modified Tardieu scale in patients with spinal cord injuries. Spinal Cord 2017;55(10): 944–949.
59. Ansari NN, Naghdi S, Hasson S, Rastgoo M, Amini M, Forogh B. Clinical assessment of ankle plantarflexor spasticity in adult patients after stroke: inter-and intra-rater reliability of the modified Tardieu scale. Brain Inj 2013;27(5):605–612.
60. Pradines M, Baude M, Marciniak C, Francisco G, Gracies JM, Hutin E, et al. Effect on passive range of motion and functional correlates after a long-term lower limb self-stretch program in patients with chronic spastic paresis. PM R 2018;10(10):1020–1031.
61. Pradines M, Poitou T, Gál O, Hoskovcová M, Bayle N, Baude M, et al. Where is the zero of Tardieu for proximal trans-joint lower limb muscles? The relevance for the estimation of muscle shortening and weakness. Front Neurol 2023;14:1–4.
62. Van't Veld RC, Flux E, van Oorschot W, Schouten AC, van der Krogt MM, van der Kooij H, et al. Examining the role of intrinsic and reflexive contributions to ankle joint hyper-resistance treated with botulinum toxin-a. J Neuroeng Rehabil 2023;20(1):19.
63. Pradines M, Ghedira M, Portero R, Masson I, Marciniak C, Hicklin D, et al. Ultrasound structural changes in triceps Surae after a 1-year daily self-stretch program: a prospective randomized controlled trial in chronic hemiparesis. Neurorehabil Neural Repair 2019;33(4):245–259.
64. Bhadane MY, Gao F, Francisco GE, Zhou P, Li S. Correlation of resting elbow angle with spasticity in chronic stroke survivors. Front Neurol 2015;6:183.
65. Chan CWY. Motor and sensory deficits following a stroke: relevance to a comprehensive evaluation. Physiother Can 1986;38: 29–34.
66. Calota A, Levin MF. Tonic stretch reflex threshold as a measure of spasticity: implications for clinical practice. Top Stroke Rehabil 2009;16(3):177–188.
67. Goulet C, Arsenault AB, Bourbonnais D, Laramée MT, Lepage Y. Effects of transcutaneous electrical nerve stimulation on H-reflex and spinal spasticity. Scand J Rehabil Med 1996;28(3):169–176.
68. Levin MF, Selles RW, Verheul MH, Meijer OG. Deficits in the coordination of agonist and antagonist muscles in stroke patients: implications for normal motor control. Brain Res 2000;853(2):352–369.
69. Levin MF, Hui-Chan C. Are H and stretch reflexes in hemiparesis reproducible and correlated with spasticity? J Neurol 1993;240(2): 63–71.
70. Ng SS, Hui-Chan CW. The timed up & go test: its reliability and association with lower-limb impairments and locomotor capacities in people with chronic stroke. Arch Phys Med Rehabil 2005;86(8): 1641–1647.
71. Nadeau S, Arsenault AG, Gravel D, Lepage Y, Bourbonnais D. Analysis of the spasticity index used in adults with a stroke. Can J Rehab 1998;11:219–220.
72. Anwar K, Barnes MP. A pilot study of a comparison between a patient scored numeric rating scale and clinician scored measures of spasticity in multiple sclerosis. NeuroRehabilitation 2009;24(4):333–340.
73. Tsai S, Blackburn J, Gaebler-Spira D. Validation of the 0–10 numeric rating scale measure of spasticity in children with cerebral palsy. J Pediatr Neurol 2016;14: (01):12–16.
74. Patti F, Messina S, Solaro C, Amato MP, Bergamaschi R, Bonavita S, et al. Efficacy and safety of cannabinoid oromucosal spray for multiple sclerosis spasticity. J Neurol Neurosurg Psychiatry 2016;87(9):944–951.
75. Stampacchia G, Rustici A, Bigazzi S, Gerini A, Tombini T, Mazzoleni S. Walking with a powered robotic exoskeleton: subjective experience, spasticity and pain in spinal cord injured persons. NeuroRehabilitation 2016;39(2):277–283.

76. Rodic SZ, Knezevic TI, Kisic-Tepavcevic DB, Dackovic JR, Dujmovic I, Pekmezovic TD, et al. Validation of the Serbian version of multiple sclerosis spasticity scale 88 (MSSS-88). PLoS One 2016; 11(1):e0147042.
77. Henze T, von Mackensen S, Lehrieder G, Zettl UK, Pfiffner C, Flachenecker P. Linguistic and psychometric validation of the MSSS-88 questionnaire for patients with multiple sclerosis and spasticity in Germany. Health Qual Life Outcomes 2014;12:119.
78. Freeman J, Gorst T, Ofori J, Marsden J. Evaluation of the multiple sclerosis spasticity scale 88: a short report. Rehab Process Outcome 2019;8:1–4.
79. Knežević T, Rodić SZ, Foti C, Nikolić-Drulović J, Dujmovic I, Konstantinović LM. Subscale Correlations between MSSS-88 and PRISM Scales in Evaluation of Spasticity for Patients with Multiple Sclerosis. Srpski arhiv za celokupno lekarstvo 2017;145(9-10):481–485.
80. Ottonello M, Pellicciari L, Centonze D, Foti C, Pistarini C, Albensi C, et al. The cross-cultural adaptation and psychometric validation of the MSSS-88 for use in Italian patients with multiple sclerosis. Disabil Rehabil 2019;41(4):465–471.
81. Lecharte T, Gross R, Nordez A, Le Sant G. Effect of chronic stretching interventions on the mechanical properties of muscles in patients with stroke: a systematic review. Ann Phys Rehabil Med 2020;63(3):222–229.
82. Gross R, Verduzco-Gutierrez M, Draulans N, Zimerman M, Francisco GE, Deltombe T. Module 3: Surg Manag Spasticity. Journal of the International Society of Physical and Rehabilitation Medicine 2022;5(Suppl 1):S38–S49.
83. Deltombe T, Wautier D, De Cloedt P, Fostier M, Gustin T. Assessment and treatment of spastic equinovarus foot after stroke: guidance from the Mont-Godinne interdisciplinary group. J Rehabil Med 2017;49(6):461–468.
84. Simpson DM, Hallett M, Ashman EJ, Comella CL, Green MW, Gronseth GS, et al. Practice guideline update summary: botulinum neurotoxin for the treatment of blepharospasm, cervical dystonia, adult spasticity, and headache. Rep the Guid Dev Subcommittee Am Acad Neurol 2016;86(19):1818–1826.
85. Biering-Soerensen B, Stevenson V, Bensmail D, Grabljevec K, Martínez Moreno M, Pucks-Faes E, et al. European expert consensus on improving patient selection for the management of disabling spasticity with intrathecal baclofen and/or botulinum toxin type a. J Rehabil Med 2022;54:1–13.
86. Wissel J, Ward AB, Erztgaard P, Bensmail D, Hecht MJ, Lejeune TM, et al. European consensus table on the use of botulinum toxin type a in adult spasticity. J Rehabil Med 2009;41(1):13–25.
87. Cramer SC, Sur M, Dobkin BH, O'Brien C, Sanger TD, Trojanowski JQ, et al. Harnessing neuroplasticity for clinical applications. Brain 2011;134(Pt 6):1591–1609.
88. Winstein C, Varghese R. Been there, done that, so what's next for arm and hand rehabilitation in stroke? NeuroRehabilitation 2018; 43(1):3–18.
89. Gracies JM, Francisco GE, Jech R, Khatkova S, Rios CD, Maisonobe P. Guided self-rehabilitation contracts combined with AbobotulinumtoxinA in adults with spastic paresis. J Neurol Phys Ther: JNPT 2021;45(3):203–213.
90. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther 1987;67(2): 206–207.
91. Ansari NN, Naghdi S, Younesian P, Shayeghan M. Inter- and intra-rater reliability of the modified modified Ashworth scale in patients with knee extensor poststroke spasticity. Physiother Theory Pract 2008;24(3):205–213.
92. Haas BM, Bergström E, Jamous A, Bennie A. The inter rater reliability of the original and of the modified Ashworth scale for the assessment of spasticity in patients with spinal cord injury. Spinal Cord 1996;34(9):560–564.
93. Platz T. Personal Communication about REPAS Via Email; 2023.
94. Deltombe T, Decq P, Mertens P, Gustin T. Does fascicular neurotomy have long-lasting effects? J Rehabil Med 2007;39(5): 421–422.

Supporting Data

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