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ASSESSMENT OF SPASTICITY IN CHILDREN WITH CEREBRAL PALSY USING THE MODIFIED TARDIEU SCALE

A narrative review of clinical applications and measurement reliability

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ABSTRACT

Background. Assessing spasticity in children with cerebral palsy requires consideration of velocity-dependent reflex responses and mechanical restrictions of passive movement. The Modified Tardieu Scale (MTS) provides a clinical description of these components, although its reliability depends on assessment conditions.

Objective. To synthesize evidence on the clinical application, measurement reliability and interpretation of the MTS in children with cerebral palsy.

Materials and methods. Ten key publications identified through PubMed records and publisher websites were examined in a narrative review. Samples, assessment conditions and reliability findings from six clinical studies were compared. Sources were checked on 19 October 2026; no meta-analysis was performed.

Results. Intrarater and interrater reliability require separate interpretation. Reliability varies across muscle groups, rater training and measured parameters. The fast-stretch reaction angle (R1), maximum passive range (R2) and R2 − R1 difference do not have equivalent measurement properties. Contemporary recommendations distinguish the evidence supporting the original Tardieu Scale from that supporting the MTS.

Conclusion. The MTS can support a comprehensive assessment when a standardized protocol is used. The R2 − R1 difference should not independently establish the presence of contracture. Findings should be interpreted alongside joint range of motion, pain, gait and functional status.

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Introduction

Cerebral palsy (CP) describes a group of conditions associated with non-progressive disturbances of the developing brain and persistent limitations in movement and postural control. Although the brain disturbance itself is non-progressive, secondary changes in muscles and joints may alter the clinical presentation as a child grows [1].

Spasticity is characterized by an increase in reflex resistance as the velocity of passive stretch increases. However, the total resistance perceived during clinical examination also reflects muscle–tendon stiffness, contracture and other factors. Using muscle tone, passive mechanical resistance and spasticity as interchangeable terms can therefore lead to misinterpretation of assessment findings [2].

The Modified Tardieu Scale (MTS) combines the response to passive stretch at different velocities with angular measurements. In the 2025 international expert evaluation, the original Tardieu Scale was classified as “recommended” for assessing spasticity, whereas the MTS was classified as “suggested”. These categories are distinct, and a recommendation for the original scale cannot automatically be extended to all its modifications [3].

This review aims to synthesize evidence on the clinical applications and reliability of the MTS in children with CP, identify limitations in the interpretation of R1 and R2, and outline the main considerations for standardizing clinical assessment.

Materials and methods

The article was prepared as a narrative literature review. PubMed bibliographic records and available publisher webpages were used to verify sources. The targeted search used combinations of “cerebral palsy”, “Modified Tardieu”, “Tardieu Scale”, “reliability”, “intrarater”, “interrater” and “standardized movement speeds”. Sources were checked on 19 October 2026.

Clinical studies evaluating the Tardieu Scale or MTS in children with CP were selected, together with reviews addressing the conceptual basis of the scales and methodological publications on measurement reliability. Findings from adults with other neurological conditions were not included as direct evidence for the pediatric population. Distinctions between the Tardieu Scale and MTS were retained as reported in the sources.

Ten key publications were included. Six were clinical studies from which the number of participants or assessed limbs, muscle groups, number of raters or training conditions, and principal reliability findings were extracted for comparison [4–9]. Interpretation was supplemented by recommendations on the selection and reporting of the intraclass correlation coefficient (ICC) [10].

No formal systematic review protocol, independent dual-reviewer screening or quantitative pooling was used. A meta-analysis was not performed because populations, scale versions and reliability measures differed across studies. Limb counts were not treated as equivalent

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to participant counts. Tables and figures present published information rather than findings from a new clinical cohort.

Results

MTS parameters and their clinical meaning

In the MTS, R1 is the angle at which a distinct muscle reaction, or "catch", occurs during rapid passive stretch. R2 is the maximum passive range achieved during slow stretch. The R2 − R1 difference represents the separation between these two angles. Its clinical meaning must be considered in relation to the angle convention and assessment protocol used [2,8]. Table 1 summarizes the main parameters.

Table 1. Main MTS parameters and limits of interpretation

Parameter	How it is obtained	Clinical meaning and limitation
R1	Catch angle during rapid passive stretch	Describes the velocity-dependent response; sensitive to technique and the child's ability to relax.
R2	Maximum passive range during very slow stretch	Indicates the limit of passive movement; does not guarantee complete elimination of reflex activity.
R2 − R1	Difference between R2 and R1 using the same angle convention	Provides information about the dynamic component; is not an independent test for contracture.
Reaction quality	Protocol-based recording of catch, release and clonus	An ordinal assessment; the scale version and scoring criteria must be specified.

Sources: [2,3,8]. Catch denotes a distinct resistance during rapid stretch. If R1 cannot be identified, the implications for calculating the difference should be documented.

V1 and V3 are commonly used to denote slow and fast passive stretch, respectively. Recording velocity, patient position and the method of angular measurement is necessary to preserve the meaning of the parameters. Figure 1 illustrates the assessment framework without specifying diagnostic cut-off values.

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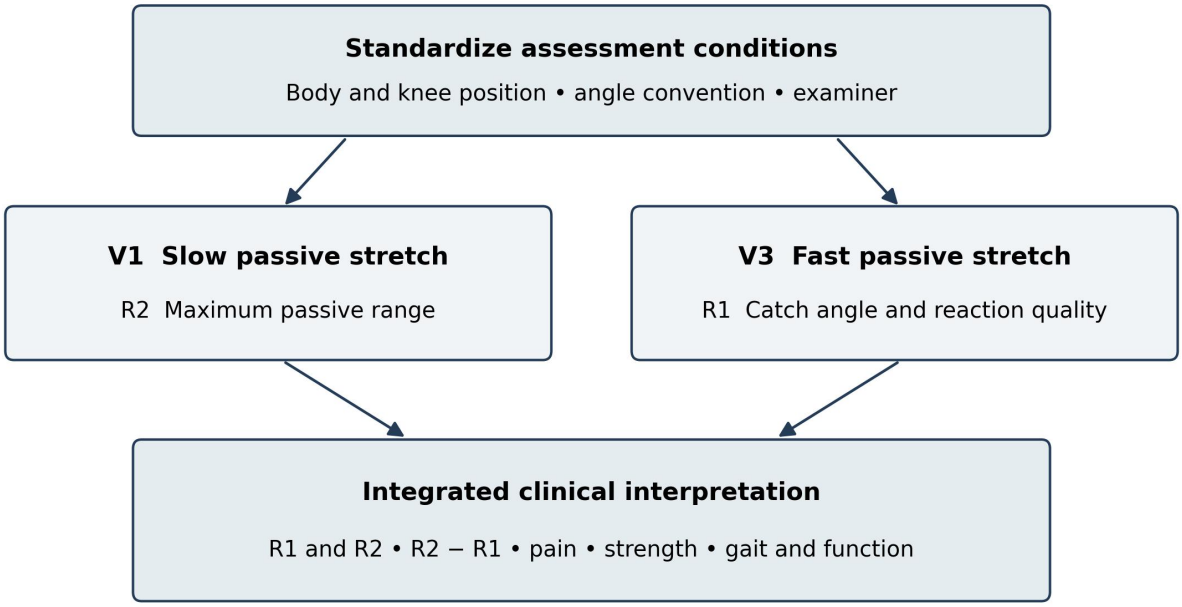


Figure 1. Acquisition and integrated interpretation of MTS parameters

Conceptual framework based on sources [2,3,8]. V1 indicates slow passive stretch and V3 indicates fast passive stretch. The framework is not a quantitative study result or a treatment algorithm.

Comparison of clinical studies

Six clinical studies represent evidence from different periods and assessment settings. Even when studies use the same scale name, the measurement property assessed and the criterion for agreement may differ. Table 2 preserves these distinctions when comparing the findings.

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Table 2. Principal clinical evidence on the Tardieu Scale and MTS in children

Study and sample	Assessment scope	Principal finding	Interpretive limitation
Fosang et al., 2003 [4] 18 children; 6 physiotherapists	Lower limbs; repeated measurements	Interrater ICC was approximately 0.70 for MTS and passive range; SEM was approximately 5°.	Small angular changes need to be considered alongside measurement error.
Yam and Leung, 2006 [5] 17 children	Two raters; 4 lower-limb muscle groups	ICC values for MAS and MTS did not reach the study's acceptable threshold of 0.75.	One standardized protocol does not ensure high agreement in other settings.
Gracies et al., 2010 [6] Study phases: 5, 3 and 15 children	Tardieu Scale; before and after training	Agreement among experienced raters increased after training; percentages are shown in Figure 2.	Original Tardieu Scale; percentage agreement is not equivalent to ICC.
Numanoğlu and Günel, 2012 [7] 37 children	One rater; 6 muscle groups	MTS intrarater reliability varied from average to good and excellent across assessments.	Intrarater findings do not directly establish interrater agreement.
Yoo et al., 2022 [8] 92 assessed limbs	Two raters; 1-week interval; standardized movement speed	Interrater MTS ICC was <0.70 for gastrocnemius and >0.75 for soleus.	The number of assessed limbs must not be interpreted as the number of participants.
Mikša Pušnik et al., 2026 [9] 23 children	MAS reliability and association with the Tardieu Scale	MAS intrarater ICC: 0.91–0.99; interrater ICC: 0.80–0.89; moderate correlation between scales.	These ICC values refer to MAS and must not be presented as MTS reliability estimates.

ICC, intraclass correlation coefficient; SEM, standard error of measurement; MAS, Modified Ashworth Scale. Study findings were not pooled.

Rater training and standardization

Gracies et al. compared agreement among experienced raters using the Tardieu Scale before and after training. Intrarater agreement changed from 77 ± 13% to 90 ± 8%, and

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interrater agreement changed from 66 ± 15% to 81 ± 13%; $p < 0.001$ was reported for both comparisons [6]. Figure 2 displays these findings.

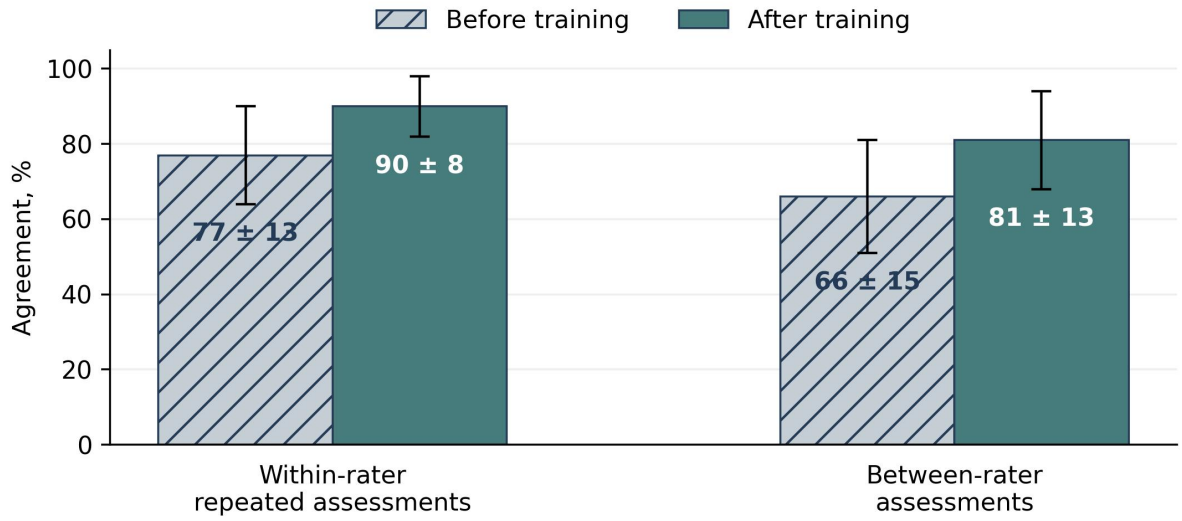


Figure 2. Tardieu Scale agreement among experienced raters

Source: Gracies et al. [6]. Bars represent mean percentages; error bars represent standard deviations (SD), not 95% confidence intervals. The pretraining and posttraining phases included 5 and 15 children, respectively. Values are not ICC estimates.

These findings support attention to rater training. However, the phase-specific samples were small and differed in size; the observed training-associated differences cannot establish a definitive causal effect applicable to every clinical setting. Evidence concerning the original Tardieu Scale also does not remove the need to examine each MTS parameter separately.

Yoo et al. used a metronome set at 120 beats per minute to standardize rapid movement. Reported ICC estimates ranged from 0.68 to 0.84 for R1 and from 0.74 to 0.93 for R2; reliability was lower for the R2 − R1 difference [8]. These ranges describe ICC values across different assessments and are not confidence intervals around a single estimate.

Clinical roles of MTS and MAS

The MTS and MAS do not provide completely interchangeable clinical information. The MAS assigns an ordinal score to overall resistance during passive movement, whereas the MTS records the response to rapid stretch separately from the range obtained during slow movement. Table 3 summarizes the practical differences [2,3].

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Table 3. Main differences between the MTS and MAS

Comparison	MTS	MAS
Main recorded measures	R1, R2, their difference and reaction quality	Ordinal score for resistance to passive movement
Attention to velocity	Slow and fast stretch are described separately	Movement speed and its implementation can affect the score
Mechanical component	R2 provides information about the passive movement limit	Reflex and mechanical resistance may both influence a single score
Reliability	Depends on muscle, parameter and rater	Varies by population and assessment protocol
Clinical interpretation	Angles are considered alongside functional findings	A score change alone does not establish functional improvement

Sources: [2,3,7–9]. The table compares general measurement features and does not imply that one scale is superior in every setting.

The 2026 study reported a moderate positive correlation between MAS and Tardieu Scale findings [9]. Correlation indicates an association between results, but it does not establish that the two methods can replace one another. Reliability, validity and responsiveness to clinical change should be evaluated as distinct measurement properties.

Discussion

The evidence reviewed highlights two conditions for interpreting MTS findings: the assessment procedure needs to be described clearly, and each finding needs to be considered against evidence relevant to the specific muscle and parameter. Combining intrarater repeatability, interrater agreement and correlations between scales under a single general label of "reliability" overstates what the evidence demonstrates.

The approximately 5° SEM reported by Fosang et al. is a useful reminder for clinical follow-up [4]. This estimate should not be adopted as a universal threshold for every muscle or protocol. Determining whether a small angular difference reflects a true change or measurement error requires error estimates derived from the relevant assessment protocol.

Interpretation of ICC requires information about the model, whether a single measurement or an average is evaluated, whether the estimate concerns absolute agreement or consistency, and the 95% confidence interval [10]. A high point estimate alone is insufficient when uncertainty is wide. Agreement in ordinal scores also needs to be distinguished from the reproducibility of R1 or R2 measured in degrees.

Because R2 − R1 is a difference score, measurement error in both angles can influence it. A larger or smaller difference may inform a clinical hypothesis but does not independently

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confirm structural contracture. The cause of restricted movement should be examined using passive range, pain, joint position and other clinical findings. Additional functional assessment is required before a change in MTS findings can be equated with improved gait or daily activity.

Practical considerations for plantar flexor assessment

The gastrocnemius crosses both the knee and ankle joints, so knee position affects its stretch response. A flexed-knee position helps relatively emphasize the soleus contribution, but does not completely isolate that muscle. Findings obtained with the knee flexed and extended should therefore not be combined as if they were collected under identical conditions.

Standardized documentation should retain the assessment date, side, muscle group, body and knee position, angular reference position, stretching method, and R1 and R2 values. Pain, anxiety or voluntary resistance that interferes with the examination should be documented. These considerations are methodological recommendations derived from the evidence reviewed, rather than a newly validated standalone protocol.

When both legs are assessed, observations from the same child may be correlated. Future analyses should use statistical approaches that account for this within-child dependence. Treating the number of legs as the number of independent participants can otherwise overstate the precision of the findings.

Evidence gaps and limitations of the review

Some of the selected clinical studies had small samples, while measurement procedures and scale versions differed. Consequently, a single reliability coefficient applicable to all muscles, age groups or rehabilitation settings cannot be derived. The different recommendation categories assigned to the original and modified Tardieu scales in 2025 further support maintaining this distinction [3].

This review used a targeted search and cannot guarantee comprehensive coverage or eliminate selection bias. The methodological quality of the sources was not formally scored. For some publications, the analysis relied on PubMed abstracts or information openly available on publisher websites. Because the findings were not quantitatively pooled, the review provides no new overall estimate of scale performance or diagnostic accuracy.

Future studies should examine gastrocnemius and soleus separately, describe rater training, and report measurement error and minimal detectable change alongside ICC estimates. Relating R1, R2 and their difference to clinically meaningful changes in gait, pain and daily activity would help clarify the practical value of the MTS.

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Conclusions

1. The MTS allows separate description of the response to rapid stretch and maximum passive range in children with CP. Its clinical value depends on standardized assessment and integration with a broader clinical evaluation.

2. Reliability depends on the muscle group, measured parameter and rater. Intrarater repeatability, interrater agreement and correlations between scales should be interpreted separately.

3. The R2 − R1 difference is not an independent criterion for confirming contracture. R1 and R2 should be considered alongside the clinical examination, pain, gait and functional measures.

4. Evidence supporting the original Tardieu Scale differs from that supporting the MTS. Further studies should clarify measurement error, muscle-specific reliability and responsiveness to clinically meaningful change.

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