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# Reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in adult patients with severe brain injury: a comparison study

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**Objective**: To assess and to compare the reliability of the Modified Tardieu Scale with the Modified Ashworth Scale in patients with severe brain injury and impaired consciousness.

**Design**: Cross-sectional observational comparison study.

**Setting**: An early rehabilitation centre for adults with neurological disorders.

**Subjects**: Thirty patients with impaired consciousness due to severe cerebral damage of various aetiologies.

**Measurement protocol**: Four experienced physical therapists rated each patient in a randomized order once daily for two consecutive days. Shoulder, elbow, wrist, hip, knee and ankle spasticity were assessed by the use of Modified Tardieu Scale and Modified Ashworth Scale data collection procedures.

**Main outcome measures**: Test−retest and inter-rater reliability ($\kappa$ = kappa value) of the Modified Tardieu Scale and the Modified Ashworth Scale.

**Results**: The test−retest reliability of the Modified Ashworth Scale was moderate to good ($\kappa = 0.47-0.62$) and of the Modified Tardieu Scale moderate to very good ($\kappa = 0.52-0.87$). Test−retest reliability was significantly higher within the Modified Tardieu Scale in comparison with the Modified Ashworth Scale ($Z > 1.96$; $p < 0.05$) except for shoulder extensor and internal rotator muscles ($Z < 1.96$; $p > 0.05$). Although inter-rater reliability of both scales was poor to moderate (Modified Ashworth Scale: $\kappa = 0.16-0.42$; Modified Tardieu Scale: $\kappa = 0.29-0.53$), significantly higher $\kappa$-values were revealed with the Modified Tardieu Scale for all tested muscle groups ($Z > 1.96$; $p < 0.05$) except for wrist extensors ($Z < 1.96$; $p > 0.05$).

**Conclusion**: In patients with severe brain injury and impaired consciousness the Modified Tardieu Scale provides higher test−retest and inter-rater reliability compared with the Modified Ashworth Scale and may therefore be a more valid spasticity scale in adults.

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## Introduction

Severe damage to the central nervous system, of varying aetiologies, often results in severe spasticity. Cerebral spasticity consists of reflex hyperexcitability, with an increase in tonic reflexes and exaggerated tendon jerks, and altered mechanical properties of the muscles. Both, reflex hyperexcitability and altered mechanical properties lead to muscle hypertonia, which is defined as an increased resistance to passive stretch. In prolonged spasticity, the constant flexed joint position, a transformation of the spastic muscles, and changes in periarticular connective tissue lead to a shortening of muscles and connective tissue, resulting in reduced active and passive joint mobility. This reduced passive range of motion (ROM) is defined as contracture. Muscle contractures and spasticity often complicate patient care, delay early rehabilitation, and/or reduce function of the limbs.[1–3]

Quantification of spasticity remains a difficult and unresolved problem.[4,5] Previous efforts have concentrated on subjective clinical measures such as the Modified Ashworth Scale or on more objective measures such as the electrophysiological reflex studies and biomechanical analysis of limb impedance to mechanical perturbation, voluntary movement or gait.[4,6] In spite of these efforts, no uniformly useful objective measurements have emerged, and therefore clinical measures such as the Modified Ashworth Scale are widely used.[4] Although standardized user guidelines have been developed to improve the reliability of the Modified Ashworth Scale, only poor to moderate inter-rater agreement for the Modified Ashworth Scale in patients with stroke,[7,8] multiple sclerosis,[9] spinal cord injury,[10] and severe brain injury[11] has been found. The Tardieu Scale, has been suggested be more appropriate for use in the measurement of clinical spasticity,[12] and was first described by Tardieu *et al.*[13] in 1954 and later modified by Held *et al.*[14] The data collection procedure involves the use of two speeds of passive movement (one very slow, the other as fast as possible) and recording the angle at which a clear 'catch' in the passive movement is felt (quality of muscle reaction and angle of muscle reaction are documented).[15,16] In children with cerebral palsy, Boyd and Graham showed that the Modified Tardieu Scale (Modified Tardieu Scale) may have less variance and might be more reliable than the Modified Ashworth Scale.[15] However, until now there have been no studies comparing the reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in adult patients with spasticity due to severe cerebral damage.

The aim of the present study was twofold, to assess the test–retest (intra-) and inter-rater reliability of the Modified Tardieu Scale and to compare the reliability of the Modified Tardieu Scale with the actual 'gold standard' of clinical spasticity scales, the Modified Ashworth Scale, in adult patients with severe cerebral damage.

## Methods

### Patients

Inclusion criteria for the study were severe cerebral damage of various aetiologies, impaired consciousness defined as Glasgow Coma Scale sum score less than 10, Coma Remission Scale sum score less than 16,[17] and duration of illness of more than 21 days. Exclusion criteria were known history of joint pain, arthrosis, surgery and/or damage of at least one joint, as determined by detailed interviews with the relatives and the family doctor. Additionally, all patients were in a stable drug programme and adapted to their current antispastic medications for at least two weeks. The study was conducted with the approval of the local Ethics Committee of the Landesärztekammer Sachsen, Germany (reference number EK-MPG-8/2000) and with the understanding and written consent of each patient's guardian.

From January to March 2004 30 patients admitted to the department of early Rehabilitation and fulfilling the inclusion and exclusion criteria were included in the study. All assessments were done during the first two weeks after admission to the department of early rehabilitation.

### Examination procedure

#### Examiners

All four examiners were physiotherapists and had at least two years experience in early neurological rehabilitation and in the assessment of contractures and spasticity. Nonetheless, according to the recommendations of Blackburn *et al.*[7] all

examiners were given two 45-min training sessions in the theoretical and practical assessment of the Modified Ashworth Scale and the Modified Tardieu Scale before the study.

*Testing procedure*

Each patient was examined in turn by each of the four examiners, and the examinations were repeated the following day. The order of the examiners' assessments was randomized using a block design. Only two patients were tested on a single day. Every patient was given a 10-min rest period between the examinations of each examiner. For reliable day-to-day comparisons, Modified Ashworth Scale and Modified Tardieu Scale scores were assessed at the same time of the day (9–10 am) with the patient in the same position. The Modified Ashworth Scale and Modified Tardieu Scale scores of the examinations were blinded between the raters.

According to the recommendations of Pandyan *et al.* we standardized the resting limb position before stretch.[18] All patients were assessed in the same position: lying supine on his or her back on a therapy couch, the upper limbs as parallel as possible to the trunk, elbows extended and wrists in a neutral position, the lower limbs parallel to one another. This was, by and large, a well-tolerated and comfortable position for the patient.[11]

**Modified Ashworth Scale data collection procedure**

The data collection procedure of the Modified Ashworth Scale has been described in detail by Bohannon and Smith,[19] Gregson *et al.*,[8] Blackburn *et al.*,[7] and Mehrholz *et al.*[11] Therefore, this procedure will be only briefly described.

All raters were instructed to move the limb through its full range of motion at a stretching velocity standardized by timing the extension of the limb (counting 'one thousand and one...') as recommended by Bohannon and Smith.[19] According to the recommendations of Nuyens *et al.* we tried to keep repeated movement cycles at a minimum.[9] Therefore, each rater was allowed to perform only one movement cycle in flexion and one movement cycle in extension for the assessment of Modified Ashworth Scale scores.

The rater extended the patient's limb first from a position of maximal possible flexion to maximal possible extension (the point at which the first soft resistance is met). Afterwards, the Modified Ashworth Scale was assessed while moving from extension to flexion. Exceptions were made during assessment of shoulder extensors (moving from extension to 90° of flexion), shoulder internal rotators (moving from neutral–zero to maximum external rotation) and ankle plantarflexors (moving from extension to flexion first with knee extended and second with knee flexed).

**Modified Tardieu Scale data collection procedure**

The data collection procedure of the Modified Tardieu Scale has been described in detail in recent publications by Boyd and Ada,[16] Gracies *et al.*,[20] and Fosang *et al.*[12] Therefore, this procedure will be also only briefly described.

The Modified Tardieu Scale is differentiated into three parts and

1) measures the passive range of motion (described as R2) at a stretching velocity as slow as possible (described as V1);
2) grades the *quality* of muscle reaction to passive stretch at the fastest stretching velocity (described as V3); and
3) measures the *angle* of muscle reaction at the point of resistance to the fastest stretching velocity when the overactive stretch reflex produces a first catch (angle of muscle reaction; described as R1).[16,20,21]

According to the recommendations of Gracies *et al.* and other researchers,[14,15,20] the rater moved the joint first with a very slow stretching velocity (described as V1) through its full range of motion. Afterwards the joint was moved by the rater 'as fast as possible' in the same direction and through the same full movement arc. The full passive range of motion was measured with a goniometer. One side of the goniometer was covered ensuring proper blinding of each rater. An observer (JM) read the goniometer values from the other side of the device.

The Modified Tardieu Scale *quality* of muscle reaction was then rated at the fastest stretching velocity, and scores range from 0 to 5. A score of 0 means no resistance through the course of the passive movement, a score of 1, slight resistance throughout the course of the passive movement arc

with no clear catch at a precise angle. A score of 2 means a clear catch occurring at a precise angle, interrupting the passive movement, followed by a release. A score of 3 means a fatigable clonus (<10 when maintaining pressure) and a score of 4 means an infatigable clonus (>10 s when maintaining pressure) occurring at a precise angle. If quality of muscle reaction score was 2 or higher, the angle of the first spasticity-provoked point of 'catch' (quantity of muscle reaction) was measured with the above-mentioned goniometer, and using the same blinding procedure as described.

To avoid possible injury to the measured joints, and according to recent suggestions of Boyd and Ada,[16] we employed a stretching velocity chosen to simulate the limb segment falling under the influence of gravity (described as V2 by Boyd and Ada[16]) instead of a maximum stretching velocity (V3), for elbow-, wrist- and knee extensor muscles.

Modified Ashworth Scale and Modified Tardieu Scale scores were assessed 192 times in each patient (two directions of each joint (shoulder flexion and external rotation, elbow, wrist, hip, and knee flexion and extension and ankle plantarflexion with knee joint flexed and extended) * two body sides (left/right) * two tests (test/retest) * four examiners).

### Statistics and reliability analysis

According to the recommendations of Pandyan, intra- and inter-rater reliability of the Modified Ashworth Scale and Modified Tardieu Scale were determined using the kappa statistics.[18,22,23] Because the scales have different ranges (Modified Ashworth Scale 0–5, Modified Tardieu Scale 0–4), calculations of the weighted kappa values with equal weights for both scales were not possible for both scales.[23] Therefore, simple (nonweighted) kappa values were calculated with the statistical package SAS. The results of the kappa statistics were interpreted as suggested by Brennan and Silman.[24] The Wald test with Bonferroni–Holm adjustment for multiple testing was used to set statistical differences between kappa values.[23] A *p*-value less than 0.05 ($Z > 1.96$) was set as statistically significant.[23]

Intraclass correlation coefficient (ICC) was calculated to determine the intra- and inter-rater

reliability of the angle of muscle reactions, because the angle is interval scaled.

## Results

Thirty patients were included in the study. The mean age, duration of illness, Glasgow Coma Scale score,[17] Coma Remission Scale score,[17] body mass index, and distributions of gender, diagnosis and antispastic therapy are shown in Table 1. Means, standard deviations, confidence intervals and ranges of the Modified Ashworth Scale and Modified Tardieu Scale for each test (test–retest) and the different examiners are not given here, to limit the length of the manuscript. Such data are available from the corresponding author.

The overall test–retest (intra-rater) and inter-rater reliability for the Modified Ashworth Scale and Modified Tardieu Scale (test and retest ratings assessed for both body sides of all patients' shoulder flexion and external rotation, elbow, wrist, hip, and knee flexion and extension and ankle plantarflexion with knee joint flexed and extended) rated by the four examiners are shown in Tables 2 and 3, respectively.

**Table 1**  Patient characteristics

| Characteristic | Patients ($n = 30$) |
| --- | --- |
| Age (years)[a] | 63.9±12.9 |
| Sex (female/male) | 9/21 |
| Diagnosis | |
|   Ischaemic stroke | 7 |
|   Intracerebral haemorrhage | 11 |
|   Traumatic brain injury | 5 |
|   Cerebral hypoxia | 7 |
| Duration of illness (days)[a] | 78±93 |
| Antispastic therapy | |
|   Local (botulinum toxin) | 0 |
|   Systemic (baclofen or tizanidine) | 2 |
|   Implanted intrathecal baclofen pump system | 0 |
| Glasgow Coma Scale score[a] | 6.9±2.3 |
| Coma Remission Scale score[a] | 8.0±4.5 |
| Body mass index (kg/m²)[a] | 24.1±3.8 |

[a]Mean±standard deviation.

**Table 2** Overall intra-rater (retest) reliability of the Modified Ashworth Scale and the Modified Tardieu Scale

| Joint/ stretching direction | Modified Ashworth Scale | | | Modified Tardieu Scale | | | | Wald test |
|---|---|---|---|---|---|---|---|---|
| | N | κ | SE | N | κ | SE | Z | p adjusted |
| Shoulder flexion | 480 | 0.55 | 0.03 | 480 | 0.65 | 0.05 | 1.68 | n.s. |
| Shoulder external rotation | 480 | 0.47 | 0.04 | 480 | 0.53 | 0.05 | 0.78 | n.s. |
| Elbow flexion | 480 | 0.47 | 0.04 | 480 | 0.78 | 0.04 | 5.68 | < 0.001 |
| elbow extension | 480 | 0.53 | 0.04 | 480 | 0.75 | 0.04 | 4.01 | < 0.001 |
| Wrist flexion | 480 | 0.58 | 0.04 | 480 | 0.87 | 0.02 | 6.26 | < 0.001 |
| Wrist extension | 480 | 0.51 | 0.04 | 480 | 0.71 | 0.04 | 3.66 | 0.001 |
| Hip flexion | 480 | 0.53 | 0.04 | 480 | 0.76 | 0.02 | 5.13 | < 0.001 |
| Hip extension | 480 | 0.49 | 0.04 | 480 | 0.72 | 0.04 | 3.76 | 0.001 |
| Knee flexion | 480 | 0.52 | 0.04 | 480 | 0.67 | 0.05 | 2.53 | 0.017 |
| Knee extension | 480 | 0.55 | 0.04 | 480 | 0.81 | 0.03 | 5.03 | < 0.001 |
| Ankle extension (knee joint flexed) | 480 | 0.62 | 0.04 | 480 | 0.82 | 0.02 | 4.62 | < 0.001 |
| Ankle extension (knee joint fully extended) | 480 | 0.47 | 0.04 | 480 | 0.72 | 0.04 | 4.32 | < 0.001 |

*N*, Number of tests (assessed by four raters for both body sides and two tests (test and retest) of 30 patients); κ, Cohen's kappa; SE, standard error; *p* adjusted, Bonferroni-Holm adjusted *p*-value; n.s., not significant.

Test–retest reliability of the Modified Tardieu Scale was significantly higher than the reliability of the Modified Ashworth Scale in all stretched muscle groups ($Z > 1.96$, $p < 0.05$), with the exception of shoulder internal rotators and shoulder extensors ($Z < 1.96$, $p > 0.05$) as shown in Table 2. Significantly higher inter-rater reliability for the Modified Tardieu Scale was revealed in comparison to the Modified Ashworth Scale for all stretching conditions ($Z > 1.96$, $p < 0.05$), except for the wrist extensors ($Z < 1.96$, $p > 0.05$), as shown in Table 3.

A scatterplot showing the relationship between the mean Modified Tardieu Scale scores and the mean Modified Ashworth Scale scores with a regression line is shown in Figure 1. Mean scores were calculated for both scales from eight assessments (four different raters and two different tests (test and retest)). Therefore, 720 pairs of mean Modified Tardieu Scale and Modified Ashworth Scale scores are represented in the scatterplot (30 patients * two directions of six joints (shoulder flexion and external rotation, elbow, wrist, hip, and knee flexion and extension and

**Table 3** Overall inter-rater reliability for the Modified Ashworth Scale and the Modified Tardieu Scale

| Joint/ stretching direction | Modified Ashworth Scale | | | Modified Tardieu Scale | | | | Wald test |
|---|---|---|---|---|---|---|---|---|
| | N | mean κ* | SE | N | mean κ* | SE | Z | p adjusted |
| Shoulder flexion | 720 | 0.29 | 0.02 | 720 | 0.44 | 0.05 | 2.52 | 0.035 |
| Shoulder external rotation | 720 | 0.16 | 0.02 | 720 | 0.39 | 0.05 | 4.35 | < 0.001 |
| Elbow flexion | 720 | 0.33 | 0.03 | 720 | 0.48 | 0.03 | 3.06 | 0.009 |
| Elbow extension | 720 | 0.42 | 0.02 | 720 | 0.51 | 0.03 | 2.49 | 0.032 |
| Wrist flexion | 720 | 0.34 | 0.06 | 720 | 0.33 | 0.07 | − 0.14 | n.s. |
| Wrist extension | 720 | 0.30 | 0.03 | 720 | 0.38 | 0.03 | 2.18 | 0.029 |
| Hip flexion | 720 | 0.31 | 0.02 | 720 | 0.42 | 0.04 | 2.39 | 0.025 |
| Hip extension | 720 | 0.24 | 0.02 | 720 | 0.37 | 0.03 | 2.96 | 0.01 |
| Knee flexion | 720 | 0.28 | 0.03 | 720 | 0.53 | 0.04 | 5.58 | < 0.001 |
| Knee extension | 720 | 0.35 | 0.02 | 720 | 0.44 | 0.03 | 2.40 | 0.033 |
| Ankle extension (knee joint flexed) | 720 | 0.20 | 0.03 | 720 | 0.47 | 0.03 | 6.26 | < 0.001 |
| Ankle extension (knee joint fully extended) | 720 | 0.14 | 0.02 | 720 | 0.29 | 0.04 | 3.28 | 0.009 |

*N*, Number of tests; mean κ, mean Cohen's kappa-value of six inter-rater pairs (rater 1 versus rater 2, rater 1 versus rater 3, rater 1 versus rater 4, rater 2 versus rater 3, rater 2 versus rater 4, and rater 3 versus rater 4) assessed for both body sides and 2 tests (test and retest) of 30 patients; SE, standard error; *p* adjusted, Bonferroni-Holm adjusted *p*-value; n.s., not significant.

ankle plantarflexion with knee joint flexed and extended) * two body sides (left/right).) The correlation coefficient is $r = 0.64$ ($r^2 = 0.41$), the equation for the regression is $y = 0.44 + 1.16x$.

### Reliability findings of the angle of muscle reaction

Calculation of ICC values of the angle of spasticity (quantity of muscle reaction = R1) was only feasible for elbow, knee and ankle flexors, because catch or clonus (indicated by a Modified Tardieu Scale score of 2 or 3, respectively) could not be found in most of the tests and/or stretched muscle groups.

Test–retest reliability of R1 was good for elbow flexors (ICC = 0.73), knee flexors (ICC = 0.72), and ankle plantarflexors with knee joint flexed (ICC = 0.70) and moderate for ankle plantarflexors with knee joint fully extended (ICC = 0.65). Inter-rater reliability was good for knee flexors (ICC = 0.72), moderate for elbow flexors (ICC = 0.46), ankle plantarflexors with knee joint fully extended (ICC = 0.55) and poor for ankle plantarflexors with knee joint flexed (ICC = 0.36).

## Discussion

The purpose of the present study was to compare the reliability of two clinical spasticity scales, the Modified Ashworth Scale and Modified Tardieu Scale. The results showed higher reliability of the Modified Tardieu Scale in comparison with the



**Figure 1**  Scatterplot of the mean Modified Tardieu Scale (MTS) scores and Modified Ashworth Scale (MAS) scores ($r = 0.64$).

Modified Ashworth Scale in patients with severe brain damage and impaired consciousness.

### Modified Ashworth Scale

In daily practice the use of the Modified Ashworth Scale procedure is quick and easy and is a common tool in the measurement of spasticity. Additionally, the Modified Ashworth Scale is widely used in research[2,3,25,26] and has been, in contrast to the Modified Tardieu Scale, extensively investigated.[19,27,28] In different patient groups such as stroke, multiple sclerosis and spinal cord injury, moderate to good intra-rater reliability and poor to moderate inter-rater reliability of the scale was found.[7–11,19,29] The results of the present study are in line with the findings in the literature and supports the conclusion that the inter-rater reliability of the Modified Ashworth Scale is limited. In addition, some researchers argue that reduced joint range of motion due to contractures might also limit the reliability of this scale.[11,18] Nonetheless, inter-rater reliability is certainly one weakness of the Modified Ashworth Scale. The Modified Ashworth Scale seems to measure resistance adequately, but neural and peripherical contributions to resistance are not differentiated.[30] Furthermore, the Modified Ashworth Scale might not gauge a velocity-dependent increase in reflex activity and would therefore not adhere to Lance's original definition of spasticity.[31] At the very least, recent neurophysiological[32] and biomechanical[33,34] studies question the Modified Ashworth Scale as a gold standard for assessing spasticity in clinical practice and research.
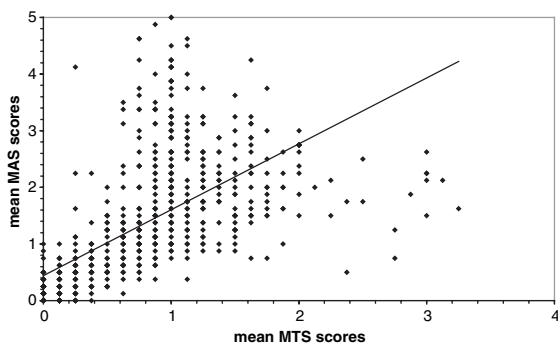
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### Clinical messages

- In patients with severe brain injury and impaired consciousness the Modified Tardieu Scale, when used by trained medical professionals, has good to very good test–retest reliability but limited inter-rater reliability.
- The reliability of the Modified Tardieu Scale may be superior to that of the Modified Ashworth Scale at least for some joints.

**Modified Tardieu Scale**

The results of this study are comparable to other investigations about the Modified Tardieu Scale. Boyd *et al*., for example, identified in children with cerebral palsy the Modified Tardieu Scale as more sensitive and precise in the detection of changes following treatment in comparison with the Modified Ashworth Scale.[15] Additionally, Fosang *et al*. showed good reliability of the Modified Tardieu Scale and only limited reliability of the Modified Ashworth Scale in children with spasticity, but a statistical comparison between both scales was not performed.[12] In addition, Gracies *et al*. found that the Modified Tardieu Scale might be sensitive enough to measure a decrease in spasticity in adult patients after stroke following an application of dynamic splints.[20] However, almost all studies about the reliability of the Modified Tardieu Scale were based on data collected in children with cerebral palsy.

The distribution of the mean scores of Modified Ashworth Scale and Modified Tardieu Scale correlate poorly for scores greater than 1 (see Figure 1). This could be interpreted to mean that both scales measure at least two different things. In contrast to the Modified Ashworth Scale, the Modified Tardieu Scale data collection procedure involves different stretching velocities. These different stretching velocities allow one to gauge a velocity-dependent increase in spasticity during stretching. Therefore, the Modified Tardieu Scale seems to measure spasticity in a manner more adherent to Lance's definition of spasticity.[31] In conjunction with the higher reliability findings, this indicates that the Modified Tardieu Scale might be a more valid instrument for the measurement of spasticity than the Modified Ashworth Scale.[35]

On the other hand, the Modified Tardieu Scale is also not without limitations. One consideration might be the range of the scale. In this study an Modified Tardieu Scale score of 4 (unfatigable cloni) was only rated by two raters and in only one condition (stretching ankle plantarflexor muscles, with knee flexed). None of the four examiners arrived at Modified Tardieu Scale scores of 3 while stretching shoulder internal rotators and hip extensors. Additionally, quantifying the muscles reaction to the fastest stretch was only feasible for elbow-, knee- and ankle flexors, because a catch or clonus (indicated by an Modified Tardieu Scale score of 2 or greater) was absent in the other muscle groups. These findings can be interpreted in two ways: The Modified Tardieu Scale might not be as sensitive in proximal muscles groups, or that cloni were simply not found very often in proximal joint muscles of the selected study population. Therefore, the scale with graduation of 0–4 may be not adequate for hip and shoulder joints. Hence, further investigations could might explore the possibility of modifying the Modified Tardieu Scale from a five point scale to a four or three point scale, and whether this would better fit in the clinical spectrum of spasticity at proximal and distal joints.

A further limitation of the scale might be demonstrated by the fact that a wide range of inter-rater reliabilities (fair to good) were found for the Modified Tardieu Scale for both quality and angle of muscle reaction. In this line, Spizzo *et al*. showed high test–retest but moderate inter-rater agreement of the Modified Tardieu Scale.[36] In additional, recently Mackey *et al*. showed that the reliability of the angle of catch or cloni may be of only limited value in assessing biceps brachii muscle spasticity in children with cerebral palsy.[37] However, even though the inter-rater reliability of the Modified Tardieu Scale is only moderate, it is higher than that for the Modified Ashworth Scale. In summary, there might be three points to be touched upon when describing the Modified Tardieu Scale as a promising tool for collecting data about spasticity. First, the Modified Tardieu Scale adheres closely to the definition of spasticity as given by Lance.[31,35] Second, reliability is higher than that of the widely used Modified Ashworth Scale.[12] Third, the sensitivity of the scale might be high enough to measure differences between pre- and posttreatment.[15,20]

**Limitations of the study**

There have been several modifications to the original method set out by Tardieu and colleagues.[12,14–16,20,21,37] For the present study we used a protocol based on the description of Boyd and Ada.[16] It does stand to reason that modification of the original description of the Tardieu Scale could result in higher or lower agreement between raters. For further studies and for clinical practise, a consistent standardization of the Modified Tardieu Scale seems to be a very important issue.

Reliability of a scale is always best tested if there is a reasonable range of all possible scores within the sample population.[38] Therefore, we decided to perform the Modified Tardieu Scale assessments on patients with severe brain damage and impaired consciousness. A full spectrum of Modified Tardieu Scale scores was not achieved, however, for each stretching direction in the present study. The presented evaluation of the quality and quantity of muscle reaction gives therefore only limited information. This is not solely a result of the selection of the study population, however. The scale structure of the Modified Tardieu Scale may have, especially for proximal joints, limitations as described above.

One aim of the study was to compare the reliability of the Modified Ashworth Scale with the reliability of the Modified Tardieu Scale. Weighted kappa statistics might be the most appropriate test for agreement between trials and raters in nominal and/or ordinal scales.[18,23] However, due to the different ranges of the scales (Modified Tardieu Scale is a four- and Modified Ashworth Scale a five-point scale) the use of weighted kappa was not feasible in the present study.[23] Additionally, Pandyan *et al*. suggested the use of kappa statistic for the Modified Ashworth Scale.[18] Therefore, Cohen's kappa statistic for reliability calculation and comparison between the scales was used.[22,23,39]

One may argue that the stretching velocities used in this study cannot be easily distinguished from each other. Furthermore, Mackey *et al*. showed recently that each rater might be able to apply different angular velocities during the Modified Tardieu Scale data collection procedure (e.g., at elbow joints).[37] Although velocity was not controlled in the present study, the clinical and study experience indicated that application of different stretching velocities was feasible.

In the rehabilitation of patients with severe brain injury and impaired consciousness, the management of contractures and spasticity is a meaningful goal for rehabilitation staff and patients' relatives.[1] Therefore, it might be important to collect and record reliable data about spasticity (e.g., to evaluate the effectiveness of treatment interventions). The results of the present study suggest that the Modified Tardieu Scale is a promising data tool for the clinical measurement of spasticity in these patients. However, the present study can only be understood as a pilot investigation of the Modified Tardieu Scale in adult patients. Further investigation is warranted, ideally involving a variety of adult patient groups.

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