**Tardieu Reliability Studies**:

The reliability of the MTS has been questioned for various patient populations and for particular muscle groups. Although there have been some studies that found insufficient reliability for the MTS, others report good to excellent test-retest and inter-rater reliability.

For any study using the MTS, it is critical that inclusion and exclusion criteria are clearly defined, a standardized protocol of how to assess a muscle group (patient & limb position, number of times to repeat the measurement, speed, etc.) is utilized as well as precise definitions of the various scores be established.

**RELIABILITY STUDIES WITH PEDIATRIC SUBJECTS:**

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| **RESEARCH STUDY** | **SUBJECTS** | **INTRA-RATER RELIABILITY** | **INTER-RATER RELIABILITY** |
| **Boyd et al. (1998)**  1 Rater  1 Lower limb muscle group (hip adductor)  MTS, MAS, PROM | N=16  Children with CP with adductor spasticity and contracture | Placebo group (saline injection): Mean of repeated values  Tardieu score 1=23.75°  Tardieu score 2=23.12°  No difference p<0.08  Good intra-rater reliability | Not performed. |
| **Fosang et al. (2003)**  6 Raters  3 Lower limb muscle groups  MTS, MAS and PROM | N=18 Children with spastic cerebral palsy | Tardieu Test-Retest ICC range for 6 raters:  Hamstrings=0.68-0.90  Gastrocs=0.38-0.90  Hip Adduct=0.61-0.93 | Tardieu Inter-Rater ICCs  Time 1 and Time 2:  Hamstrings=  0.74 (0.55-0.88) & 0.72 (0.52-0.87)  Gastrocs=  0.55 (0.33-0.77) & 0.71 (0.53-0.87)  Hip Adduct =  0.64 (0.43-0.83) & 0.58 (0.37-0.79) |
| **Gracies et al. (2010)**  6 Raters  3 Upper/Lower limb muscle groups  Tardieu | N=20  Children with cerebral palsy | Experienced raters without training:  77 ± 13%  Non-experienced raters after formal training, intra-rater agreement rates  80 ± 14%  Experienced raters after formal training, intra-rater agreement rates  90 ± 8%  XV1 had good to excellent intra-rater agreement rate whichever joint considered.  XV3 and the Spasticity Angle X, were also good to excellent at the elbow and ankle.  The Spasticity Grade Y had good to excellent agreement rates for all joints. | Experienced raters without training:  66 ± 15  Non-experienced raters after formal training, inter-rater agreement rates  74 ± 16%  Experienced raters after formal training, inter-rater agreement rates  81 ± 13%  XV1 had good to excellent inter-rater agreement rate whichever joint considered.  XV3 and the Spasticity Angle X, were also good to excellent at the elbow and ankle.  The Spasticity Grade Y had good to excellent agreement rates for all joints. |
| **Mackey et al. (2004)**  1 Rater  1 Upper limb muscle group (biceps brachii)  MTS and MAS and three-dimensional kinematics | N=10  Pediatric CP upper limb hemiplegia | V1 Intrasessional 3 (1-16)  V2 Intrasessional 4 (1-30)  V3 Intrasessional 5 (0-20)  90% of the measurement differences were below 12 degrees for the three velocities. | V1 Intersessional 10 (0-18)  V2 Intersessional 4 (1-31)  V3 Intersessional 13 (2-27)  90% of the measurement differences were below 17 degrees for the slow velocity, 16 degrees for gravity, and 25 degrees for fast.  For R2-R1, 3 of 10 subjects had greater than 20° change in this value from week one to week two. |
| **Numanoğlu & Günel (2012)**  1 Rater  6 Upper/Lower limb muscle groups  MTS and MAS | N=37 Children with spastic cerebral palsy | Quality of Muscle Reaction or Spasticity Grade ICCs at slow & fast velocities:  Elbow flexors=0.65 & 0.63  Wrist flexors=0.92 & 0.76  Hip adductors=0.66 & 0.94  Hamstrings=0.93 & 0.92  Gastrocs=0.63 & 0.55  Soleus=0.56 & 0.54  Angle of Muscle Reaction or Spasticity Angle ICCs:  Elbow flexors  R1=0.90, R2=0.77, R2-R1=0.91  Wrist flexors  R1=0.92, R2=0.93, R2-R1=0.86  Hip adductors  R1=0.86, R2=0.79, R2-R1=0.83  Hamstrings  R1=0.87, R2=0.87, R2-R1=0.77  Gastrocs  R1=0.91, R2=0.91, R2-R1=0.78  Soleus  R1=0.87, R2=0.95, R2-R1=0.67 | Not performed |
| **Yam & Leung (2006)**  2 Raters  2 Lower limb muscle groups  MTS and MAS | N=17 Children with cerebral palsy | Not performed | Hip adductors knee flexed ICCs:  R1=0.71 (0.51-0.84)  R2=0.74 (0.55-0.85)  R2-R1=0.53 (0.26-0.72)  Quality=0.66 (0.44-0.81)  Hip adductors knee extended ICCs :  R1=0.71 (0.50-0.84)  R2=0.53 (0.25-0.72)  R2-R1=0.69 (0.48-0.83)  Quality=0.71 (0.51-0.84)  Ankle plantar flexors knee extended ICCs :  R1=0.55 (0.29-0.74)  R2=0.17 (-0.15-0.46)  R2-R1=0.40 (0.09-0.63)  Quality=0.22 (-0.11-0.50)  Ankle plantar flexors knee flexed ICCs :  R1=0.37 (0.06-0.61)  R2=0.36 (0.05-0.61)  R2-R1=0.53 (0.26-0.73)  Quality=0.44 (0.15-0.67) |

**RELIABILITY STUDIES WITH ADULT SUBJECTS:**

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| **RESEARCH STUDY** | **SUBJECTS** | **INTRA-RATER RELIABILITY** | **INTER-RATER RELIABILITY** |
| **Akpinar et al. (2017)**  2 Raters  3 Lower limb muscle groups  MAS and Modified Tardieu Scale (MTS) | N=65  Adults with spinal cord injuries | Spasticity Grade/Quality of Muscle Reaction Kappa Coefficients:  Hip adductor к=0.805  Hip extensor к=0.825  Knee flexor к=0.917  Knee extensor к=0.752  Ankle plantar flexor к=0.838  Spasticity Angle/Angle of Muscle Reaction ICCs:  Hip adductor  R1=0.796, R2=0.637, R2-R1=0.934  Hip extensor  R1=0.929, R2=0.937, R2-R1=0.894  Knee flexor  R1=0.943, R2=0.451, R2-R1=0.962  Knee extensor  R1=0.910, R2=0.31, R2-R1=0.914  Ankle plantar flexor  R1=0.494, R2=0.876, R2-R1=0.912 | Spasticity Grade/Quality of Muscle Reaction Kappa Coefficients:  Hip adductor к=0.692  Hip extensor к=0.876  Knee flexor к=0.860  Knee extensor к=0.746  Ankle plantar flexor к=0.768  Spasticity Angle/Angle of Muscle Reaction ICCs:  Hip adductor  R1=0.809, R2=0.248, R2-R1=0.973  Hip extensor  R1=0.958, R2=0.578, R2-R1=0.951  Knee flexor  R1=0.932, R2=0.633, R2-R1=0.932  Knee extensor  R1=0.764, R2=0.094, R2-R1=0.874  Ankle plantar flexor  R1=0.454, R2=0.804, R2-R1=0.911 |
| **Ansari et al. (2008)**  2 Inexperienced Raters  1 Upper limb muscle group (elbow flexors)  MTS | N= 30  Adults with hemiplegia | Not performed. | * ICCs: * R1= 0.74 (0.52-0.87) * R2= 0.56 (0.26-0.76) * R2-R1= 0.72 (0.50-0.86) * MTS Quality of Muscle Reaction (Spasticity Grade)= 0.74 |
| **Ansari et al. (2013)**  2 Raters  1 Lower limb muscle group (ankle plantar flexors)  MTS | N=30  Adults post stroke | ICCs:  R1= 0.70 (0.46-0.84)  R2= 0.62 (0.35-0.80)  R2-R1= 0.40 (0.05-0.66)  MTS Quality of Muscle Reaction (Spasticity Grade)= 0.68 | ICCs:  R1= 0.52 (0.20-0.74)  R2= 0.46 (0.13-0.70)  R2-R1= 0.57 (0.27-0.77)  MTS Quality of Muscle Reaction (Spasticity Grade)= 0.71 |
| **Ben-Shabat et al. (2013)**  2 Raters  8 Lower limb muscle groups  MTS | N=30  Adults with various chronic neurological injuries and lower limb spasticity | Spasticity Angle/Angle of Muscle Reaction ICCs Affected Muscles:  Hip adductor  R1=0.59, R2=0.48, R2-R1=-0.13  Hamstrings  R1=0.90, R2=0.84, R2-R1=0.75  Gastrocnemius  R1=0.86, R2=0.86, R2-R1=0.45  Rectus femoris  R1=0.70, R2=0.81, R2-R1=0.67  Soleus  R1=0.74, R2=0.93, R2-R1=0.67  Quadriceps  R1=0.35, R2=0.37, R2-R1=0.44  Limits of Agreement (LOA)=20° or more for all=unacceptable.  Kappa Affected Muscles:  Anterior tibialis  R1=0.65, %Agree=0.66  R2=0.68, %Agree=0.86  R2-R1=0.53, %Agree=0.69  Posterior tibialis  R1=0.57, %Agree=0.49  R2=0.77, %Agree=0.71  R2-R1=0.52, %Agree=0.60  Spasticity Grade/Quality of Muscle Reaction Weighted Kappa and Percentage Agreement Affected Muscles:  Hip adductor *k*=0.37 %Agree=0.66  Hamstrings *k*=0.49 %Agree=0.77  Gastroc *k*=0.47 %Agree=0.57  Rectus fem *k*=0.30 %Agree=0.60  Soleus *k*=0.65 %Agree=0.71  Quadriceps *k*=0.31 %Agree=0.60  Anterior tib *k*=0.60 %Agree=0.77  Posterior tib *k*=0.70 %Agree=0.80 | Spasticity Angle/Angle of Muscle Reaction ICCs Affected Muscles:  Hip adductor  R1=0.71, R2=0.65, R2-R1=0.13  Hamstrings  R1=0.81, R2=0.72, R2-R1=0.63  Gastrocnemius  R1=0.75, R2=0.69, R2-R1=0.04  Rectus femoris  R1=0.77, R2=0.79, R2-R1=0.76  Soleus  R1=0.63, R2=0.82, R2-R1=0.37  Quadriceps  R1=0.45, R2=0.34, R2-R1=0.40  Limits of Agreement (LOA)=20° or more for all=unacceptable.  Kappa Affected Muscles:  Anterior tibialis  R1=0.46, %Agree=0.60  R2=0.53, %Agree=0.80  R2-R1=0.27, %Agree=0.65  Posterior tibialis  R1=0.38, %Agree=0.44  R2=0.45, %Agree=0.51  R2-R1=0.29, %Agree=0.29  Spasticity Grade/Quality of Muscle Reacton Weighted Kappa and Percentage Agreement Affected Muscles:  Hip adductor *k*=0.34 %Agree=0.57  Hamstrings *k*=0.57 %Agree=0.74  Gastroc *k*=0.41 %Agree=0.63  Rectus fem *k*=0.58 %Agree=0.69  Soleus *k*=0.39 %Agree=0.57  Quadriceps *k*=0.39 %Agree=0.54  Anterior tib *k*=0.42 %Agree=0.66  Posterior tib *k*=0.52 %Agree=0.56 |
| **Li et al. (2014)**  2 Raters  2 Upper/Lower limb muscle groups  MTS and MAS | N=51  Adults with post stroke hemiplegia | Elbow flexors ICC:  R1=0.71  R2=0.83  R1-R2=0.70  Plantar flexors ICC:  R1=0.77  R2=0.75  R1-R2=0.66  Kappa Statistics:  Elbow flexors=0.73  Plantar flexors=0.79 | Elbow flexors ICCs:  R1=0.78  R2=0.58  R1-R2=0.67  Plantar flexors ICCs:  R1=0.80  R2=0.88  R1-R2=0.62  Kappa Statistics:  Elbow flexors=0.73  Plantar flexors=0.82 |
| **Mehrholz et al. (2005)**  4 Raters  6 Upper/Lower limb muscle groups  MTS and MAS | N=30  Adults with severe cerebral damage either from stroke, traumatic brain injury or cerebral hypoxia | к=0.52 - 0.87  Compared to the MAS, the intra-rater reliability of the MTS was significantly higher for all muscles (P<0.05), except for the shoulder extensor and internal rotator muscles of the shoulder (P>0.05).  Cohen’s Kappa:  Shoulder flexion=0.65  Shoulder external rotation=0.53  Elbow flexion=0.78  Elbow extension=0.75  Wrist flexion=0.87  Wrist extension=0.71  Hip flexion=0.76  Hip extension=0.72  Knee flexion=0.67  Knee extension=0.81  Ankle extension(knee flexed)=0.82  Ankle extension(knee extend)=0.72   * Angle of muscle reaction (quantity of muscle reaction) ICCs: * Elbow flexors=0.73 * Knee flexors=0.72 * Ankle PF with knee flexed=0.70 Ankle PF with knee extended=0.65 | к=0.29 - 0.53  Compared to the MAS, the inter-rater reliability of the MTS was significantly higher for all muscles (P<0.05) except for wrist extensor muscles (P>>0.05).  Cohen’s Kappa:  Shoulder flexion=0.44  Shoulder external rotation=0.39  Elbow flexion=0.48  Elbow extension=0.51  Wrist flexion=0.33  Wrist extension=0.38  Hip flexion=0.42  Hip extension=0.37  Knee flexion=0.53  Knee extension=0.44  Ankle extension(knee flexed)=0.47  Ankle extension(knee extend)=0.29   * Angle of muscle reaction (quantity of muscle reaction) ICCs: * Elbow flexors=0.46 * Knee flexors=0.72 * Ankle PF with knee flexed=0.36 Ankle PF with knee extended=0.55 |
| **Naghdi et al. (2017)**  1 Rater  3 Lower limb muscle groups  MTS | N=30  Adults with multiple sclerosis | Quality of Muscle Reaction (Spasticity Grade) Kappas:  Hip adductor=0.54  Knee extensor=0.89  Ankle plantar flexor=0.63  Overall=0.72  MTS Angle of Muscle Reaction ICCs:  Hip adductors  R1=0.45, R2=0.47, R2-R1=0.48  Knee extensors  R1=0.80, R2=0.74, R2-R1=0.83  Ankle plantar flexors  R1=0.75, R2=0.60. R2-R1=0.67 | Not performed |
| **Paulis et al. (2011)**  2 Raters  1 Upper limb muscle group (elbow flexors)  Tardieu Scale using both goniometers and inertial sensors (IS) | N=13  Adults post stroke | Elbow flexors ICCs  R1  Gonio=0.91 (0.66-0.96)  IS=0.82 (0.51-0.94)  R2  Gonio=0.87 (0.67-0.96)  IS=0.86 (0.64-0.96)  R2-R1  Gonio=0.86 (0.58-0.95)  IS=0.76 (0.46-0.93) | Elbow flexors ICCs  R1  Gonio=0.60 (0.30-0.90)  IS=0.87 (0.61-0.95)  R2  Gonio=0.89 (0.68-0.97)  IS=0.89 (0.80-0.98)  R2-R1  Gonio=0.66 (0.33-0.91)  IS=0.84 (0.59-0.95) |
| **Singh et al. (2011)**  2 Raters  2 Upper/Lower limb muscle groups  MTS | N=91  Adults with acute stroke | Elbow flexors ICCs:  R1= 0.998  R2= 0.978  R2-R1= 0.991  MTS scores= 0.847  Ankle plantar flexors ICCs:  R1= 0.990  R2= 0.995  R2-R1= 0.907  MTS scores= 0.863 | Not performed. |
| **Waninge et al. (2011)**  2 Raters  2 Upper/Lower limb muscle groups  MAS and MTS | N=35  Adults with profound intellectual & multiple disabilities | Elbow:  R1: ICC=0.627, Spearmen=0.624  R2: ICC=0.815, Spearmen=0.792  Knee:  R1: ICC=0.850, Spearmen=0.680  R2: ICC=0.741, Spearmen=0.402 | Elbow:  R1: ICC=0.851, Spearmen=0.825  R2: ICC=0.806, Spearmen=0.813  Knee:  R1: ICC=0.877, Spearmen=0.726  R2: ICC=0.766, Spearmen=0.696 |