**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 Rater1 Lower limb muscle group (hip adductor)MTS, MAS, PROM | N=16Children with CP with adductor spasticity and contracture | Placebo group (saline injection): Mean of repeated valuesTardieu score 1=23.75°Tardieu score 2=23.12°No difference p<0.08Good intra-rater reliability | Not performed. |
| **Fosang et al. (2003)**6 Raters3 Lower limb muscle groupsMTS, MAS and PROM | N=18 Children with spastic cerebral palsy | Tardieu Test-Retest ICC range for 6 raters:Hamstrings=0.68-0.90Gastrocs=0.38-0.90Hip 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 Raters3 Upper/Lower limb muscle groupsTardieu | N=20Children 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 ± 15Non-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 Rater1 Upper limb muscle group (biceps brachii)MTS and MAS and three-dimensional kinematics | N=10Pediatric 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 Rater6 Upper/Lower limb muscle groupsMTS 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 & 0.63Wrist flexors=0.92 & 0.76Hip adductors=0.66 & 0.94Hamstrings=0.93 & 0.92Gastrocs=0.63 & 0.55Soleus=0.56 & 0.54Angle of Muscle Reaction or Spasticity Angle ICCs:Elbow flexors R1=0.90, R2=0.77, R2-R1=0.91Wrist flexors R1=0.92, R2=0.93, R2-R1=0.86Hip adductorsR1=0.86, R2=0.79, R2-R1=0.83HamstringsR1=0.87, R2=0.87, R2-R1=0.77GastrocsR1=0.91, R2=0.91, R2-R1=0.78Soleus R1=0.87, R2=0.95, R2-R1=0.67 | Not performed |
| **Yam & Leung (2006)**2 Raters2 Lower limb muscle groupsMTS 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 Raters3 Lower limb muscle groupsMAS and Modified Tardieu Scale (MTS) | N=65 Adults with spinal cord injuries | Spasticity Grade/Quality of Muscle Reaction Kappa Coefficients:Hip adductor к=0.805Hip extensor к=0.825Knee flexor к=0.917Knee extensor к=0.752Ankle plantar flexor к=0.838Spasticity Angle/Angle of Muscle Reaction ICCs:Hip adductor R1=0.796, R2=0.637, R2-R1=0.934Hip extensorR1=0.929, R2=0.937, R2-R1=0.894Knee flexorR1=0.943, R2=0.451, R2-R1=0.962Knee extensorR1=0.910, R2=0.31, R2-R1=0.914Ankle plantar flexor R1=0.494, R2=0.876, R2-R1=0.912 | Spasticity Grade/Quality of Muscle Reaction Kappa Coefficients:Hip adductor к=0.692Hip extensor к=0.876Knee flexor к=0.860Knee extensor к=0.746Ankle plantar flexor к=0.768Spasticity Angle/Angle of Muscle Reaction ICCs:Hip adductor R1=0.809, R2=0.248, R2-R1=0.973Hip extensorR1=0.958, R2=0.578, R2-R1=0.951Knee flexorR1=0.932, R2=0.633, R2-R1=0.932Knee extensorR1=0.764, R2=0.094, R2-R1=0.874Ankle plantar flexorR1=0.454, R2=0.804, R2-R1=0.911 |
| **Ansari et al. (2008)**2 Inexperienced Raters1 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 Raters1 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 Raters8 Lower limb muscle groupsMTS | N=30Adults 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=-0.13HamstringsR1=0.90, R2=0.84, R2-R1=0.75GastrocnemiusR1=0.86, R2=0.86, R2-R1=0.45Rectus femorisR1=0.70, R2=0.81, R2-R1=0.67SoleusR1=0.74, R2=0.93, R2-R1=0.67QuadricepsR1=0.35, R2=0.37, R2-R1=0.44Limits of Agreement (LOA)=20° or more for all=unacceptable. Kappa Affected Muscles:Anterior tibialisR1=0.65, %Agree=0.66R2=0.68, %Agree=0.86R2-R1=0.53, %Agree=0.69Posterior tibialisR1=0.57, %Agree=0.49R2=0.77, %Agree=0.71R2-R1=0.52, %Agree=0.60Spasticity Grade/Quality of Muscle Reaction Weighted Kappa and Percentage Agreement Affected Muscles: Hip adductor *k*=0.37 %Agree=0.66Hamstrings *k*=0.49 %Agree=0.77Gastroc *k*=0.47 %Agree=0.57Rectus fem *k*=0.30 %Agree=0.60Soleus *k*=0.65 %Agree=0.71Quadriceps *k*=0.31 %Agree=0.60Anterior tib *k*=0.60 %Agree=0.77Posterior 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=0.13HamstringsR1=0.81, R2=0.72, R2-R1=0.63GastrocnemiusR1=0.75, R2=0.69, R2-R1=0.04Rectus femorisR1=0.77, R2=0.79, R2-R1=0.76SoleusR1=0.63, R2=0.82, R2-R1=0.37QuadricepsR1=0.45, R2=0.34, R2-R1=0.40Limits of Agreement (LOA)=20° or more for all=unacceptable. Kappa Affected Muscles:Anterior tibialisR1=0.46, %Agree=0.60R2=0.53, %Agree=0.80R2-R1=0.27, %Agree=0.65Posterior tibialisR1=0.38, %Agree=0.44R2=0.45, %Agree=0.51R2-R1=0.29, %Agree=0.29Spasticity Grade/Quality of Muscle Reacton Weighted Kappa and Percentage Agreement Affected Muscles:Hip adductor *k*=0.34 %Agree=0.57Hamstrings *k*=0.57 %Agree=0.74Gastroc *k*=0.41 %Agree=0.63Rectus fem *k*=0.58 %Agree=0.69Soleus *k*=0.39 %Agree=0.57Quadriceps *k*=0.39 %Agree=0.54Anterior tib *k*=0.42 %Agree=0.66Posterior tib *k*=0.52 %Agree=0.56 |
| **Li et al. (2014)**2 Raters2 Upper/Lower limb muscle groupsMTS and MAS | N=51 Adults with post stroke hemiplegia | Elbow flexors ICC:R1=0.71R2=0.83R1-R2=0.70Plantar flexors ICC:R1=0.77R2=0.75R1-R2=0.66Kappa Statistics:Elbow flexors=0.73Plantar flexors=0.79 | Elbow flexors ICCs:R1=0.78R2=0.58R1-R2=0.67Plantar flexors ICCs:R1=0.80R2=0.88R1-R2=0.62Kappa Statistics:Elbow flexors=0.73Plantar flexors=0.82 |
| **Mehrholz et al. (2005)**4 Raters6 Upper/Lower limb muscle groupsMTS 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=0.65Shoulder external rotation=0.53Elbow flexion=0.78Elbow extension=0.75Wrist flexion=0.87Wrist extension=0.71Hip flexion=0.76Hip extension=0.72Knee flexion=0.67Knee extension=0.81Ankle extension(knee flexed)=0.82Ankle 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 - 0.53Compared 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=0.44Shoulder external rotation=0.39Elbow flexion=0.48Elbow extension=0.51Wrist flexion=0.33Wrist extension=0.38Hip flexion=0.42Hip extension=0.37Knee flexion=0.53Knee extension=0.44Ankle extension(knee flexed)=0.47Ankle 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 Rater3 Lower limb muscle groupsMTS | N=30Adults with multiple sclerosis | Quality of Muscle Reaction (Spasticity Grade) Kappas:Hip adductor=0.54Knee extensor=0.89Ankle plantar flexor=0.63Overall=0.72MTS Angle of Muscle Reaction ICCs:Hip adductorsR1=0.45, R2=0.47, R2-R1=0.48Knee extensorsR1=0.80, R2=0.74, R2-R1=0.83Ankle plantar flexorsR1=0.75, R2=0.60. R2-R1=0.67 | Not performed |
| **Paulis et al. (2011)**2 Raters1 Upper limb muscle group (elbow flexors)Tardieu Scale using both goniometers and inertial sensors (IS) | N=13Adults post stroke | Elbow flexors ICCsR1Gonio=0.91 (0.66-0.96)IS=0.82 (0.51-0.94)R2Gonio=0.87 (0.67-0.96)IS=0.86 (0.64-0.96)R2-R1Gonio=0.86 (0.58-0.95)IS=0.76 (0.46-0.93) | Elbow flexors ICCsR1Gonio=0.60 (0.30-0.90) IS=0.87 (0.61-0.95)R2Gonio=0.89 (0.68-0.97)IS=0.89 (0.80-0.98)R2-R1Gonio=0.66 (0.33-0.91)IS=0.84 (0.59-0.95) |
| **Singh et al. (2011)**2 Raters2 Upper/Lower limb muscle groupsMTS | N=91 Adults with acute stroke | Elbow flexors ICCs: R1= 0.998R2= 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 Raters2 Upper/Lower limb muscle groupsMAS and MTS | N=35 Adults with profound intellectual & multiple disabilities | Elbow:R1: ICC=0.627, Spearmen=0.624R2: ICC=0.815, Spearmen=0.792Knee:R1: ICC=0.850, Spearmen=0.680R2: ICC=0.741, Spearmen=0.402 | Elbow:R1: ICC=0.851, Spearmen=0.825R2: ICC=0.806, Spearmen=0.813Knee:R1: ICC=0.877, Spearmen=0.726R2: ICC=0.766, Spearmen=0.696 |