Ashworth/MAS Validity:

Most validity studies aim to correlate the MAS with other clinical measurements of spasticity, neurophysiological measures, or biomechanical indices or test the sensitivity of the MAS to detect changes after treatment. Some studies fail to support the validity of the MAS while other studies support the validity. And an equal number of studies provide evidence for both conclusions (positive correlations for only certain neurophysiological or biomechanical measures or support for only specific muscle groups). It is important to note that many of these studies provide little information about the subjects, protocol for assessment, or other aspects of the study, not only making comparisons difficult but also making it difficult to critically examine the results. Furthermore, many studies have small subject numbers or restrict the assessments to only one or two muscle groups. Additionally, the very definition of a correlation being classified as poor, fair, adequate, good, or excellent vary from study to study. Finally, some studies failed to understand that this is a nominal or potentially ordinal scale and should not be used as an interval or ratio scale.

In general, there is sufficient evidence to conclude that the MAS is a valid measure of resistance to passive movement.

For any study using the MAS, 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.

VALIDITY STUDIES WITH PEDIATRIC SUBJECTS:

RESEARCH STUDY SUBJECTS	COMPARISONS/ LABORATORY MEASURES	RESULTS/ CONCLUSION
Alhusaini et al. (2010) 1 lower limb muscle group (Plantar flexors) Content validity Ashworth Scale vs Tardieu Scale N=27 Children with CP	Ashworth Scale and Tardieu Scale compared to laboratory measures (stretch-induced electromyographic activity) of spasticity and contracture	The Tardieu Scale was more effective than the Ashworth Scale in identifying the presence of spasticity (88.9%, κ=0.73), the presence of contracture (77.8%, κ=0.503), and the severity of contracture (r=0.49). However, neither scale was able to identify the severity of spasticity. Percentage Exact Agreement for Ashworth vs EMG in identifying spasticity measurements was 81.5% k=0.24. Pearson Correlation with Ashworth vs EMG to identify the severity of spasticity was not a significant correlation (r = 0.009 *P* = 0.7).
Bar-On et al. (2014) 1 Lower limb muscle group (medial hamstrings) Responsiveness Predictive ability MAS & MTS N=31 Children with CP	Comparison of clinical scales (MAS & MTS) and instrumented spasticity assessments both biomechanical (position & torque) and electrophysiological (surface electromyography) after BTX treatment and casting.	Both clinical & instrumented parameters improved post-BTX. However, the MAS identified 14 responders compared to 25 responders identified by instrumented parameters. Responsiveness: Detection ability: The percentage exact agreement between the MAS and instrumented assessments was statistically significant. Instrumented spasticity assessments showed higher responsiveness/sensitivity to detect change than the clinical scales. The MAS showed no predictive ability.
Damiano et al. (2002) 1 Lower limb muscle group Validity Ashworth Scale	Investigators used an isokinetic dynamometer to quantify resistance to passive stretch and surface EMG to verify if a stretch response occurred and at what joint angle. The investigators	The Ashworth correlated with instrumented measures showing near complete agreement at the extremes of the scale, but with marked inconsistencies in midrange values. Ashworth scores were correlated with instrumented measures, especially for quadriceps, with higher

N=22 Children with CP & N=9 controls	sought to determine which components of passive resistance (magnitude, rate of change, onset angle of stretch or velocity dependence) were most related to Ashworth scores and which were related to motor function.	correlations to the rate of change in resistance (stiffness) and onset angle of stretch than to peak resistance torque. Those with greater resistance tended to have poorer function with isokinetic relations typically stronger. Resistance torque 30 KE (rho)=0.64, 60 KE=0.53, and 120 KE=0.59 and Stiffness 30 (rho)=0.58, 60=0.56, and 120=0.73 Instrumented measures tended to have stronger relationships with function than the Ashworth Scale.

VALIDITY STUDIES WITH ADULT SUBJECTS:

RESEARCH STUDY SUBJECTS	COMPARISONS/ LABORATORY MEASURES	RESULTS/ CONCLUSION
Akman et al. (1999) 3 lower limb muscle groups Validity Ashworth N=33 Adults with SCI and 14 age-matched controls	Correlation between Ashworth grades and average torque values using a computerized isokinetic dynamometer to quantify passive resistance. Maximum peak torque values (mT) and sum of torque amplitudes (∑T) for five repetitions of each type of joint motion at 5 velocities was recorded.	Significant correlation between Ashworth grades and average torque values: Knee flexors mT r=0.76 P<0.01, ∑T r=0.72 P<0.01 Knee extensors mT r=0.69 P<0.01, ∑T r=0.68 P<0.01 Hip adductors mT r=0.48 P<0.01, ∑T r=0.39 P<0.05 Ankle plantar flexors mT r=0.82 P<0.01, ∑T r=0.82 P<0.01 However limited sensitivity noted for subjects with mild spasticity; subjects with only slightly increased muscle tone did not differ from normal controls.
Alibiglou et al. (2008) 2 upper/lower limb muscle groups Validity MAS N=20 Adults with stroke for the ankle study & N=14 for the elbow study	Correlation of the MAS with quantitative measures on neural and muscular components of spasticity (joint reflex torque, intrinsic stiffness, reflex stiffness, joint angle)	No significant correlation was noted between reflex torque/stiffness and MAS scores for either the ankle or the elbow. The slope and intercept of reflex and intrinsic stiffness plotted against the joint angle were not correlated with the MAS. The MAS neither characterize the contributions of neuromuscular components to spasticity nor their modulation with position and velocity of the joint stretch.
Allison & Abraham (1995) 1 lower limb muscle group (Plantar flexors) Concurrent validity MAS N=34 Adults with traumatic brain injury	Correlated the MAS with 4 objective measures of spasticity: H-reflex testing with and without Achilles tendon vibration, H-reflex with and without dorsiflexor contraction, reflex threshold angle and timed toe tapping (TTT).	Statistically significant relationships of low to moderate strength among lab measures, MAS, and TTT. Correlation of quantitative spasticity measures with MAS scores ranged from 0.39 to 0.49. Reflex Threshold Angle (r = 0.49) H-reflex during dorsiflexion (r = 0.47) H-wave during vibration (r = 0.39)
Allison & Abraham (2001) 1 lower limb muscle group (Plantar flexors) Sensitivity to change MAS	Correlated the MAS with 4 quantitative measures of spasticity: H-reflex testing with/without vibration, H-reflex with/without dorsiflexor contraction, reflex threshold angle & timed toe tapping. Used pre & post cryotherapy treatment comparison to	MAS demonstrated appropriate sensitivity to the reduction in spasticity resulting from cryotherapy. Supported the validity of the MAS with a significant difference of p<0.001.

N=26 Adults with traumatic brain injury	detect sensitivity to change in spasticity levels.	
Annaswamy et al. (2007) 1 lower limb muscle group (Plantar flexors) Sensitivity to change MAS N=34 Adults with TBI	Comparing the MAS to a biomechanical measure, resistance torque (RT), and quantitative electrophysiological measures in quantifying spasticity. Used pre & post cryotherapy treatment comparison to detect sensitivity to change in spasticity levels.	Significant ($p<0.001$) correlation coefficients were noted between RT and MAS scores in both pre-treatment (0.4148) and post-treatment (0.4155). The multiple *R* value for the correlation between MAS scores and the linear combination of electrophysiological scores & RT was 0.62 pre-treatment and 0.62 post-treatment.
Bakheit et al (2003) 1 Lower limb muscle group Known groups validity MAS N=24 Adults with stroke	Correlation between MAS scores and the excitability of alpha motor neurons by dividing their subjects into two groups according to MAS scores. Analyzed whether MAS scores were able to distinguish between individuals with higher values in the H- reflex latency and H/M ratio from those with lower values of H-reflex latency and H/M ratio.	No significant difference between the groups was found, however the excitability of the alpha motor neurons was higher in the group of patients with a '2' on the MAS than those who had a score of '1'. There is a relation between MAS scores and alpha motor neuron excitability, although not linear. Known groups validity, as calculated using the student t-test, showed that the Modified Ashworth Scale is not able to distinguish between clients with lower and higher values of H-reflex latency and H/M ratio, two neurophysiologic tests for spasticity.
Cooper et al. (2005) 2 Lower limb muscle groups Criterion Concurrent validity MAS N=31 Adults with stroke & N=20 controls	Comparison of the MAS to surface electromyography.	The MAS showed a positive correlation with the magnitude ($p<0.05$) and duration ($p<0.001$) of the surface electromyography response. Affected muscles with high MAS scores were more likely to show (1) larger responses and (2) produce sustained responses. There was a significant correlation between the MAS and the type of response. There was a significant correlation between the surface electromyography reflex magnitude and MAS scores. Muscles with contracture had significantly higher MAS scores.
Franzoi et al. (1999) 1 lower limb muscle group (knee) Validity Ashworth N=12 Adults with complete traumatic thoracic SCI & N=12 controls	Comparison of groups classified according to level of spasticity and maximum eccentric peak torque in passive knee isokinetic flexion & extension in displacements of 30, 60, and 120° per second. Group SCI 1= Ashworth scores I & 2. Group SCI 2= Ashworth score 3.	In speeds of 60 & 120, significant differences were found using variance analysis. In extension, the torque averages in SCI 1 were found significantly lower than those in the control group and the averages in the SCI 2 groups were found significantly higher. In flexion movement, the torque averages in SCI I were equal to those in the control group, and these significantly lower than those in SCI 2. By using isokinetic assessment, it was possible to quantify hypertonic spasticity in a group of subjects with SCI, distinguishing groups with higher and lower levels of spasticity as compared to a control group.
Heidari et al. (2011) 1 upper limb muscle group (wrist) Validity MAS	Correlation between clinical (MAS scores) and electrophysiological measures of spasticity. An electromyogram (EMG) machine was used to elicit H_{max} and M_{max} from the flexor carpi radialis muscle. Subjects were divided into	Correlation between MAS and H_{max} / M_{max} ratio scores: Spearman's rho= 0.183, not significant ($p=0.323$).

N=34 Adult stroke patients	four groups based on MAS scores 1, 1+, 2, and 3.	
Katz et al. (1992) 1 upper/multiple lower limb muscle groups Construct Convergent / Discriminant validity MAS N=10 Adults with hemiplegia from stroke	Comparison of a clinical scale (MAS) to objective measurements of spasticity including torque and EMG measurements during ramp and hold angular displacement about the elbow, pendulum test of the lower extremity, and H/M ratio studies of upper and lower extremities and motor function using the Fugl-Meyer Motor Assessment Scale.	The pendulum test and reflex threshold measurements during ramp and hold joint extension were consistently related to clinical measures of spastic hypertonia and the Fugl-Meyer had a significant correlation with the MAS. Validity of the MAS supported especially in the upper extremity. Excellent convergent validity. Significant correlations: MAS flexion vs Fugl-Meyer (*r* = -0.946) MAS extension vs Fugl-Meyer (*r* = -0.735) MAS flexion vs R&H-TA 30° (*r* = -0.873) MAS flexion vs R&H-TA 60° (*r* = -0.778) MAS extension vs R&H-TA 30° (*r* = -0.822) MAS extension vs R&H-TA 60° (*r* = -0.711) MAS extension vs Pendulum test (*r* = -0.671)
Kumar et al. (2006) 1 upper limb muscle group (elbow) Known groups validity MAS N=111 Adults with stroke	To assess the validity of the MAS, spasticity was clinically graded using MAS and resistance to passive movement (RPM), applied force, angular displacement, mean velocity, PROM, and time required was measured by a biomechanical device (force transducer and flexible electrogoniometer).	There was no difference in RPM among MAS scores 0 through 2 however grade 4 was higher than 3 and below ($p<0.05$). The force required increased with the increasing MAS scores while velocity ($p<0.01$) & PROM decreased. ($p<0.001$) There was no difference between no stiffness & mild, but mild & moderate as well as moderate & severe were different ($p<0.01$).
Lin & Sabbahi (1999) 1 upper limb muscle group (wrist) Construct validity Convergent validity MAS N = 10 Adults with hemiplegia due to stroke	Comparison of the MAS to hyperactive stretch reflex measures such as electromyography, torque response and velocity sensitivity of the stretch reflexes as well as to motor performance measures such as the Fugl-Meyer Assessment the Box and Block test, active range of motion and grip strength.	Correlations between the MAS and motor performance measures for both day 1 and 2 were all excellent: Fugl-Meyer Assessment (rho1= -0.83; rho2= -0.76), Box and Block Test (rho1= -0.83; rho2=-.76), active range of motion (rho1= -0.74; rho2= -0.62) and grip strength (rho1= -0.86; rho2= -0.85). With respect to the hyperactive stretch reflexes, excellent correlations were found between the MAS and electromyography of muscles at rest on day 1 (rho= 0.77) and day 2 (rho= 0.67), electromyography of active muscles at day 1 (rho= 0.77), on day 2 (rho= 0.74) and the torque of muscles at rest on day 1 (rho= 0.80). Adequate correlations were found between the MAS and velocity sensitivity on day 1 (rho = 0.52) and day 2 (rho = 0.57). Poor correlations were found between the MAS and torque of muscles at rest on day 2 (rho = -0.25) and the torque of active muscles on day 1 (rho = 0.26) and on day 2 (rho = 0.21).
Malhotra et al. (2008) 1 upper limb muscle group (wrist) Validity MAS N=100 Adults with stroke	Investigation into the agreement between clinical (MAS), biomechanical (resistance to passive movement) and neurophysiological (muscle activity) measures of spasticity.	Based on muscle activity measurement, 87 patients had spasticity. According to the MAS, 44 patients had spasticity. There were no statistically significant associations between muscle activity patterns and the MAS. Sensitivity of the MAS when compared with muscle activity recordings was 0.5 and specificity was 0.92. Biomechanical measures showed no consistent relationship with MAS nor muscle activity.

		Stiffness did not systematically increase with an increase in the MAS scores. Grades 1+ & 3 were similar. Grades 0, 1 & 2 were similar.
Min et al. (2012) Content Validity MAS 1 upper limb muscle group (biceps) N= 21 Adults with hemiplegia from stroke	Correlation between the MAS and amplitude and latency of biceps T-reflex.	There was a significant Spearman Correlation Coefficient between increasing level of MAS scores and amplitude of biceps T-reflex (0.464 and 0.573 for two different raters). However, there was no correlation with latency.
Pandyan et al. (2001) 1 upper limb muscle group (elbow) Convergent validity MAS N=16 Adults with acute stroke	Compared the MAS to biomechanical measures of resistance to passive movement (RTPM), passive range of motion (PROM) and speed.	The association between the two measures was fair (kappa = 0.366). The speed and PROM were greater in subjects with a MAS score of 0 ($p<0.05$). Resistance to passive movement was higher in the impaired arm ($p<0.05$) and tended to decrease with repeated measures and increasing speeds. RTPM was significantly higher in MAS grade 1+ compared to grade 0 and 1, but no significant difference in RTPM between grade 0 and 1, the correlation between MAS and RTPM was low. Speed and PROM were significantly higher in grade 0 compared to grades 1 and 1+, but not significant between grades 1 and 1+.
Pandyan et al. (2003) 1 upper limb muscle group (elbow) Convergent validity MAS N=63 Adults with stroke	Compared the MAS to a biomechanical measure of resistance to passive movement of the elbow (RTPM), passive range of motion (PROM) and speed.	A moderate correlation between the MAS and RTPM was found (rho = 0.51). RTPM was found significantly different from the MAS between grade 0 and higher grades (higher in grades 1 and 3 compared to grade 0). However, no significant difference was found between grades 1, 1+ and 2.
Patrick and Ada (2006) 2 upper/lower limb muscle groups Validity Ashworth Scale vs Tardieu Scale N=16 Adult stroke patients	Ashworth Scale and Tardieu Scale compared the as well as laboratory measures of spasticity (stretch-induced EMG activity) and contracture	Presence of spasticity: The percentage exact agreement was 63% for both elbow flexors (kappa=0.24) and ankle plantar flexors (kappa=0.25) between the Ashworth Scale and laboratory measures of spasticity. Severity of spasticity: The relationship between the Ashworth Scale and laboratory measures of spasticity in the elbow flexors was r=0.33 and the ankle plantar flexors was r=0.15. In all cases with contractures, spasticity was overestimated by the Ashworth Scale. They concluded that their findings suggest that the Tardieu Scale differentiates spasticity from contracture whereas the Ashworth Scale is confounded by it.
Pisano et al. (2000) 2 upper limb muscle groups (forearm flexors & wrists) Validity MAS N=53 Adult stroke patients	Quantitative evaluation of muscle tone, correlation of biomechanical indices with conventional clinical scales (MAS & MRC) and neurophysiological measures, and characterization of passive and neural components of muscle tone (*H*max/*M*max ratio, stretch reflex threshold speed	There was a strong correlation of biomechanical measures with clinical scores. TSI (r=0.55), SRTS (r=-0.46), SR latency (r=-0.37), and SR area (r=0.36) were highly correlated to the MAS. H reflex latency (r=0.01) and *H*max/*M*max (r=0.03) did not show significant correlation to the MAS nor did ISI.

	(SRTS), stretch reflex (SR) latency and area, passive (ISI) and total (TSI) stiffness indices).	
Pizzi et al. (2005) 2 upper limb muscle groups Convergent validity MAS N=65 Adults with stroke	Estimated the convergent validity of the MAS by comparing it to neurophysiologic assessments of spasticity (H-reflex and M-response), passive range of motion of the elbow and wrist, and pain.	An adequate correlation between the MAS and the neurophysiologic assessment of the wrist was found (rho = 0.40). Also, higher scores (>3) on the MAS were significantly associated with a decrease in passive range of motion at the wrist and elbow (F = 6.8). No correlation was found between pain and MAS values for either the elbow or the wrist.
Skold et al. (1998) 1 lower limb muscle group Validity MAS N=15 Adults with SCI	This study evaluated whether the MAS correlated with electromyographic (EMG) recordings of muscle activity.	80% of EMG recordings correlated significantly with the corresponding MAS score. Among EMG parameters, duration of movement-associated electrical activity invariably correlated significantly with the MAS grades. Furthermore, MAS measurements showed a positive correlation with the EMG parameters mean, peak, and start to peak of electrical activity. Each increasing grade on the MAS corresponded to increasing myoelectric activity levels for each movement.