Myth #2 : The Modified Ashworth Scale (MAS) is a valid test of spasticity

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When JW Lance (1980) inserted the words "muscle tone" into his description of spasticity as "a velocity-dependent increase in tonic stretch reflexes ("muscle tone") with exaggerated phasic reflexes", he threw a fox into the hen house of understanding. When muscle tone is considered as a status of resistance to passive stretch, it is not possible to distinguish reflex-related and non-reflex properties of passive elasticity and viscosity in the muscle and soft tissues. Muscle tone is not velocity dependent. Spasticity – or exaggerated reflex responses to passive stretch at high velocity - appears to be, though that notion has never been validated *(Pandyan et al 2005).*

Hypertonus is a state of increased stiffness, and hypotonus is a state of reduced stiffness, in the presence of passive stretch at any velocity *(de Vlugt et al 2010).* The literature holds abundant evidence of the prevalence of increased passive stiffness (hypertonus) in the triceps surae (TS) muscles of children and adults with CNS dysfunction *(Castle et al 1979, Tardieu et al 1982, 1982a & 1989, Hurschmidt et al 1985, Ito et al 1996, O'Dwyer et al 1996, Rose et al 1994 & 1998, Vattanasilp et al 2000, Singer et al 2003, Gracies et al 2005, Galiana et al 2005, Dietz et al 2007, Pohl et al 2007, Chung et al 2008, Gao et al 2008 & 2009, Lorentzen et al 2010, Willerslev-Olsen et al 2013, de Gooijer-van de Groep et al 2013).*

Challenging the assumption that stiffness is evidence of spasticity, EMG recordings have shown that in children and adults with CNS dysfunction, some muscles exhibit both exaggerated reflexes and stiffness, while others show only stiffness *(Perry 1993, Damiano et al 2002)*.

Bohannon and Smith modified the Ashworth Scale – originally proposed as a spasticity assessment tool - to add a half grade between 1 and 2, producing the Modified Ashworth Scale (MAS)*(Bohannon et al 1987).* Though stretch velocity is not a part of the MAS assessment procedures, the scale is used with great regularity as a clinical test of spasticity. The nature of the MAS allows it to overestimate spasticity because it assumes that any increase in resistance to passive movement is the result of abnormal reflex activity.

MODIFIED ASHWORTH SCALE (MAS)

The scoring system:

0	No increase in muscle tone.
1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end range of motion when the part is moved in flexion or extension/abduction or adduction, etc.
1+	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM.
2	More marked increase in muscle tone through most of the ROM, but the affected part is easily moved.
3	Considerable increase in muscle tone, passive movement is difficult.
4	Affected part is rigid.

The MAS has been validity tested by several researchers using EMG and mechanically imposed stretch torque and quantified resistance to passive movements. Repeatedly,
the MAS was found to lack validity as a spasticity measure, though it many suggested that it may provide a measure of resistance to passive movement caused by non-reflexive tissue changes *(Faist et al 1994, Sehgal et al 1998, Vattanaslip et al 2000, Damiano et al 2002, Pandyan et al 1999, Chung et al 2004, Patrick et al 2006, Scholtes et al 2006, Mutlu A et al 2008, Alibiglou et al 2009, de Vlugt et al 2010).*

The MAS scores were also shown to have a highly significant correlation with collagen content in the tested muscles *(Booth et al 2001).* The Task Force on Childhood Motor Disorders suggested the MAS might be used to grade the severity of involvement *(Sanger 2003).*

Bohannon and Smith (1987) reported high reliability of their findings obtained while testing for elbow flexor spasticity in 30 patients with intracranial lesions. Fosang et al (2003) and Mutlu et al (2008) undertook reliability studies of the MAS when evaluating three or more lower extremity joints in children with CP. Fosang's ICC values for intra-rater (test--retest) reliability for ankle DF ranged from .21 to 0.72. Interrater reliability for the same test ranged from 0.10 to 0.54 on the first occasion, and from 0.22 to 0.70 on the second occasion occurring within a week of the first. Mutlu et al (2008) reported better ICC values for the MAS as a composite score obtained from tests at the hip joints, hamstrings, and ankle joints. Inter-rater ICC values were between 0.61-0.87 and intra-rater values were between 0.36 and 0.83. Mutlu concluded that reliability of the MAS is related to muscle and joint characters and that the scores were unaffected by experience or by repetition of measurements by the same physiotherapist. They state, *"These scales are not very reliable and assessments of spasticity using these scales should be therefore interpreted with great caution."* [p.44.]

Yam et al (2006) also reported low reliability for the MAS.

Relevance: The growing body of literature that invalidates the MAS as a spasticity scale and attributes the scores to non-reflexive soft tissue stiffness should provoke the reader to interpret all MAS scores that claim to quantify spasticity as inaccurate. The unawareness of this distinction and the research that supports it is wide spread on the part of physicians who claim that neurolytic injections that temporarily paralyze the injected gastrocnemius muscle fibers reduce MAS scores, and so, reduce spasticity in young children. It is reasonable to assume that as young

children age, and tonically recruited TS muscles stiffen and shorten, the same injections are "less effective in reducing spasticity" as is indicated by progressively less impressive MAS scores, because the MAS is a reflection of nonreflexive soft tissue transformation.

Examples of Misapplication of the Ashworth and Modified Ashworth Scales

Three studies exemplify the prevailing misunderstanding of the lack of validity of the MAS as a spasticity measure.

1. Kim et al (2011) They brought a path model to an investigation of the causal relationships between "spasticity" – as assessed by the MAS; weakness – assessed using the manual Muscle Test; gross motor function - according to the Gross Motor Function Measure (GMFM); and functional outcome via the Functional Skills domain of the Pediatric Evaluation of Disability Inventory (PEDI). Eighty-one school-aged children with CP participated: 28 with quadriplegia, 44 with diplegia, and nine with hemiplegia. GMFCS Levels were distributed as follows: I (14), II(9), III (13), IV (5), and V (40). *(I wonder how many of those with diplegia and hemiplegia were in Level V.)* They determined that direct effects were significant between "spasticity" (actually, stiffness) and gross motor function, between strength and gross motor function, and between gross motor function and functional outcome. "Spasticity" (actually, stiffness) had a significant negative indirect effect, and strength had a significant positive indirect effect on functional outcome through effects on gross motor function.

   The authors have drawn a inaccurate conclusions here because they assume that a resistance to passive stretch quantifies spasticity.

2. Hagglund et al (2008) used the Ashworth Scale (AS) as a test of spasticity (which they referred to as tone) rather than of stiffness. The authors undertook 6218 AS examinations on 547 Swedish children with CP, ages 0 to 15 years, during the period of 1995-2006. They gathered those with AS scores of 0-1 into one category, and those with scores of 2-4 into another. Overall, the AS scores increased up to age 4 years, after which they decreased up to age 12 years, whether or not the children had undergone selective dorsal rhizotomy, intrathecal baclofen pump implantation, or a tendo-Achilles lengthening, At age 4 years ~47% of the children had "spasticity" - i.e. TS muscles graded as 2-4. After age 12 years, 23% of the children scored in that range. The CP subtypes spastic bilateral and spastic unilateral showed the same pattern as the total sample. Children with the dyskinetic type of CP showed an increasing muscle tone up to age 6, followed by a decreasing pattern up to age 15 years. The authors concluded that in children with CP, muscle tone as measured with the Ashworth scale increases up to 4 years of age and then decreases up to 12 years of age.

   In more than 4-0 years of working with children with CP, I have never observed this trend.

3. Later, Hagglund et al (2011) brought the assumption that spasticity may inhibit muscle growth to a study to determine whether "spasticity" - *measured with the AS* - is related to a gradual reduction in ankle DFROM in children with CP. From January of 1995 through June of 2008 they measured ROM and administered the AS annually – acquiring results from 2796 examinations - for a population of 355 Swedish children with CP of ages 0-18 years. Ankle DFROM decreased overall by a mean of 19^{o} during the first 18 years of life. They found a statistically significant association between the ROM and the child's AS scores ("spasticity level") during the year preceding the ROM measurement. Spasticity is related to the development of muscle contracture. Knowing that the AS and MAS scores do not correlate with most coincidental assessments of hyperreflexia using EMG, and that they probably represent the magnitude of soft tissue resistance to stretch due to nonreflex tissue stiffness, Hagglund's group actually determined that TS *stiffness* is associated with loss of DFROM...

   Combining the findings of both Hagglund studies, the data suggest that in this large population, while ankle DFROM decreased overall, TS AS scores (presumed to represent spasticity but actually accounting for stiffness) increased only to age four years, and then decreased again to 12 years. Therefore, the association between stiffness (misconstrued as spasticity), particularly as a CAUSE of diminishing ankle DFROM with age, is inconsistent with the data.

The profound conclusions about the causal effects of spasticity on ankle mobility and motor skills presented by Kim et al (2011) and Hagglund et al (2008 and 2011), both based on a tremendous body of work assessing and analyzing data obtained from great numbers of children, are simply wrong because the spasticity test they used is not valid as a test of spasticity.

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