RESEARCH REVIEW JOURNALS
Volume-03
Issue-12
December -2018

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com [UGC Listed Journal]

Clinical and Electromechanical Methods of Spasticity Assessment: A Review

[*1]Shakti Divya & [2]Mathew Lini

[1]*ME Scholar, Department of Electrical Engineering, National Institute of Technical Teachers Training and Research, Chandigarh (India)*

[2]*Associate Professor, Department of Electrical Engineering, National Institute of Technical Teachers Training and Research, Chandigarh (India)*

ARTICLE DETAILS

Article History
Published Online: 10 December 2018

Keywords
Spasticity, Ashworth Scale, Modified Ashworth scale, Tardieu Scale, Inertial Measurement Unit
.

[*]Corresponding Author
Email: goeldivyashakti[at]gmail.com

ABSTRACT

Spasticity is a neurological disorder which results in disordered sensorimotor control owing to an upper motor neuron lesion. The muscles are continuously contracted which causes stiffness in the muscle which hinders the movement of muscle from their natural movement. It is mainly caused due to an injury to the central nervous system. Commonly used assessment methods of spasticity like the Ashworth and modified Ashworth scales do not quantify the degree of spasticity in the patients as they simply make available a semi quantitative degree of the force applied by the foot as resistance to passive movement with restricted inter-rater reliability. Electromechanical methods like isokinetic dynamometers can be used only when an objective quantitative weigh is available for the resistance to passive motion. Electrophysiological methods are valuable for the understanding of the pathophysiological procedures tangled in spasticity. But none of the methods are easy and reliable.

1. Introduction

One of the most common diseases which potentially disables the person is Spasticity which affects the Spinal Cord Lesion (SCL) of the individual. According to studies 70% SCL patients end up having spasticity within one year of injury[1] and the anti-spastic medication is so scarce that only half receives them[2]. For having an effective treatment and validations of possible effects of new treatment inventions quantitative assessment of spasticity and spasms have to be done. Spasticity, though, easy to recognize but is not easy for its quantification. The main aim of this review paper is an evaluation of the reliability of the commonly used procedures for the spasticity quantification. Also, it determines the relationship between the tests used in the clinic which are generally done manually and more objective and quantifiable neurophysiological and electrophysiological techniques generally used for further investigation. To determine the positive potential effects of new treatment inventions a quantitative assessment of spasticity and spasms has to be done. Although spasticity is generally easy to recognize, it is not the same in terms of its quantification. Therefore, the main purpose of this paper is an assessment of the most frequently used methods for their reliability and quantification.

The distinguishing feature between the spasticity and other syndromes where there is a change in resistance to passive movement is its velocity dependency. The main problems with stiffness, fibrosis, contractures and atrophy change the muscle mechanical properties and also their classification and definition found in patients with SCL[3]. A significant relation between contracture and spasticity is the reduced range of motion (ROM)[4]. These changes distinguish them from spasticity but their determination is very difficult clinically. The distinction is of great significance as it determines the drugs to be given as well as the anti-spastic therapy to be given. SCL suffering patients have less severity of spasticity as compared to those with nominal sparing of voluntary movement[1,2,4]. The degree of spasticity ranges from trivial to serious disabilities. Variation in spasticity during the day time it termed as cervical SCL[5].

2. Clinical Methods

Clinical methods provide the quantitative and semi-quantitative measure of the resistance to passive motion. Various clinical methods have evolved over the time. Some clinical methods are discussed are Ashworth Scale, Modified Ashworth Scale, Tardieu Scale, Modified Tardieu Scale, Pendulum Test, Spasm Frequency Scales, Mynometric Devices, Neurophysiological, Electromechanical techniques as shown in Fig. 1.

2.1 The Ashworth and Modified Ashworth scales

The most often used procedures for the assessment of spasticity and its estimation are the Ashworth Scale (AS) and Modified Ashworth Scale (MAS). The simplicity of AS and no instrument requirement makes it a quick and easy method to carry out in numerous research studies. Bohannon and Smith established that a scale to the lower end to be added as several of their patients manifested that level of spasticity[6]. To make the scale less discrete, they included an extra category and they modified the scale. During the research, the rater should have an adequate training of the rating procedure before beginning the testing procedure and a well-designated procedure should be followed by the rater. Because of the large variation in the rater, it is suggested that only one rater should accomplish the entire test in an examination. For determination of all the influences from passive muscle structure, the operation of the limb at a speed should be done under the threshold of stretch reflex activity and the comparison should be done between the resistance at this speed and the higher speed of movements.

Pandyan et al concluded that for a nominal level of measure of resistance to passive movement AS can be utilized but not for spasticity assessment[7]. MAS can be used for measurement of the nominal level of the resistance to passive motion until the uncertainty between the scale of 1 and 1p grades is fixed. It can be concluded that AS and MAS may not be suitable for persons with SCL[8]. Sko'ld [5] concluded the study with 45 individuals suffering from SCL and derived that there was a substantial correlation between the Visual Analogue Scale (VAS) self-rating of spasticity and MAS.

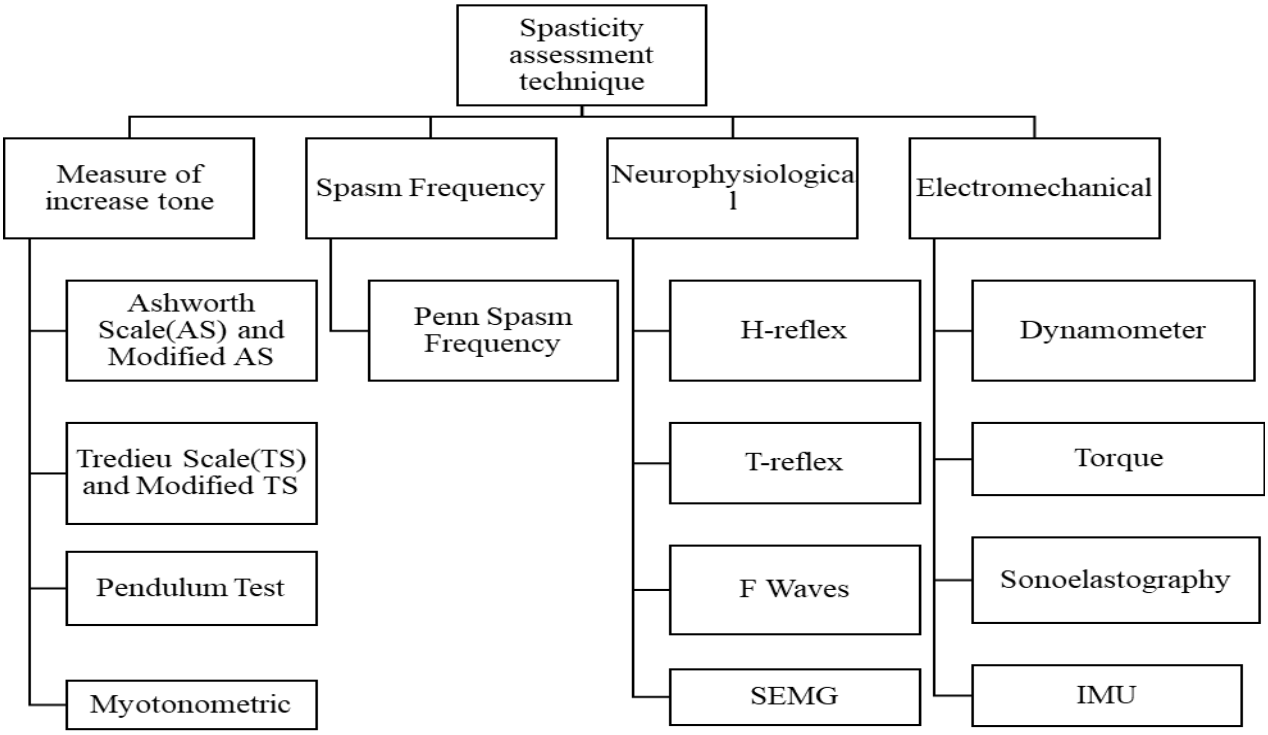

Fig. 1: Different methods of Spasticity Assessment

2.2Tardieu and Modified Tardieu Scale

Some recent studies have revealed that Tardieu scale can be easily used for quantification of the spasticity and is more reliable than the MAS. Tardieu scale is based on the concept of velocity dependent increase in the stretch reflexes[9]. The quantification of the muscle tone is done by measuring the intensity of the muscle stretch reflexes at some specified velocities. This scale has a distinct description for the proper positioning of the patient and also for the velocities for which each muscle has to be tested. It also has a score for the quality of the muscle reaction or reflex. So it can be concluded that it has shown more reliability than AS and MAS [10].

Modified Tardieu Scale (MTS) quantify the muscle activity at the maximum stretching velocity and the scores are given to the muscle reflex from 0 to 5. The measurement of the resistance can be easily done with MAS but velocity dependent increase in the reflex activity of the muscle cannot be assessed so it deviates from the main definition of spasticity. Moreover, no clear distinction for the peripheral and neural contributions to the reflex of muscle. On the other hand MTS is more precise and sensitive for this change in muscle reflex [11].

2.3 Pendulum test

Pendulum test was first developed by Wartenberg back in 1951. It has been analyzed in the further research[12–15]. The patient is made to sit or lie over the end of a couch with his lower leg hanging. The patient's leg is then extended to a horizontal position by the examiner while the patient is in a relaxed state. The leg is then released and it swings under the effect of gravity without restrictions. The electro-goniometers are used to evaluate the swing of the leg about the knee joint. The person with spasticity shows a reduction in the swing. Goniometer are used to measure the initial flexion and the final position of the knee joint and their ratio is employed for its' quantification. It crucially depends on the posture of the sitting person and his ability to relax fully. It can merely be employed for knee muscle spasticity and thus it does not contain any useful information about severe spasticity. The quantification of the reduction in the swing is done.

2.4 Myotonometric Devices

Another method for the quantitative assessment of the muscle tone is Myotonometric measurements. Myotonometric devices are dependable for measuring the tone of the muscle in relaxation and contracted muscle stiffness. It can be used for the varying levels of the contraction i.e. 25%, 50%, 80% and 100% of Maximal Voluntary Contraction (MVC) by means of frequency, stiffness and Area Under the Curve (AUC) parameters [16].

2.5 Spasm frequency scales

Penn spasm frequency scale was basically produced so that the consequence of intrathecal baclofen can be determined in 20 patients suffering from spasticity due to multiple sclerosis and SCL[17]. The scale developed was sensitive and was giving less optimal results when used for other purposes. A substitute frequency scale for spasm has been suggested which does the rating on the basis of spasm frequency per day[18]. A spasticity score was created as a product of the degree of muscle tone in accordance with the Ashworth Scale and frequency of spasm. Priebe et al[19] did the study with 85 subjects suffering from SCL with varying degree of spasticity and deduced a relationship between Penn spasm frequency and self-report scales of interference with function and aching spasm.

2.6 Neurophysiological methods

Stretching of the muscle(stretch reflex), tendon tap(T-reflex) or electrical stimulation of peripheral nerve supplying the muscle(H-reflex) gives rise to responses measured by EMG for the assessment of the spasticity from past many years for evaluation of these responses exaggerated in spastic individuals and related to the degree of spasticity. Even EMG response to passive manipulation of the limb has been used by the examiner for the measurement[20,2122].

2.7 Electromechanical methods

Electromechanical methods frequently used for the evaluation and assessment of spasticity are Isokinetic dynamometers. The major benefit is that standardization is made between the operating velocity stretch and possible amplitude and therefore it is possible to quantify the velocity dependent resistance offered by the muscle to inactive movement.

2.7.1 Dynamometer Measurements

The trustworthiness and legitimacy of isokinetic dynamometers were observed in many studies[23–27]and concluded that the values of the resistive force are highly reproducible for both low and high velocity and for both the healthy subjects as well as subjects with SCL and cerebral palsy. In all the studies described earlier the resistance to the passive motion of the muscle in both flexion extension and/or of a joint is quantified for the variable stretch velocities, i.e. the torque is quantified with sensitivity to the velocity of a stretch. In others, the total resistance of the muscle is evaluated at various velocities of stretch and in some the intrinsic and velocity dependent components are differentiated with torque components. With isokinetic dynamometers, the muscle resistance dependency on velocity, contributions from intrinsic muscle resistance and muscle resistance evoked from stretch can be determined[28,29]. Future scope is to develop these methods and making new portable and semi portable devices which can be easily used in clinical settings[30].

2.7.2 Torque interaction

It is based on the principle of cosine tuning which is the basis of muscle activity modulation. The muscle activity of the knee and hip joint is quantified by the linear summation of both torques i.e. knee joint torques (T_k) and hip joint torques (T_h).

$$M = aT_k + bT_h \qquad (1)$$

This equation can be reduced as

$$M = [|P||T|\cos\theta] \qquad (2)$$

where P = (a,b), T = ($[T_k T_h]$) and θ is the angle between them. This principle is called the cosine tuning and the quantification of this muscle activity torque is done for the assessment of muscle activity [31].

2.7.3 Sonoelastography

In Sonoelastography the calculation ofYoung's modulus is done which is the main physical quantity for measuring of stiffness[32]. In sonoelastography scanning light, reiterative compression was applied by hand with the portable transducer[33]. The visual feedback to the sonographer is provided by the quality bar indicator to monitor the compression technique. It is a seven-box indicator which begins to illuminate when the repetitive compression is applied. If 5 boxes, how green illumination then the displacement with the repetitive compression is sufficient. This color indication displays the relative stiffness of the muscle which ranges from red to blue with increasing trend of hardness with green and yellow color showing the medium spasticity. Sonoelastography is an encouraging indicative tool for assessing stiffness which is more objective [34].

2.8 Inertial Measurement Methods

An inertial sensor can be easily used for the characterization of the leg kinematics during the pendulum test and thus can be used for quantitative assessment of the spasticity of the quadriceps. Though a variety of methods has been discussed for the assessment of spasticity[35] no method is widely used in today's clinical practice and AS and MAS has been always the most diffused methods for the evaluation[36]. Both the scales only determine the resistance to the passive movement with a specific joint taken into consideration. Though they are much simpler to apply, the evaluation done by them is neither objective nor quantitative and largely depends upon the rater. Both also suffer from the limitation of poor sensitivity. Fleuren et al are against the use of AS for the assessment and has shown that it is neither reliable nor valid[37]. Even these raters cannot abandon this method due to lack of any particular judicious alternative.

The more practical approach for evaluating the spasticity of the quadriceps is by generating the movement by gravity same as in pendulum test. The pendulum test is always used for evaluation due to its simplicity. Recently developed devices which are widely used are Inertial Measurement Units (IMU) as they are highly accurate, lightweight and small so it can be used for tracking the proper 3D motion of the joint. It's simple use, portability, and low-cost helps in the encouragement of this new unit for the assessment in clinical practices. Thus the pendulum test done using IMU can be used for the assessment of the spasticity[38].

3. Conclusions

Various tests and measurements have been done to assess various aspects of spasticity. For minimizing effects of confusing factors, strict guidelines have to be adhered to for the assessment procedures in addition to a regular training program for the assessors. In clinical methods there is no general assess to quantify spasticity. Assessment techniques like AS and the MAS are most frequently used techniques. Though, their validity has been questioned as they focus on grading of resistance and not get the velocity-dependent characteristic of spasticity. The TS and MTS take the velocity-dependent characteristic of spasticity and are therefore recommended to be a most suitable measure for spasticity as compare to the AS.

Moreover, an amalgamation of electro-physiological and bio-mechanical techniques results in some better results of the full characterization of the spasticity; preferably, during functional passive/active movements as this may outcome in a much better assessment and closer to the clinical based phenomena. Goniometry is a vague method to measure the true AoC (Angle of Catch) due to inaccurate re positioning of the joint to the position where the catch was felt. Newly available inertial sensors can accurately measure orientation in space Inertial sensors are reliable and accurate to use in TS measurements to quantify Spasticity. There is a need for reliable and reproducible quantitative measures for the assessment of novel treatments of spasticity. Advancement and standardization of electro-mechanical techniques are to be done for having an effective and reproducible instrument. But in day to day clinical routine, simple instruments are needed which can be appreciated.

Acknowledgment

I would like to acknowledge the electrical department of NITTTR Chandigarh.

References

1. Kirshblum S. Treatment alternatives for spinal cord injury related spasticity. *J Spinal Cord Med*. 1999;22(3):199-217. doi:10.1080/10790268.1999.11719570
2. Maynard FM, Karunas RS, Waring WP. Epidemiology of spasticity following traumatic spinal cord injury. *Arch Phys Med Rehabil*. 1990;71(8):566-569. http://www.ncbi.nlm.nih.gov/pubmed/2369291.
3. Mayer NH. Clinicophysiologic concepts of spasticity and motor dysfunction in adults with an upper motoneuron lesion. *Muscle Nerve Suppl*. 1997;6:S1-S13. doi:10.1002/(SICI)1097-4598(1997)6
4. Sköld C, Levi R, Seiger Å. Spasticity after traumatic spinal cord injury: Nature, severity, and location. *Arch Phys Med Rehabil*. 1999;80(12):1548-1557. doi:10.1016/S0003-9993(99)90329-5
5. Sköld C. Spasticity in spinal cord injury: Self- and clinically rated intrinsic fluctuations and intervention-induced changes. *Arch Phys Med Rehabil*. 2000;81(2):144-149. doi:10.1053/apmr.2000.0810144
6. Bohannon RW, Smith MB. Inter rater reliability of a modified Ashworth Scale of muscle spasticity. *Phys Ther*. 1987;67:206-207. doi:10.1007/978-1-4471-5451-8_105
7. Pandyan AD, Johnson GR, Price CIM, Curless RH, Barnes MP, Rodgers H. A review of the properties and limitations of the Ashworth and modified Ashworth Scales as measures of spasticity. *Clin Rehabil*. 1999;13(5):373-383. doi:10.1191/026921599677595404
8. Haas BM, Bergström E, Jamous A, Bennie A. The inter rater reliability of the original and of the modified Ashworth scale for the assessment of spasticity in patients with spinal cord injury. *Spinal Cord*. 1996;34(9):560-564. doi:10.1038/sc.1996.100
9. Paulis WD, Horemans HLD, Brouwer BS, Stam HJ. Excellent test-retest and inter-rater reliability for Tardieu Scale measurements with inertial sensors in elbow flexors of stroke patients. *Gait Posture*. 2011;33(2):185-189. doi:10.1016/j.gaitpost.2010.10.094
10. Morris S. Ashworth And Tardieu Scales: Their Clinical Relevance For Measuring Spasticity In Adult And Paediatric Neurological Populations. *Phys Ther Rev*. 2002;7(1):53-62. doi:10.1179/108331902125001770
11. Mehrholz J, Wagner K, Meßiner D, et al. Reliability of the modified tardieu scale and the modified ashworth scale in adult patients with severe brain injury: A comparison study. *Clin Rehabil*. 2005;19(7):751-759. doi:10.1191/0269215505cr889oa
12. Bajd T, Vodovnik L. Pendulum testing of spasticity. *J Biomed Eng*. 1984;6(1):9-16. doi:10.1016/0141-5425(84)90003-7
13. Bohannon RW. Variability and reliability of the pendulum test for spasticity using a Cybex® II isokinetic dynamometer. *Phys Ther*. 1987;67(5):659-661. doi:10.1093/ptj/67.5.659
14. Brown RA, Lawson DA, Leslie GC, et al. Does the Wartenberg pendulum test differentiate quantitatively between spasticity and rigidity? A study in elderly stroke and Parkinsonian patients. *J Neurol Neurosurg Psychiatry*. 1988;51(9):1178-1186. doi:10.1136/jnnp.51.9.1178
15. Lin DC, Rymer WZ. A Quantitative Analysis of Pendular Motion of the Lower Leg in Spastic Human Subjects. *IEEE Trans Biomed Eng*. 1991;38(9):906-918. doi:10.1109/10.83611
16. Jarocka E, Marusiak J, Kumorek M, Jaskólska A, Jaskólski A. Muscle stiffness at different force levels measured with two myotonometric devices. *Physiol Meas*. 2012;33(1):65-78. doi:10.1088/0967-3334/33/1/65
17. Penn RD, Savoy SM, Corcos D, et al. Intrathecal Baclofen for Severe Spinal Spasticity. *N Engl J Med*. 1989;320(23):1517-1521. doi:10.1056/NEJM198906083202303
18. Snow BJ, Tsui JK, Bhatt MH, Varelas M, Hashimoto SA, Calne DB. Treatment of spasticity with botulinum toxin: a double-blind study. *Ann Neurol*. 1990;28(4):512-515. doi:10.1002/ana.410280407
19. Priebe MM, Sherwood AM, Thornby JI, Kharas NF, Markowski J. Clinical assessment of spasticity in spinal cord injury: A multidimensional problem. *Arch Phys Med Rehabil*. 1996;77(7):713-716. doi:10.1016/S0003-9993(96)90014-3
20. Sköld C, Harms-Ringdahl K, Hultling C, Levi R, Seiger Å. Simultaneous ashworth measurements and electromyographic recordings in tetraplegic patients. *Arch Phys Med Rehabil*. 1998;79(8):959-965. doi:10.1016/S0003-9993(98)90095-8
21. Zupan B, Stokić DS, Bohanec M, Priebe MM, Sherwood AM. Relating clinical and neurophysiological assessment of spasticity by machine learning. In: *International Journal of Medical Informatics*. Vol 49. ; 1998:243-251. doi:10.1016/S1386-5056(98)00043-4
22. Voerman GE, Gregorič M, Hermens HJ. Neurophysiological methods for the assessment of spasticity: The Hoffman reflex, the tendon reflex, and the stretch reflex. *Disabil Rehabil*. 2005;27(1-2):33-68. doi:10.1080/09638280400014600
23. Farrell M, Richards JG. Analysis of the reliability and validity of the kinetic communicator exercise device. *Med Sci Sports Exerc*. 1986;18(1):44-49. doi:10.1249/00005768-198602000-00009
24. Mayhew TP, Rothstein JM, Finucane SDG, Lamb RL. Performance characteristics of the Kin-Com® dynamometer. *Phys Ther*. 1994;74(11):1047-1054. doi:10.1093/ptj/74.11.1047
25. Snow CJ, Blacklin K. Reliability of knee flexor peak torque measurements from a standardized test protocol on a Kin/Com dynamometer. *Arch Phys Med Rehabil*. 1992;73(1):15-21. http://www.ncbi.nlm.nih.gov/pubmed/0001729967.
26. Lamontagne A, Malouin F, Richards CL, Dumas F. Evaluation of reflex- and nonreflex-induced muscle

resistance to stretch in adults with spinal cord injury using hand-held and isokinetic dynamometry. *Phys Ther*. 1998;78(9):964-975; discussion 976-978.
27. Kakebeeke TH, Lechner H, Baumberger M, Denoth J, Michel D, Knecht H. The importance of posture on the isokinetic assessment of spasticity. *Spinal Cord*. 2002;40(5):236-243. doi:10.1038/sj/sc/3101282
28. Franzoi AC, Castro C, Cardone C. Isokinetic assessment of spasticity in subjects with traumatic spinal cord injury (ASIA A). *Spinal Cord*. 1999;37(6):416-420. doi:10.1038/sj.sc.3100849
29. Akman MN, Bengi R, Karatas M, Kilinç Ş, Sözay S, Özker R. Assessment of spasticity using isokinetic dynamometry in patients with spinal cord injury. *Spinal Cord*. 1999;37(9):638-643. doi:10.1038/sj.sc.3100892
30. Burridge JH, Wood DE, Hermens HJ, et al. Theoretical and methodological considerations in the measurement of spasticity. *Disabil Rehabil*. 2005;27(1-2):69-80. doi:10.1080/09638280400014592
31. Nozaki D. Torque interaction among adjacent joints due to the action of biarticular muscles. *Med Sci Sports Exerc*. 2009;41(1):205-209. doi:10.1249/MSS.0b013e318183c103
32. Hall TJ. Beyond the basics: elasticity imaging with US. *Radiographics*. 2003;23(6):1657-1671. doi:10.1148/rg.236035163
33. Park G-Y, Kwon DR. Application of real-time sonoelastography in musculoskeletal diseases related to physical medicine and rehabilitation. *Am J Phys Med Rehabil*. 2011;90(11):875-886. doi:10.1097/PHM.0b013e31821a6f8d
34. Kesikburun S, Yaşar E, Adigüzel E, Güzelküçük Ü, Alaca R, Tan AK. Assessment of Spasticity With Sonoelastography Following Stroke: A Feasibility Study. *PM R*. 2015;7(12):1254-1260. doi:10.1016/j.pmrj.2015.05.019
35. Biering Sørensen F, Nielsen JB, Klinge K. Spasticity Assessment: a Review. *Spinal Cord*. 2006;44(12):708-722. doi:10.1038/sj.sc.3101928
36. Kumar RTS, Pandyan AD, Sharma AK. Biomechanical measurement of post-stroke spasticity. *Age Ageing*. 2006;35(4):371-375. doi:10.1093/ageing/afj084
37. Fleuren JFM, Voerman GE, Erren-Wolters C V., et al. Stop using the Ashworth Scale for the assessment of spasticity. *J Neurol Neurosurg Psychiatry*. 2010;81(1):46-52. doi:10.1136/jnnp.2009.177071
38. Sterpi I, Caroli A, Meazza E, Maggioni G, Pistarini C, Colombo R. Lower limb spasticity assessment using an inertial sensor: A reliability study. *Physiol Meas*. 2013;34(11):1423-1434. doi:10.1088/0967-3334/34/11/1423