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# Modified Ashworth Scale (MAS) Model based on Clinical Data Measurement towards Quantitative Evaluation of Upper Limb Spasticity

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**Abstract**. Spasticity is common symptom presented amongst people with sensorimotor disabilities. Imbalanced signals from the central nervous systems (CNS) which are composed of the brain and spinal cord to the muscles ultimately leading to the injury and death of motor neurons. In clinical practice, the therapist assesses muscle spasticity using a standard assessment tool like Modified Ashworth Scale (MAS), Modified Tardiue Scale (MTS) or Fugl-Meyer Assessment (FMA). This is done subjectively based on the experience and perception of the therapist subjected to the patient fatigue level and body posture. However, the inconsistency in the assessment is prevalent and could affect the efficacy of the rehabilitation process. Thus, the aim of this paper is to describe the methodology of data collection and the quantitative model of MAS developed to satisfy its description. Two subjects with MAS of 2 and 3 spasticity levels were involved in the clinical data measurement. Their level of spasticity was verified by expert therapist using current practice. Data collection was established using mechanical system equipped with data acquisition system and LABVIEW software. The procedure engaged repeated series of flexion of the affected arm that was moved against the platform using a lever mechanism and performed by the therapist. The data was then analyzed to investigate the characteristics of spasticity signal in correspondence to the MAS description. Experimental results revealed that the methodology used to quantify spasticity satisfied the MAS tool requirement according to the description. Therefore, the result is crucial and useful towards the development of formal spasticity quantification model.

## 1. Introduction

Muscle control disability is resulted from imbalanced signals from the central nervous system (CNS) which are composed of brain and spinal cord to the muscles. This factor causes restriction for the disables to perform their Activities of Daily Living (ADL). Upper limbs are part of the human body that is used in many tasks such as eating, writing and other prehensile actions. Thus, the affected subjects have to undergo rehabilitation training program in order to recover from the disabilities.

Stretching the muscle repeatedly may potentially increase the muscle tension and resistance to passive movement [1]. Therefore, subjects need the assistance from expert therapist to perform the training. Three common causes of spasticity are due to stroke, cerebral palsy and traumatic brain injury [2]. According to National Stroke Association Malaysia (NASAM), stroke is the second largest cause of death after heart disease, while cerebral palsy is high amongst the children. It is important for subject to have regular training and therapy in order to reduce the stiffness or tightness of the muscles in order to recover muscle control.

Before undergoing training, subject need to be assessed by therapist to determine his muscle spasticity severity. In the current assessment methodology, this is done purely on qualitative basis and subjected to therapist's jurisdiction and experience [3, 4]. Thus, the assessment is susceptible to variation and this could pose a challenge to monitor the progress of the subject effectively especially if the training sessions are conducted by different therapists. There exist quite a number of assessment tools that were used in clinical practice to measure the level of spasticity. These tools are going to be discussed in the next section.

In this paper, clinical data measurement was elaborated towards the development of upper limb quantitative assessment model. It is composed of four sections where in section 2, spasticity assessment tools are briefly described. The subsequent sections explain on the system description, the methodology of clinical data measurement and, the result with discussion.

**2. Spasticity Assessment Tools**

Management of spasticity is required for clinical evaluation of the subject. Clinical assessment of spasticity should be based on a validated assessment system. Most of conventional clinical therapies refer to certain assessment tools such Fugl-Meyer Assessment (FMA), Modified Tardieu Scales (MTS) and Modified Ashworth Scale (MAS).

Fugl-Meyer Asessment tool is used to assess motor control of the patient. It is created to assess motor function, balance, sensation and joint function in subjects with post-stroke hemiplegia [5, 6]. It is applied clinically and in research to determine the severity level of the disease, describe motor recovery, and to plan and assess treatment [7]. However, this tool is inadequate for spasticity assessment due to its main function more on motor control of particular affected part assessment.

The Tardieu scale and the modified Tardieu scale [8, 10] are the tool that takes into account resistant to the passive movement at both slow and fast speeds. It measures quality of muscle reaction to passive movement and angle of muscle reaction at the point of resistance to the fastest movement speed [10]. Several researches indicated that MTS can be used as reliable measurement for quantifying spasticity of lower limb [11, 12] due to high inter rater validity results.

The more famously used tool found in the practice is the Ashworth scale or the modified Ashworth scale [13, 15].The scale measures the resistance and spasticity (or catch) in the joint during passive movement. The resistance is scored from 0 to 4 (Ashworth scale) and from 0 to 5 (modified Ashworth scale). The score is based on the classification and description as shown in Table 1. According to [14], there is high inter-rater reliability when using the MAS compared to MTS to assess the upper limb spasticity [14, 15].

The shortcomings of all of these tools are that they are subjective and dependent on the therapist impression of spasticity on passive movement. Previous studies have shown that spasticity scales provide insufficient information about muscles involved in spastic movement and the reliability and validity of the scales has been questioned in clinical practice [16, 17]. Thus, introducing quantitative measurement based on the MAS may help to overcome the inadequacy of current method.

**Table 1** Modified Ashworth Scale (MAS) Scoring System

| Grade | Description |
|---|---|
| 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 of the range of motion when the affected part(s) is moved in flexion or extension |
| 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 affected part(s) easily moved |
| 3 | Considerable increase in muscle tone, passive movement difficult |
| 4 | Affected part(s) rigid in flexion or extension |

**3. System Description**

The measurement of spasticity level is done with the help of a mechanical system. It is used to collect data of the passive flexion movement of upper extremity. As shown in Figure 1, the system has a kinematic structure of 1-DOF system which consists of a single revolute joint. This preliminary system is composed of four main parts which are the lever, platform, torque sensor and potentiometer. Platform was placed along X to be revolute within fixed axis at angle $\theta_1$.Torque sensor and potentiometer are attached to the pivotal point of the system. The function of each part is described in Table 2.

**Table 2** System Desription

| Part/Component | Function |
|---|---|
| Lever (manual handle) | To make passive movement of forearm (flexion) and control by human (therapist). |
| Platform | To hold subject's forearm during passive movement. |
| Torque Sensor (custom made) | To measure torque exert by the subject's forearm. |
| Potentiometer (981 HE) | To measure angle between upper and lower limb and to detect the catch position. |

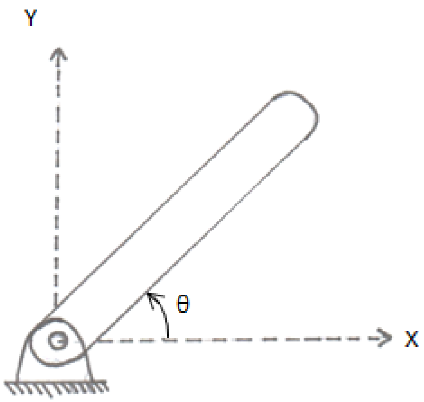


**Figure 1** Kinematic Model

**4. Methodology**

Before the start of data collection process, an ethical clearance has been obtained from the IIUM Research Ethics Committee (IREC) [Ref No: IREC 659]. The selection of subjects is based on certain criteria that are they must have abnormality in motor control with hemiparesis condition and aged over 18 years old. The work is only focused on the upper limb part of the subjects. The subject was brief before the data collection process started and his consent was obtained. The clinical data collection was conducted at the Physical Rehabilitation Centre, IIUM Kuantan and the ambient temperature of the room where the experiment took place was set to $24^0$C.

*4.1 Data collection set-up*

The therapist explained to the subject on the system and the process of data collection together with safety issues. The therapist was assisted by a technical team on the procedure in handling the system during measurement process.

Torque sensor was placed along the pivot point of the elbow joint to measure the spasticity experienced by the subject during passive movement induced by the therapist based on lever mechanism. A single turn potentiometer was used to measure range of motion (ROM) and angle where the catch happened. Catch is defined as a sudden appearance of increased muscle activity in response to a fast passive stretch, which leads to an abrupt stop or sudden increased resistance during the movement, at a certain angle before ROM is reached[18,19]. Both the torque sensor and potentiometer are connected to a DAQ system and the data was recorded using Labview software.

Before the measurement of spasticity by using the mechanical system was conducted the level of muscle spasticity for each subject was accessed by therapist using manual method which is based on the Modified Ashworth Scale tool. Then, the subject was asked to place his arm in the supine position (relax position) and his forearm placed on the platform with the elbow joint parallel to the pivot point of the system. The length of the forearm was measured and recorded. The platform was then moved against the subject's forearm as it flexed at slow and fast speed by the therapist using the lever throughout the full range of motion. The slow movement is to determine the accessibility range of the motion of the affected upper limb. Meanwhile the fast movement is to detect the catch position throughout the full range of motion. Based on the previous study, the average active range of motion (ROM) of elbow flexion was 130 degree [20]. The data measured by the sensors were measured and recorded.

The process is repeated three times for each subject to get the best estimated model of the muscle spasticity. The flow of the data collection process is captured in Figure 2.

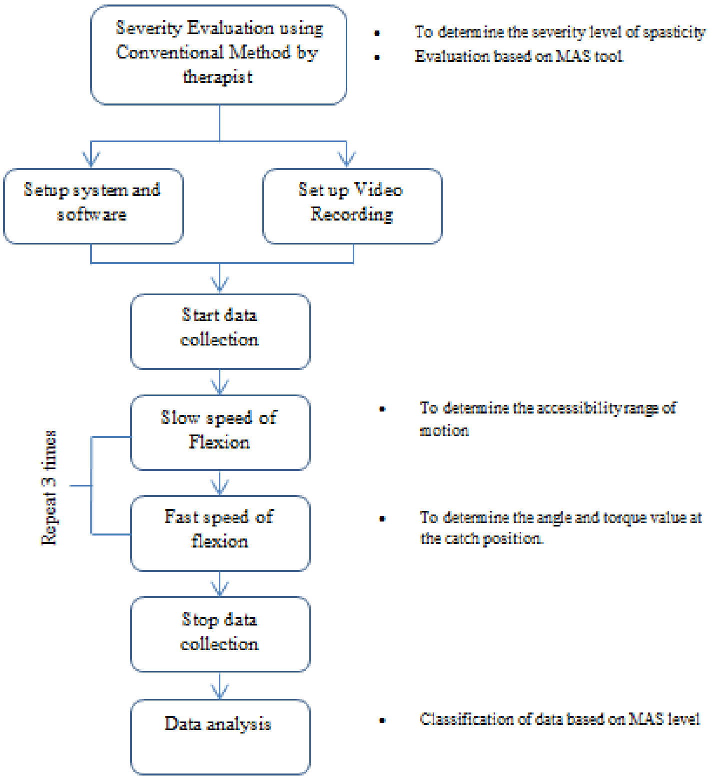


**Figure 2** Flowchart of experiment protocol

**5. Result and Discussion**

The data for torque representing muscle spasticity together with the flexion angle of the forearm were recorded for all the sessions. Figure 3 and 4 depicts the signal measured for subject 1 and 2 respectively. The torque value is plotted against the flexion angle in order especially to identify the catch position.

Based on Figure 3, it shows that the full ROM is $120^{0}$and catch happen at $59^{0}$ which is less than half of the ROM with a minimal release. From the MAS description, the condition satisfies MAS level 2 as more marked increase in muscle tone is seen through most of the ROM. The catch position is detected at the peak point of the torque which happens at $59^{0}$ flexion angle.

In Figure 4, the full ROM is shown to be $135^{0}$ and the resistance keeps increasing throughout the full ROM. Prior to that, there is no catch and release appears. The graph satisfies the description of MAS level 3 as a considerable increase in muscle tone with passive movement difficulty is captured. Table 3 summarizes the description of the subjects with their respective level of spasticity.

**Table 3** Results of clinical assessment based on the preliminary system

| Subject Number | 1 | 2 |
|---|---|---|
| Gender | Male | Male |
| Spastic Arm | Left | Right |
| Cause of symptom | Traumatic Brain Injury | Stroke |
| MAS level | 2 | 3 |
| Catch position (degree) | 59 | None |

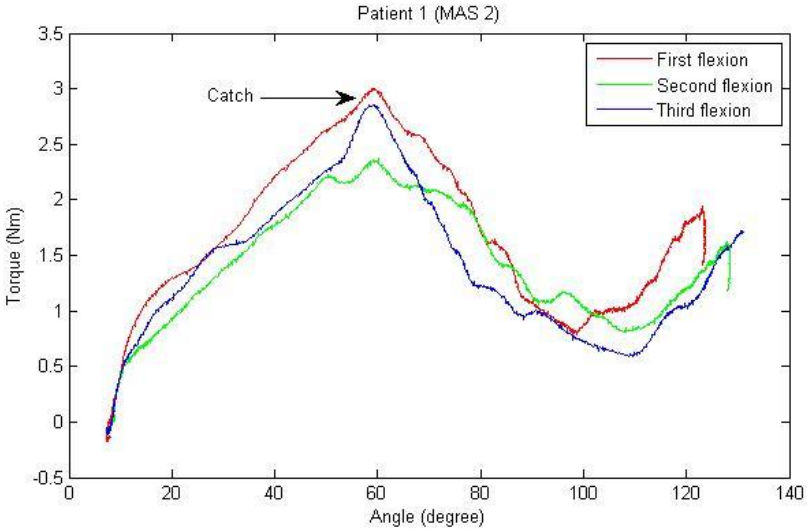


**Figure 3** Clinical data for Subject 1 with MAS level 2

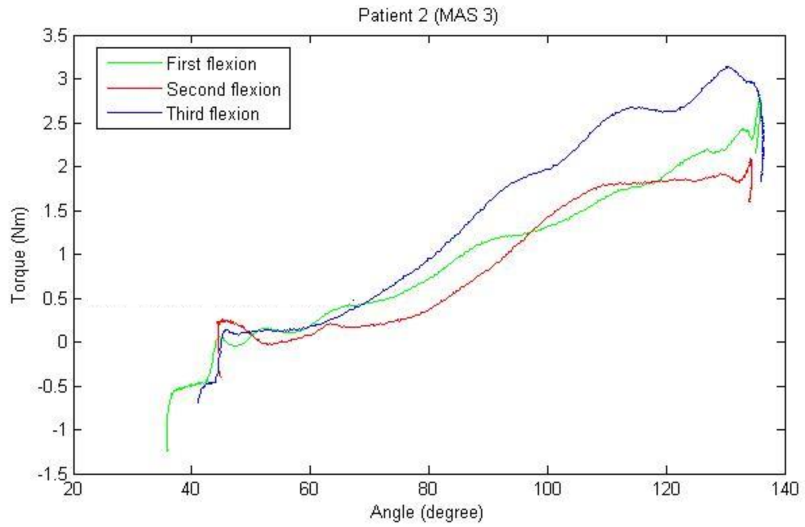


**Figure 4** Clinical data for subject 2 with MAS level 3

## 6. Conclusion

In a nutshell, the paper proposes the use of a mechanical system to measure muscle spasticity of upper limb. The methodology leverages on a standard mean in data collection of muscle tone during fast and slow movement which can be analyzed quantitatively. The preliminary experimental result also suggests that the method for spasticity quantification satisfies the MAS tool requirement based on its description. We have planned in the future to collect more sample data with larger sample size in order to generalize the model.

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