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RESEARCH ARTICLE

Use of reliability tested clinically data towards a portable device measurement kit system for upper limb spasticity

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Abstract

Spasticity refers to the abnormal symptom of having resistance in the joints when patients tried to make a movement. Patients with spasticity need to undergo multiple therapy sessions with medical intervention to ensure that the upper limb achieve maximal function. Modified Ashworth Scale (MAS) is frequently used in clinical assessment with grading on a scale. However, this scale is limited in sensitivity and the accuracy of this evaluation is dependent on the physician's and therapist's experience. This study suggests developing a portable measurement device kit system during clinical assessment to reduce inter- and intra-rater variability, and to assist clinicians in making quick clinical evaluation of spasticity. In this study, 19 patients were involved in the data acquisition. Assessment data from upper limb of patients with spasticity were recorded using a Manual Muscle Tester (MMT) and digital goniometer to measure force and the angular motion. During the assessment, patients were examined through slow and fast motion for spasticity evaluation. The collected data were analyzed to study intra-rater reliability value by using Statistical Package for the Social Sciences (SPSS). The results of Intraclass Correlation Coefficient (ICC) values for all patients were in range 0.78 to 0.89. It can be considered that the collected data was reliable and can be used to formulate a model towards the development of a portable device measurement kit system for upper limb spasticity.

Keywords: Upper limb, stroke; rehabilitation

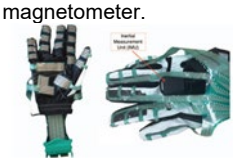
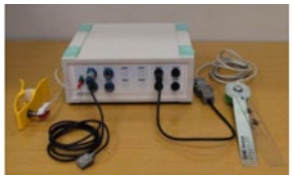
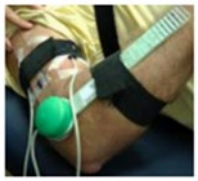
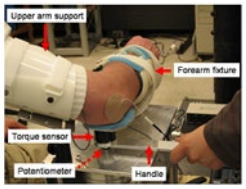
INTRODUCTION

Stroke is one of the biggest contributors to spasticity (Organization, 2004). Spasticity can be defined as hypertonia with several signs, which are the resistance to externally imposed movement that increases with increasing speed of stretch and varies with the direction of joint movement as well as the resistance to externally imposed movement that rapidly rises above a threshold speed or joint angle. From both signs mentioned, spasticity creates stiffness and tightness (Satkunam, 2003). The resistance is the reason why the muscles are unable to complete their Range of Motion (ROM) since it gives the sign of increased muscle tone (Adams & Hicks, 2005). One side of human body will be weakened or paralyzed and needs time to recover from spasticity (Oujamaa *et al.,* 2009). At this stage, the patients suffering from spasticity need rehabilitation to regain their normal movement. However, determining the efficacy of these management techniques depend on measurement tools that can objectively quantify spasticity. The quantitative assessment of spasticity is important for evaluation of potential effects of treatment interventions, with assessments of spasticity being challenged as having poor sensitivity and is not simple to execute (Silva *et al.,* 2014).

From the review, past and current measurement devices are not suitable for everyday clinical use by physician to patient (refer Table 1). The goniometer is designed to measure the range of motion of the elbow joint (Kim *et al.,* 2011). On the other hand, a manual muscle tester is used to measure the force given by the physician on the forearm of the subjects during a passive stretch motion. Other researcher also uses EMG sensor for force measurement.

There are technologies that have been shown to accurately measure spasticity, but they are often limited to laboratory-based research and are not suitable for everyday clinical use (Burridge *et al.,* 2005). Clearly, there is a need for a clinically friendly tool that can improve spasticity assessment, which are clinically relevant for physicians. Thus, there is a gap to develop a measurement kit and a system that can enhance a physician's method of improving spasticity assessment. Generally, standardizing the level of spasticity is difficult to achieve since different physicians/clinicians lead to different evaluation findings (Biering-Sørensen *et al.,* 2006). In which, the accuracy of this evaluation is depended on the physicians and clinicians' experience (Wu *et al*., 2006). Therefore, the physician/clinician needs a measuring device system to improve the rehabilitation process. In this paper, we present a conceptual design of a portable measurement device kit system and reliability test analysis of the input data from a single physician.

Table 1 List of previous study of improved measurement device for spasticity assessment.

Journal	Authors, Year	Prototype	Assessment Procedure	System Evaluation and Research Limitation
Quantification of elbow muscle tone from an instrumented manual stretch-reflex test (Mcgibbon, Sexton, Jones, & Connell, 2016)	McGibbon, Sexton , Jones, and O'Connell, 2016	Name: BioTone system Function: portable toolkit to conduct comprehensive and quantitative assessment of muscle impairment and function in patients with mobility disorders. 	1. Fibre-optic goniometer (FOG) was used to measure elbow angle; 2. Grip strength measurement device (GSMD); 3. Limb strength measurement device (LSMD); 4. EMG and FOG set-up for stretch-reflex testing of elbow flexors and extensors.	They used LDA to classify patients by their probability of belonging to a MAS category. Assessment done only for seated subject.
An Instrumented Glove for Improving Spasticity Assessment (Jonnalagedda et al., 2016)	Jonnalagedda , Deng, Douglas, Chukoskie, and Yip,2016	Name : The glove Function: include spatially-resolved, and force-dependent resistive sensor elements. Measurement unit consists of an accelerometer, a gyroscope, and a magnetometer. 	The researchers wore the glove and performed cycles of movement with the patient, for example elbow flexion and extension, and the sensor recorded the force F (Newton) versus time.	They evaluated the device with a mock-patient arm with adjustable resistance to motion and sensors to report the load and angular displacement.
Proposal of a real-time computational tool for the measurement of spasticity in stroke patients (Silva et al., 2014)	Silva, Silva, Marques, Naves, and Soares, 2014	Name: MyosystemBr1. Specifications: 8 EMG channels and 4 auxiliary ones, with 16 bit A/D resolution. Programmable settings such as total gain, low pass filter cutoff frequency and sampling rate for each channel. 	Used one EMG channel for recording the biceps brachial muscle and one auxiliary for recording the electrogoniometer. 	This paper presented the proposal of a real-time application for the measurement of spasticity based on tonic stretch reflex threshold (TSRT). No update paper of approached device.
Reaching Toward Quantitative Metrics of Spasticity (Krasner, Wininger, Kim,& Craelius, 2011)	Krasner, Wininger, Kim and Craelius, 2011	Function: for quantifying movement smoothness that can recognize and quantify degrees of spasticity and is applicable to any limb. 	Each subject was seated with his/her arm supported by the Mechanical Arm Supporter and Tracker (MAST). The MAST supports the arm while the elbow flexes and extends, against variable resistances.	Non-smooth movements are difficult to quantify and compare to smooth movements. Suitable only for seated subject.
Measurement of Elbow Spasticity in Stroke Patients Using a Manual Spasticity Evaluator (Wu *et al.*, 2006)	Wu, Park, Ren, Gaebler-Spira, and Chen, 2006	Name: Manual Spasticity Evaluator Function: clinician using extended handle to evaluate the spastic elbows easily with joint torque measured by a torque sensor. 	The device measured the joint torque and angle using a torque sensor and a potentiometer respectively. With the patient's arm mounted onto the device, surface electrodes (DE-2.1, Delsys Inc., MA, USA) were placed on the biceps brachii and triceps brachill.	Complicated setup and risk of error during clinician hold the handle to evaluate spasticity.

CONCEPTUAL STUDY

The purpose of this study was to develop a portable device measurement kit for improving spasticity assessment. In this portable device measurement kit, it includes a manual muscle tester (MMT), digital goniometer with sensor DAQ interface and laptop installed with evaluation system software (refer Fig 1). The developed system can evaluate the level of spasticity based on the Modified Ashworth Scale (MAS) in real time using neural network. The database will be saved from the classified data of spasticity during assessment. From this database, an algorithm for the system to be readable for identifying the level of spasticity was generated. At the end of the assessment, the neural network determined the level of spasticity according to quantifying the properties of spastic biceps muscle. Then, the measurement device measured the data in real time and translated the measurement data for spasticity evaluation in screen display. The outcome of this measurement device system was compared with our physician's evaluation to ensure the system was able to identify different levels of spasticity. The outcome may lead to improving the quality of post-stroke evaluation and thus the quality of post-stroke care.

Fig 1 Conceptual idea of portable device measurement kit.

METHODOLOGY

The clinical data measurement was done by a professional rehabilitation physician in a government hospital and a university teaching centre in Malaysia. A total of 19 patients with spasticity were involved in the study. Each patient had different characteristics and levels of spasticity. Before conducting the clinical assessment, ethics approval was granted from UiTM Research Ethics Committee and the Medical Research Ethics Committee (MREC). The assessment was conducted with fast and slow passive motion of the elbow joint, where we measured the range of motion (ROM) and catch position of each patient (Zakaria et al., 2014). The goniometer (GNM-BTA from Vernier) was used to measure the angle of patient's arm movement and manual muscle tester from Sakaimed was used to measure the force.

Before the clinical procedures began, the goniometer was attached to the patient's arm and manual muscle tester placed to physician's palm. Both are connected to a Vernier SensorDAQ for data acquisition. The clinical procedures begin with slow motion through the range of movement. The physician stretched the forearm of the patient until reaching fully stretched position during slow extension. The estimated time for reaching fully stretched position was about 7 to 8 seconds and repeated three times. The clinical procedure continued with fast motion session. The physician stretched the patient's arm as fast as the patient can in order to obtain catch position. The estimated time to complete the fast motion session about 3 seconds and also repeated three times. Both motion sessions were recorded and the evaluation of level of spasticity determined by the physician.

RESULTS AND DISCUSSION

Standard Error Measurement (SEM) was used to obtain the error of measurement for the patients. To calculate the error happen during clinical procedure, the equation of Standard Error Measurement (SEM) is

$$SEM = SD \times \sqrt{1 - ICC} \quad (1)$$

The equation consists of standard deviation (SD) multiply with square root of sum of one minus Intraclass Correlation Coefficient (ICC) value. If the SEM values are below to one, the final answer will be same with SD value. If the SEM values is higher than 1, the SEM value will be equal to zero. Table 2 shows the Standard Error Measurement (SEM) value for slow and fast extension of the patients. Referring to Table 2, SEM values for the patients is equal to zero. Therefore, it can be assumed that the error measurements did not exist during the clinical procedure and the clinical data collected is valid and acceptable.

Table 2 SEM values for slow and fast extension of patient.

Patient	SD_{slow}	SEM_{slow}	SD_{fast}	SEM_{fast}
4	110.58	0	106.70	0
5	121.30	0	144.09	0
6	108.86	0	118.74	0
7	129.73	0	131.21	0
10	161.82	0	138.45	0
11	120.95	0	98.25	0
12	171.31	0	166.19	0
15	151.83	0	146.80	0
16	120.60	0	127.34	0
17	128.60	0	113.07	0
18	153.35	0	117.30	0
19	140.13	0	149.91	0

The reliability test analysis is important towards this study to validate physician evaluation data as a database in our evaluation system. Intraclass Correlation Coefficient (ICC) is a descriptive statistic used when quantitative measurements are made on units that are organized into groups. To obtain the intra-rater reliability, the ICC was used during the data. It is used to calculate the consistency of measurements made by multiple observers measuring the same quantity. Table 3 shows the ICC value for slow and fast extension of the patients. From the table, the ICC values for slow and fast extension of patients shows good interpretation by referring to Koo and Li (2016). The ICC values for all patients ranged from 0.78 to 0.89. The variables selected such as time taken, angle, and moment are in same quantity. Since all the patients showed good interpretation in intra-rater reliability test, this validated data can be used to formulate a system model towards the development of a portable device measurement kit system for upper limb spasticity.

Table 3 Intraclass Correlation Coefficient (ICC) values for patients.

Patient	ICC_{slow}	Interpretation	ICC_{fast}	Interpretation
4	0.86	Good	0.78	Good
5	0.85	Good	0.78	Good
6	0.87	Good	0.79	Good
7	0.85	Good	0.79	Good
10	0.85	Good	0.81	Good
11	0.89	Good	0.82	Good
12	0.84	Good	0.80	Good
15	0.85	Good	0.81	Good
16	0.89	Good	0.86	Good
17	0.89	Good	0.82	Good
18	0.86	Good	0.81	Good
19	0.88	Good	0.82	Good

CONCLUSION

In conclusion, it shows that there are numerous assessment tools that can be used to measure spasticity. However, various issues are associated with these tools such as inconsistent psychometric properties and feasibility of using the measure in the clinical setting. In this work, previous study of improving measurement device was reviewed and a conceptual design based on reliable clinical data for the development

of a portable measurement device kit approach has been presented. The limitation of the study was that there were several patients that have insufficient data. The incomplete data collected limited the researchers' ability to measure the intra-rater reliability. Further study needs to continue with more variable patient's data.

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