

TOWARDS A CLINICALLY COMPLIANT UPPER LIMB PART-TASK TRAINER IN SIMULATED LEARNING PROGRAM

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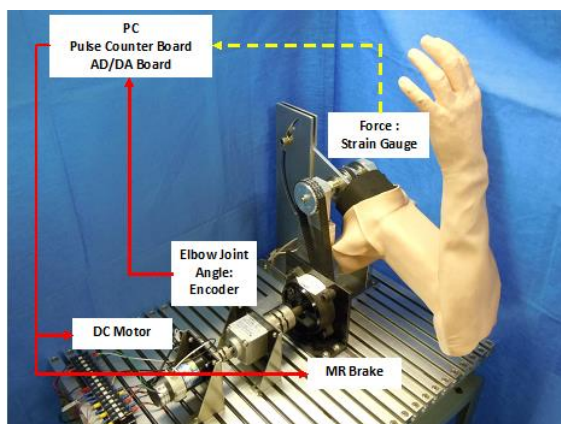
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Graphical abstract



Abstract

Patient simulator is one of the methods physiotherapists and occupational therapists trainee use to improve their skills. The focus here is on spasticity as part of the upper motor neuron (UMN) syndrome. The rehabilitation process for patients with UMN syndrome and management of spasticity is very important because spasticity will affect function and quality of life. A rehabilitation process requires physicians, occupational therapists and physiotherapists to assess the spasticity level using clinical assessment methods. To engage directly with the patients, the clinicians should have enough skill and experience to reduce risk of injury to the patients. Thus, it is mandatory for the physiotherapists and occupational therapists trainee to go through comprehensive training before they can conduct the therapy session. This paper reveals the research urgency in therapist education tools for upper limb rehabilitation training and points out the significance of having compliance with clinical assessment scales.

Keywords: Stroke, spasticity, stroke rehabilitation, training simulator, therapist education

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1.0 INTRODUCTION

Technology-assisted physical activity is one of the approaches that assist patient to gain motor recovery. Robotic technology uses robotic devices to assist impaired limbs with performing repetitive motion to regain the strength and function. By using the same concept, a robotic patient simulator and part-task

trainer has been developed to increase the training frequency of therapist trainee to gain experience without putting the patients at risk. Physicians, physiotherapists and occupational therapists play very important roles in a multidisciplinary rehabilitation process. To obtain skills for the physiotherapists and occupational therapists, clinical training is required involving real patients. It might be risky as the

physiotherapists and occupational therapists trainee have inadequate skills and experience to handle patients with spasticity. In the training course in Japan, they are normally practicing with healthy person who are role playing as a simulated patient [1]. This method is impractical because actual symptoms of spasticity cannot be demonstrated. For that reason, it is important to develop a patient simulator for therapist education purpose. In [2], an experiment comparing treatment administrated by a qualified physiotherapist and treatment delegated to a trained and closely supervised physiotherapy assistant was conducted. The result showed that, patients who received the treatment from qualified therapist were very satisfied with the therapy session conducted. This is due to the qualified therapist is more professional and knowledgeable than the supervised assistant. With a focal point on the upper limb spasticity, this paper reveals the research urgency concerning the training simulators for the upper limb disorders.

2.0 SPASTICITY AND PATHOPHYSIOLOGY

Stroke is one of the worldwide greater health problems that affect human daily routine [3]. Stroke is an UMN Syndrome, with neurological deficits that can result in disabling complications. It is a syndrome resulting from different impairments such as primary cerebral ischemia and cerebral hemorrhage which will cause sudden-onset disruption of blood supply to the brain[4]. As a result, the brain cells will not function normally. As stroke causes great disability, it is classified as a medical emergency which may result in permanent neurological damage or even worse, death [3].

There are two types of stroke; Ischemic stroke and Hemorrhagic stroke[4]. Ischemic stroke occurs when blood in the artery is blocked and incapable to reach the brain. Some possible causes of Ischemic stroke are, blood clot in the artery, air bubble or fat globule in the blood vessels or blockage in the tiny bloody vessels in the brain [5]. The other type of stroke is Hemorrhagic stroke. Hemorrhagic stroke occurs when blood vessel ruptures and blood accumulates in the tissue around the rupture. This produces pressure on the brain and a loss of blood to certain areas [6]. There are two types of hemorrhagic stroke; intracerebral hemorrhage which is the most common type of stroke and subarachnoid hemorrhage which involves bleeding in

the area between the brain and the tissue covering the brain [6]. Intracerebral hemorrhages are rupture of blood vessel inside the brain and leaks blood into the surrounding brain tissue. The motor focus of the stroke problem will be in hemiparesis and hemiplegia. Hemiparesis is a disability or weakness of one side of the body while hemiplegia is paralysis on one side of the body.

Spasticity is one of the later signs of stroke [7]. Spasticity refers to the abnormal symptom of having resistance in the joints when patients try to make a movement [8]. Damage to the central nervous system may cause UMN Syndrome, with increased risk of developing spasticity [9]. Patients with spasticity will need continuous treatment to train their muscles and recall the basic movements. The process of training and re-learning is termed rehabilitation. Rehabilitation process is very important to promote their recovery of lost function, independence and early re-integration into social and domestic life.

Upper limb rehabilitation is an integral part of post-stroke therapy to ensure the arm regains maximal function. The therapist will apply repetitive arm training for the patient for rehabilitation purpose and the brain will slowly record the repetitive movement [2]. This technique will help the brain to regain the normal movement at both of their affected and unaffected side [9]. During early post stroke rehabilitation, the therapy sessions may be one-on-one with a patient to a therapist.

3.0 CLINICAL ASSESSMENTS FOR SPASTICITY

There are few approaches for clinical assessment in spasticity [10]. The most frequently used clinical assessment are the Ashworth Scale (AS) and the Modified Ashworth Scale (MAS) [11] (Table 1). AS and MAS is straightforward to conduct as it requires no additional devices and it was proven to have high reliability for upper limb spasticity [12]. The interrater and intra-rater reliability of the two assessments have been reported in several studies and compiled in [13]. Other than AS and MAS, the Modified Tardieu Scale is reported to provides higher inter-rater reliability compared with the MAS for adult spasticity [14].

Table 1 List of identified stakeholders[11]

Ashworth Scale	Score	Modified Ashworth Scale
No increase in tone	0	No increase in muscle tone
Slight increase in tone giving a 'catch' when the limb was moved in flexion or extension	1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end 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 Range Of Motion
More marked increase in tone but limb easily flexed	2	More marked increase in muscle tone through most of the Range Of Motion, but the affected part(s) is easily moved
Considerable increase in tone - passive movement difficult	3	Considerable increase in muscle tone, passive movement is difficult
Limb rigid in flexion or extension	4	Affected part(s) rigid in flexion or extension

4.0 THERAPIST EDUCATION

In order to become a qualified therapist, individuals are required to complete an accredited therapy training program before possessing a valid diploma or degree. Professional therapists regulation vary between countries but must be referred to particular regulatory bodies such as the World Confederation for Physical Therapy (WCPT), World Federation of Occupational Therapists (WFOT) and Canadian Association of Occupational Therapists (CAOT). The therapist trainees need to undergo theoretical part of therapy work such as anatomy and applying the theory to solve practical problems during Problem Based Learning (PBL). It is followed by clinical practice with patients in hospitals or related agencies to learn therapy technique and assessment methods. Consequently clinical practice has been discussed from different perspectives with the focused in protecting the patients [15]. Some regulatory bodies have been promoting the Simulated Learning Program (SLP) which usually consists of role-play, e-learning programs, low fidelity mannequins, part-task trainer, Standardized Patient actors, etc [16] to create patients-free environment. This initiative is to enforce repetition in practicing specific skills accordingly to increase decision-making reliability such as in AS, MAS and Modified Tardieu Scale.

5.0 SIMULATOR IN THERAPIST EDUCATION

Pursuing the SLP in therapist training, four studies have been reported in developing patient simulator and part-task trainer of upper limb disorder (Table 2). Noor Ayuni Che Zakaria et al. has brought significant improvement in the training of medical practitioners with the development of an upper limb spasticity part-

task trainer in the clinical education field [17-19]. The research is focusing on developing an artificial human upper limb. The part-task trainer is built with one Degree Of Freedom (DOF) of active elbow joint and a passive shoulder joint. The elbow joint is able to flex and extend within the range of 140°. The elbow joint is connected by cantilever mechanism of belt and pulley. The part-task trainer is supported with a set of DC servo motor and Magneto-Rheological (MR) brake to emulate spasticity. A set of clinical data from Malaysia consists of 19 patients have been collected as the spasticity database [20] and is used as a reference in developing mathematical modeling to emulating spasticity of the bicep muscle. The data collection is still in ongoing stage. The research is one of the pioneers in creating safe environment to clinical training.

Hyung-Soon Park et al. produced a Haptic Elbow Spasticity Simulator (HESS) for improving accuracy and reliability of clinical assessment of spasticity [21, 22]. The robotic system bring inspiration of standardizing the clinical assessment of spasticity by means of recreate the haptic feedback of spasticity based on the quantitative measurement (position, velocity and torque) collected on subjects. A mathematical model has been developed to program the haptic device to produce accurate joint torques at given input conditions. The accuracy and the reliability of the haptic model were validated by eight experienced clinicians, consist of six physical therapist and two physicians. The result showed that the haptic assessment had high matching MAS scores. It is proved that the HESS and the haptic model can provide a novel clinical analysis and training strategy for physiotherapist studies yet there are no latest studies reporting the progress of the work in implementing the HESS into therapy education.

Table 2 Comparison of upper limb part-task trainers

	SIT Part-Task Trainer	HESS	Haptic Simulation Elbow Joint	Robot Hand
References	[17] [18] [19] [20]	[21] [22]	[23]	[24] [25]
Research Center	Research Organization for Advance Engineering, Shibaura Institute of Technology, Japan	National Institutes of Health, Clinical Center, Rehabilitation Medicine Department, Bethesda, MD 20892 USA	Department of Mechanical Eng. Laboratory for Computational Sensing and Robotics, The Johns Hopkins University	Gifu University, Gifu, Japan
Last Publication	On going	2012	2008	2008
Target symptoms	Spasticity	Spasticity	Spasticity	Contracture
Level of Disease	5 (MAS 0, 1, 1+, 2, and 3)	4 (MAS 1, 1+, 2, and 3)	None	none
Clinical Data	19 adult patients and ongoing data acquisition	Data from 4 paediatric patients		Simulated patients data - 3 therapists
Model Simulator Size	Adult	Adult	Child	Adult (greater than human hand)
Actuator	<ul style="list-style-type: none"> Magneto Rheological Brake (slow particle settling rate) (need to be supported by) DC Servo Motor Harmonic drive (to reduce backlash) 	<ul style="list-style-type: none"> Brushless DC Motor (fast responses) Cable driven speed reduction mechanism (small friction, near zero backlash) 	<ul style="list-style-type: none"> DC brushed motor Disc brake 	<ul style="list-style-type: none"> ServoMotor
Sensor	Strain Gauge	Torque Sensor	None	Distributed Tactile Sensor
Arm Structure	<ul style="list-style-type: none"> Build with humerus, ulna and radius bones Flexion/Extension Movement Pronation/Supination Movement Wrist extension movement Covered with prosthetic silicon glove 	<ul style="list-style-type: none"> Build with mannequin forearm no elbow Flexion/Extension Movement Fixed position 	<ul style="list-style-type: none"> Build with aluminium plate forearm Covered with prosthetic silicon glove 	<ul style="list-style-type: none"> Build with forearm and 5 fingers 2 DoF- pronation/ supination and palmar flexion/dorsiflexion Each finger have 3 joints- MP, PIP, DIP Covered with artificial skin glove
Evaluators	Ongoing research	3 raters (reducing inter raters variability)	1 physical therapist	2 therapists
Evaluation Summary	The research focused on the training device with haptic feedback system. Previous system from the same institute was not based on clinical data. For improvement, clinical data has been applied in the system.	The research involved clinical data collection and clinical evaluation. Poor to moderate inter rater reliability during evaluation.	The research was not focusing on training device. Related research focus on modelling haptic feedback using brake torque.	Evaluation using 1 - 5 grades, 10 items Torque response was not quick but follow desired value.

D. I. Grow *et al.* reported a development of a child spastic arm simulator [23]. To ensure the clinicians get good experience with force feedback to control the movement on the patients arm, a haptic device was created and it is design as a spastic elbow of a child by using a brake actuator and high-resolution optical encoder. The child spastic arm simulator was build based on simulated trajectory without a clinical data reference. The simulator was tested and validated by an expert physical therapist and it is found that one

of the simulated models is more realistic with variety velocity reflex. The researcher planned to conduct another two experiments in future however further studies has not been reported since 2008.

Tetsuya Mouri *et al.* has developed a robot hand for therapist education purpose [24, 25]. The robot hand is able to generate torque based on patient contracture condition with 5-fingered hand driven by servo motor. Resembling human hand, it consists of two joints at the forearm and DC servomotor

mounted on the forearm. The first joint allows pronation and supination movement and another joints allows palmar flexion and dorsiflexion. A small and light-weight control system was constructed for the robot hand and it was covered by artificial skin glove to make the robot hand feel like a real human hand. The system of the robot hand consists of hand control system and measurement systems for the distributed tactile sensor. The prototype was evaluated by a therapist in order to evaluate the efficiency of the robot hand and the therapist express some doubt regarding range of the movement. In the future, the researchers plan to allow therapist to evaluate the rehabilitation robot hand for practical purpose.

6.0 CONCLUSION

The rehabilitation process for stroke patients plays a major part in patient care. It is a significant phase to maximize recovery. Patients with spasticity need to go through therapy session in order to do movements training. Therefore, it is essential for the therapist to have good skills to manage the patients. In order to provide good practical learning, the patient simulator/part-task trainer used during the training should exhibit the same spasticity components. Clearly from the number of studies that have been reported, the therapist-training device for upper limb disorder under development is relatively insufficient. For the purpose of emulating the symptoms of upper limb disorders, a clinical database is important for mathematical modeling to emulate such symptoms with haptic feedback. Current prototypes are not supported with large clinical data as their references. Larger clinical data is required to guarantee accurate clinical presentation of the simulator. Once the simulator or part-task trainer has achieved this level of accuracy, only then can it be applicable in clinical training programmes.

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References

- [1] Tomohiro Fujisawa M. T., Yoshiyuki T., Kaoru I., Takafumi T., Yukio K. and Takashi K., Basic Research on the Upper Limb Patient Simulator. *IEEE 10th International Conference on Rehabilitation Robotics*. Noordwijk, The Netherlands. 2007. 48-51.
- [2] Parry R. H., Lincoln N. B., and Appleyard M. A. 1999. Physiotherapy for the Arm and Hand after Stroke. 85: 417-425.
- [3] Woo M. H. D., Sekar P., Kissela B., Khoury J., Schneider A., Kleindorfer D., Szafarski J., Pancioli A., Jauch E., Moomaw C., Sauerbeck L., Gebel J., and Broderick J., Effect of untreated hypertension on hemorrhagic stroke. 35: 1703-1708,
- [4] Markus H. S. Stroke: causes and clinical features. 32: 57-61.
- [5] Kunst M. M. and Schaefer P. W. 2000. Ischemic stroke. 49: 1-26.
- [6] Worthley L. I. and Holt A. W. Acute haemorrhagic stroke. 2: 209-219.
- [7] Cardoso E., Rodrigues B., Lucena R., Oliveira I. R. D., Pedreira G., and Melo A. 2005. Botulinum toxin type a for the treatment of the upper limb spasticity after stroke: A meta-analysis. 63: 30-33,
- [8] Mindy G.F, Levin F., Adifi A. M., Marcos R. 2013. A New Standard in Objective Measurement of Spasticity. *Journal of Medical Devices*. 7: 1-2,
- [9] Sparkes V. 2000. Physiotherapy for Stroke Rehabilitation: A need for evidence-based handling techniques. 86: 348-356.
- [10] Pierson S. H. 1997. Outcome Measures in Spasticity Management. 6: S1-S25,
- [11] Bohannon R. W. and Smith M. B. 1987. Interrater Reliability of a Modified Ashworth Scale of Muscle Spasticity. 67: 206-207.
- [12] Pandyan G. R. J. A. D., Price C. I. M., Curless R. H., Barnes M. P. and Rodgers H. 1999. A review of the properties and limitations of the Ashworth and modified Ashworth Scales as measures of spasticity.13: 373-383,
- [13] Biering-Sorensen F. N. J. B., Klinge K. 2006. Spasticity-assessment: a review. 44: 708-722.
- [14] Jan Mehrholz K. W., Daniel M., Kay G., Christian Z., Rainer K., Marcus P. 2005. Reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in adult patients with severe brain injury: a comparison study. 19: 751-759.
- [15] Ziv A. W. P., Small S.D., Glick S. 2003. Simulation-based medical education: an ethical imperative. 78: 783-788.
- [16] C. Physiotherapy, "Report for Physiotherapy," Health Workforce Australia National Simulated Learning Project2010.
- [17] Che Zakaria N. A., Komeda T., and Low C. L. 2012. Design of Upper Limb Patient Simulator. 41 : 1374-1378.
- [18] Noor Ayuni C.Z , Low C. L. , Kaoru I. and Stephan R. 2013. Emulation of Spasticity Symptoms in Upper Limb Part-Task Trainer for Physiotherapist Education," 393 : 999-1004.
- [19] Noor Ayuni C. Z., Low C.Y. and Kaoru I. 2014. Emulating Upper Limb Disorder for Therapy Education. 11.
- [20] Noor Ayuni C. Z., Low C.Y, Hanapiah F. A., Komeda T., Inoue K., Shazidi M. S., and Hamsan H. M. 2014. Evaluation of Upper Limb Spasticity towards the Development of a High Fidelity Part-task Trainer. 15: 818-827.
- [21] Jonghyun K., Hyung-Soon P., and Damiano P. D. 2011. Accuracy and reliability of haptic spasticity assessment using HESS (Haptic Elbow Spasticity Simulator). *Engineering in Medicine and Biology Society,EMBC, 2011 Annual International Conference of the IEEE, 2011*. 8527-8530.
- [22] Jonghyun K., Hyung-Soon P., and Damiano P. D. 2012. Development of a Haptic Elbow Spasticity Simulator (HESS) for improving accuracy and reliability of clinical assessment of spasticity. *IEEE Trans Neural Syst Rehabil Eng*. 20 : 361-370.
- [23] Grow D. I, Mengnan W., Locastro M. J., Arora S. K., Bastian A. J., and Okamura A. M. 2008. Haptic Simulation of Elbow Joint Spasticity. *Haptic interfaces for virtual environment and teleoperator systems, 2008*. 475-476.
- [24] Mouri T., Kawasaki H., Nishimoto Y., Aoki T., and IshigureY. 2007. Development of robot hand for therapist education/training on rehabilitation. *Intelligent Robots and Systems, 2007. IROS 2007. IEEE/RSJ International Conference*. San Diego, CA, USA, 2007. 2295-2300.

- [25] Tetsuya M., Yutaka N., Takaaki A., Yasuhiko I., and Makoto T. 2008. Robot Hand Imitating Disabled Person for Education/Training of Rehabilitation. *Journal of Robotics and Mechatronics*. 20 : 280-288.