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SPASTICITY RULE-BASED SYSTEM MODELING FOR UPPER LIMB SPASTICITY DIAGNOSIS ACCORDING TO MODIFIED ASHWORTH SCALE

KHAIRUNNISA BINTI JOHAR

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ABSTRACT

This thesis presents the diagnostic modeling of a Spasticity Rule-based System to develop the Upper Limb Spasticity Measurement Device (ULSMeD), a diagnosis device designed for quantitatively assessing spasticity. Spasticity is characterized by increased muscle tone and exaggerated tendon jerks, significantly impairing mobility, and quality of life. Current assessment methods are subjective and rely on clinical judgment, leading to issues with consistency and accuracy. This study bridges the gap by employing a comprehensive approach that combines clinical assessment techniques with mathematical modeling. It examines the range of motion (ROM) and force resistance across a 208 clinical dataset. The research includes a multi-phase approach, beginning with identifying a quantitative relationship between the Modified Ashworth Scale (MAS) profile and angular acceleration. Following this finding, a Spasticity Rule-Based System was developed for the decision-making system, leading to the development of the ULSMeD using sensor technologies. The device's prototype integrates components of the MPU6050 angle sensor and FSR402 force sensor embedded with the Internet of Things (IoT) via a mobile phone User Interface. Sensor testing showed exceptional performance with over 99.6% accuracy in angle measurements and approximately 98.5% accuracy in force measurements. Clinicians played a main role in the evaluation phase, providing feedback on the device's usability and functionality. The device was evaluated in clinical settings with four clinicians showing a 60% exact accuracy and an ICC of 73.5%. This research marks a significant advancement in spasticity assessment, offering a more objective, standardized, and user-friendly tool. It sets up the foundation for upcoming improvements in diagnosing spasticity, which could have a positive impact on patient outcomes during stroke rehabilitation.

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INTRODUCTION

1.1 Research Background

Stroke is the leading cause of spasticity, which can result in severe and disabling complications for patients. Approximately half of the patients with post-stroke develop spasticity during the first month, but spasticity can develop more than three months after the stroke starts (Nam et al. 2019). Spasticity is clinically identified as a form of hypertonia, characterized by a velocity-dependent increase in tonic stretch reflexes or muscle tone, along with an exaggeration of tendon jerks (Laureys et al., 2013). The effects of these symptoms include a significant increase in muscle stiffness and tightness, impacting the patient's mobility and quality of life (Satkunam 2003).

The evaluation of spasticity involves muscle testing to identify the specific muscles affected by the condition. Various measurement techniques are available and they are divided into three main categories: clinical methods, biomechanical methods, and electrophysiological methods (Biering-Sørensen et al., 2006). Clinical methods include the Tardieu Scale (TS), Modified Tardieu Scale (MTS), Ashworth Scale (AS), and the Modified Ashworth Scale (MAS) (Hugos and Cameron 2020). These scales measure muscle contraction strength and volume of voluntary movements. The Medical Research Council Scale (MRCS) allows for the estimation of the strength of muscle contraction and amplitude of active movements in the limb (Kovalenko et al. 2020). Meanwhile, biomechanical methods employ devices like the pendulum test, myometers, and isokinetic dynamometers to assist in measuring spasticity (Haas and Crow 1995). Electrophysiological methods for assessing spasticity include surface electromyography (sEMG) and H-reflex tests (Biering-Sørensen, Nielsen, and Klinge 2006). Among these, the MAS is widely used in clinical practice due to its user-friendly application in clinical settings for spasticity and as a standard against which many newly developed devices are compared (Yoo et al., 2022).

Despite the availability of these methods, a significant gap remains in clinical practice. Many existing biomechanical tools are limited to research settings and lack practicality for routine clinical use (Guo et al., 2022). This challenge highlights the urgent need for a clinically applicable device that enhances the assessment of spasticity.