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Original Research Article

Reliability of stiffness measurement device during passive isokinetic spastic wrist movements of healthy subjects and hemiplegics

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ABSTRACT

The consistency of torque measurements during repetitive moving arm movements and also during passive wrist movements at two angular velocities of slow (~6°/s) and moderate (~120°/s) was investigated. The designed and developed device was applied to 3 cases, to a spring, to 8 able-bodied subjects and to 2 hemiplegic patients. While the mean of the intra-class correlation coefficient of subjects were 0.65 and 0.75 for slow and moderate angular velocities, those of the hemiplegic patients and the spring respectively ranged between excellent values of 0.93–1 and 0.91–1. The Pearson's product-moment correlation coefficients of the 3 cases for the 2 slow and moderate angular velocities ranged between 0.80 and 1. We could verify that the device can be used in our future researches and it can (1) reliably rotate a moving arm horizontally with angular velocities between 3 and 350°/s constantly in a range of motion between −60 and 60° and (2) simultaneously capture the data of angular displacement, torque, and two electromyogram activities. For the standardization of our future studies with the device, we could verify the stability of the last two repeated passive wrist movements in case of patients. The results of the study with the able-bodied subjects are also important as a reference for our studies with the hemiplegic.

1. Introduction

Stiffness of a muscle can be as a result of the spasticity that develops as a result of the damage to part of the brain or the damage to the nerves that go from the brain to the spinal cord. Resulted hyperactivity of muscles by spasticity causes an increased resistance against muscles' passive movement [1]. Spasticity is defined [2] as "disordered sensorimotor-control, resulting from upper neuron lesion, presenting as intermittent

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or sustained involuntary activation of muscles''. The other [3] widely used definition of spasticity is ''a velocity-dependent increase in tonic stretch reflexes to phasic stretch, in the absence of voluntary activity'' that causes increased muscle activity and consequent increase of stiffness to the movement.

The reluctance to stretch the affected muscle is described as the sensation of stiffness [4]. Stiffness and sourness can result from different elements. Muscle spasm [5], influx or accumulation of calcium that can cause excessive contracture in the damaged fibers [6], and restriction of motion and apparent decrease in resting length of the muscles [7] are some of the elements that can cause stiffness.

Mechanical devices have applied for the assessment of stiffness or spasticity of the hemiplegics wrists [8–10]. While the first 2 researches apply horizontally movable arms to assess wrists stiffness, the latter uses a vertically movable arm. Unlike the 1st research that uses a freely movable arm, the other two have center of the moveable arm coupled to a motor. In both researches [8,9], the hands are fixed to the moving arm with their fingers extended. In [10], the palms and backs of the hands are fixed while leaving hand fingers in a relaxed curved state. The aim of the application of such assessment devices is to obtain an objective view of patient's spasticity. Important characteristics of these types of assessment devices are their consistency and sensitivity [10].

Two important essentials of spasticity measurement devices are their ability to produce variable angular velocities (AVs) and simultaneous recording of the measurements of electromyogram (EMG) and torque [11]. Other two important properties of stiffness measurement devices are their abilities to reproduce the same results under the same conditions and to yield constant AVs. While the former guaranties the reliability of the device, the latter ensures the consistency of the movement.

In this study, our purpose was to design and develop a precise and reliable stiffness measurement device that could rotate the hand with a constant AV. The device had to also be applicable for researches and be capable of simultaneously measuring torque and EMG at different AVs between 3 and 350°/s for both fingers situations, stretched and relaxed curved state. The reliability and reproducibility of the device was verified by the application of the device to a spring, to 8 able-bodied subjects and to 2 hemiplegic patients.

2. Material and methods

The developed stiffness measurement device is shown in Fig. 1. Electro-mechanical parts, a forearm supporting device, an upper arm holding device, a horizontally rotating flat plate, and two limiting switches were mounted on a mobile table at which the subject could sit comfortably. The forearm supporting and upper arm holding devices were used to hold the arm of the subject in position. A circular padded cylinder with a diameter of 4 and height of 10 cm was mounted on the horizontally rotating plate to which the hand could be secured using a belt and a Velcro strap. This circularly padded cylinder can be changed with another vertical flat plate that can keep hand fingers extended during the arm movement. The horizontally rotating arm can rotate freely with almost

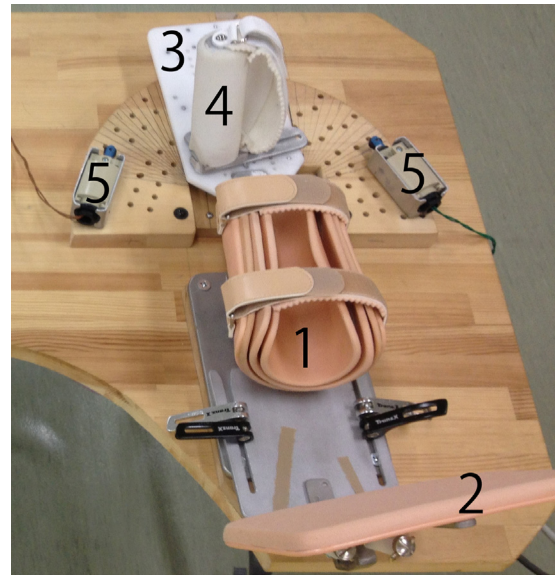

Fig. 1 – The wrist stiffness measurement device is shown. Electromechanical components (motor, gear, controller, electrical parts), a forearm supporting device (1), an elbow holding device (2), a horizontally rotating plate (3) with a position adjustable vertical cylinder (4), and two limiting switches (5) are mounted on a table.

no friction. The limiting switches were used to keep the range of motion (ROM) of the moving arm within a safe limit. A potentiometer attached to the table next to the rotating shaft was used to record the angular rotation. Simultaneously, EMGs of the extensor (Ext) (extensor carpi radialis longus and extensor carpi radialis brevis) and flexor (Flx) (flexor carpi radialis, palmaris longus, and flexor carpi ulnaris) muscle groups were measured by using two silver-silver chloride electrodes. After preparing the skin according to standard procedures [12], the two 8 mm diameter passive electrodes were filled with electrode gel and were placed on the lateral head of the two muscle groups in a bipolar configuration. In the case of both muscle groups, the electrodes were placed in parallel to the direction of muscle fibers while the center to center distances between electrodes were about 30 mm [12,13]. Neuropack[1] MEB-2300 Series EMG measuring system was used for EMG measurement. The EMG and strain gauge values were digitally recorded by using CONTEC[2] (AI-1608AY-USB), a 16 bit resolution analog to digital converter. Strain gauge, potentiometer and EMG data were sampled at 1 kHz.

An EPOS2[3] 70/10 controller was used for the control of the angular movement of a MAXON DC motor (RE40 GB 150 W). A MAXON gear head (GP42C 15 Nm) was used for reducing the AV. The ROM of the horizontally rotating arm was between −60 and 60°. The rotating arm could be constantly moved with an AV between 1 and 350°/s. MATLAB[4] and LabVIEW[5] were

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