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Electromyogram-Assisted Upper Limb Rehabilitation Device

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Abstract: In the Philippines, therapists are relied upon for rehabilitation of stroke patients. In developed countries automated rehabilitation devices are used, enabling therapy to accurately target affected muscle groups. This study developed an automated rehabilitation device for use on upper limbs of stroke patients particularly for medial and lateral rotations. The prototype detects electromyogram (EMG) signals, pulse rates and temperature as part of the process. It has three types of activities: passive, active-passive and active. During passive activity, the device guides the patient through a series of movements while providing visual stimulus. Active mode requires the patient to move his/her arm according to instruction on screen. Active-passive activity requires the patient to move but will provide assistance if the target is not reached or if there is no muscle activity detected via EMG. Patient information is also recorded by the device so that therapists could evaluate the progress of the patient. Upon testing, temperature readings and pulse rate measurements by the device show minimal deviation when compared with commercially available devices. EMG detection by the prototype was also accurate during the passive-active mode of operation.

Key Words: automation; electromyography; rehabilitation; stroke; biomedical devices

1. INTRODUCTION

In the year 2002, there were 24,368 deaths due to stroke in the Philippines (Mackay, Mensah et al. 2004). Stroke also continues to be one of the leading causes of disability in the country, badly affecting 400,000 Filipinos (Balane August 17, 2006).

Robot-aided neuro-rehabilitation devices are being used in some developed countries for treating stroke patients. Some of these devices are currently available (Nef, Mihelj et al. 2007) in the market but are not feasible for the use of Filipino patients because of its high acquisition and maintenance cost. Attempts have been made by local researchers to come up with cost-effective ways to gain access to robot-aided rehabilitation. Studies by (Estanislao-Clark, Bugtai et al. 2010) to show elderly stroke patient motivation and the prototype made by (Ang, Limkaichong et al. 2010) have laid the groundwork for this vision to become reality.

This research aims to improve on the Robotic Arm Rehabilitation Machine with Biofeedback prototype (Ang, Limkaichong et al. 2010). This previous machine rehabilitates the muscles during lateral and medial rotation of a human arm. This

study will incorporate an Electromyogram (EMG)-assisted mechanism to the existing time-delay mechanism in order to promote target accuracy in muscle activity. Pulse rate and temperature monitors that can be used by medical practitioners in diagnosing and evaluating their stroke patients are also incorporated.

2. METHODOLOGY

2.1 Conceptual Framework

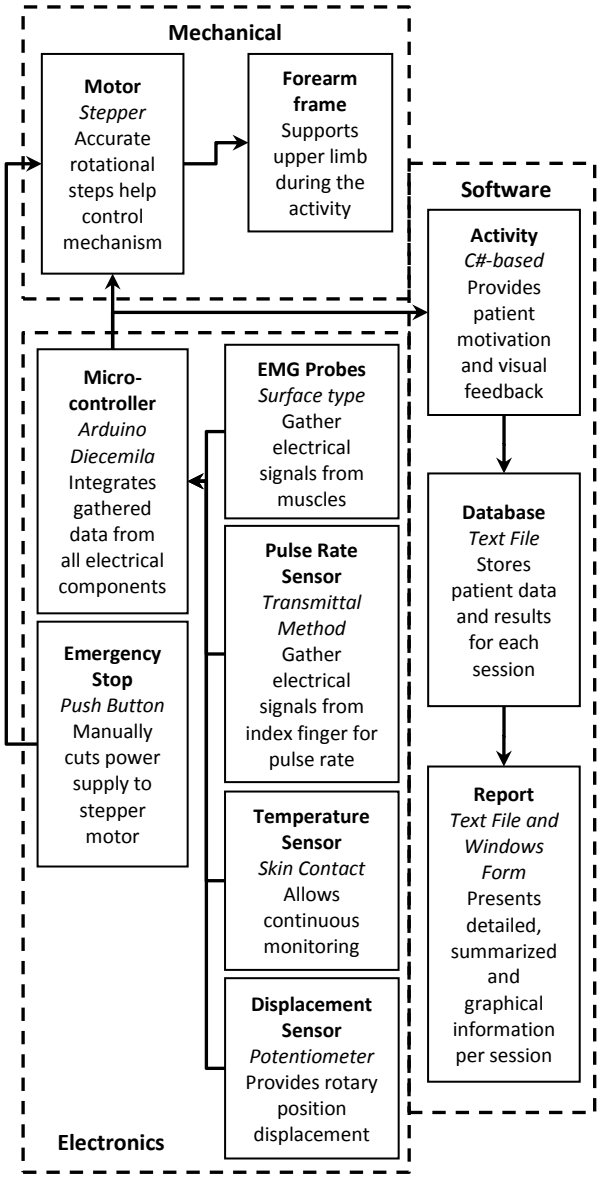

Fig. 1: EMG-Assisted Upper Limb Rehabilitation Device Conceptual Framework

2.2 Muscles used for sending EMG signals during medial and lateral rotations

Based on research, the list of muscles was narrowed down to those that are used for arm rehabilitation. The chosen muscles were then tested for both their left and right counterparts.

The muscles chosen for EMG testing are pectoralis major clavicular (figure 2) and infraspinatus (figure 3). Pectoralis major clavicular is responsible for medial rotation and flexion of the shoulder and horizontal adduction of the arm. It is used for shoulder and arm rehabilitation. Infraspinatus is responsible for lateral rotation of shoulder joint and is used for rehabilitation of the upper extremities of stroke patients (Cram and Criswell 2011).

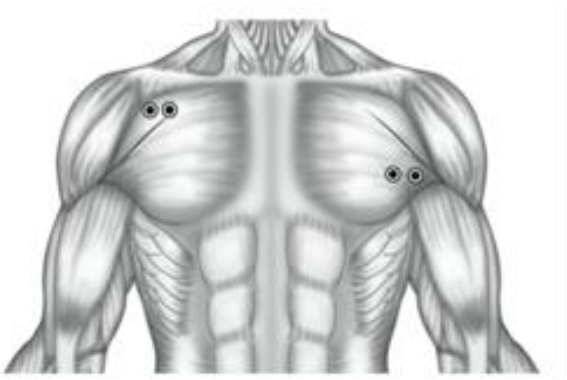

Fig. 2: Electrode Placement for the Pectoralis Major Clavicular (Right Side) and Sternal (Left Side) Sites (Cram and Criswell 2011)

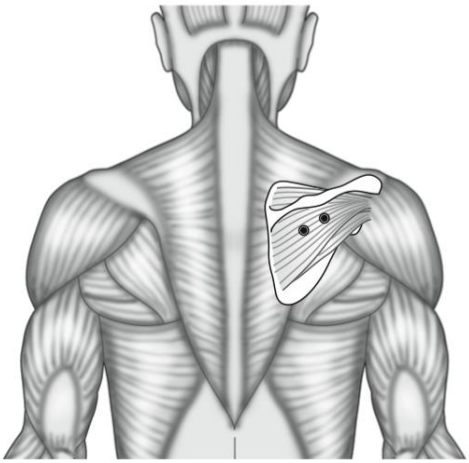

Fig. 3: Electrode Placement for the Infraspinatus Site (Cram and Criswell 2011)

2.3 Types of Motor Settings During Activity

1) *Active* – In an Active type activity, the patient controls the forearm frame without any help from the motor.

2) *Passive* – In a Passive activity, it is the motor that controls the forearm frame for the patient and the patient's upper limb merely follows the forearm frame's movement.

3) *Active-Passive* – An Active-Passive type activity is a combination of the two previous activity types as the motor helps the patient control the forearm frame when the patient cannot reach the target in time. For a patient to be assisted in an Active-Passive activity, two conditions must be met: (1) forearm frame's location is not yet within target range; and (2) a patient must be exerting effort to move the device, which is done by determining if the patient's instantaneous EMG values exceeded the threshold values set during calibration.

3. RESULTS AND DISCUSSION

Experiments were conducted to check if the main components of the prototype are performing as specified.

3.1 Temperature Monitor Test

The objective of this experiment is to determine if the temperature monitor presents an output which is accurate and precise.

Table 1. Accuracy Testing of the Temperature Monitor Experimental Results

Subject	Sample Size	Mean	Standard Deviation
1	10	0.4	0.16330
2	10	0.39	0.18529
3	10	3.15	0.63645

Standard Deviations Test and One-Way Analysis of Variance (ANOVA) were conducted in order to verify the significant differences among the samples of the three sample sets and the chance percentage of detecting temperature differences at 99% Confidence Interval.

Calculations made through Minitab 16 Statistical Software showed that the differences among the standard deviations (P = 0.060) of the three sample sets at the 0.01 level of significance are not significant. On the other hand, One-Way ANOVA results showed that there is at least a 90% chance of detecting a difference of 1.0039 degrees Celsius and at most a 60% chance of detecting a difference of 0.28403 degrees Celsius.

3.2 Pulse Rate Monitor Test

The objective of this experiment is to determine if the pulse rate monitor presents an output which is accurate and precise.

Table 2. Accuracy Testing of Pulse Rate Monitor Experimental Results

Subject	Sample Size	Mean	Standard Deviation
1	10	1.4	0.84327
2	10	1.3	1.4181
3	10	2.3	1.6364

Standard Deviations Test and One-Way Analysis of Variance (ANOVA) were also conducted in order to verify the significant differences among the samples of the three sample sets and the chance percentage of detecting pulse rate differences at 99% Confidence Interval.

Calculations made through Minitab 16 Statistical Software showed that the differences among the standard deviations (P = 0.183) of the three sample sets at the 0.01 level of significance are not significant. On the other hand, One-Way ANOVA results showed that there is at least a 90% chance of detecting a difference of 3.2575 (approximately 4) beats per minute and at most a 60% chance of detecting a difference of 1.8806 (approximately 2) beats per minute.

3.3 EMG Response Test

The objective of this experiment is to determine if the prototype can detect and respond to EMG stimulus.

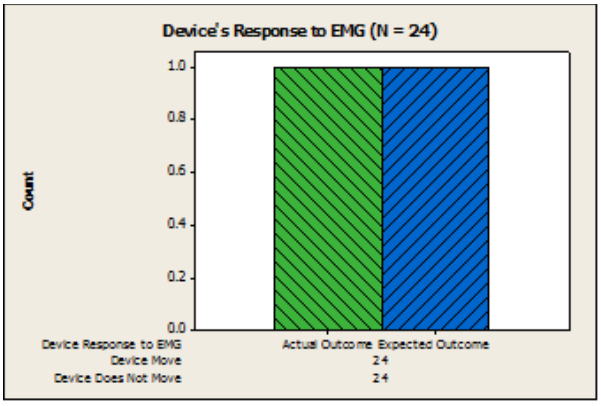

Fig. 4: Prototypes Response to EMG

The experiment shows that the device was able to respond to an EMG signal. The device moved as the EMG circuit detected a signal outside the boundaries of the measured threshold range. The EMG graph of trials wherein the device is expected not to move is usually flat while the EMG graph of trials in which the device is expected to move usually has spikes in the middle of the graph.

3.4 Emergency Stop Functionality Test

The objective of this experiment is to determine if the prototype can detect and respond to the emergency stop button.

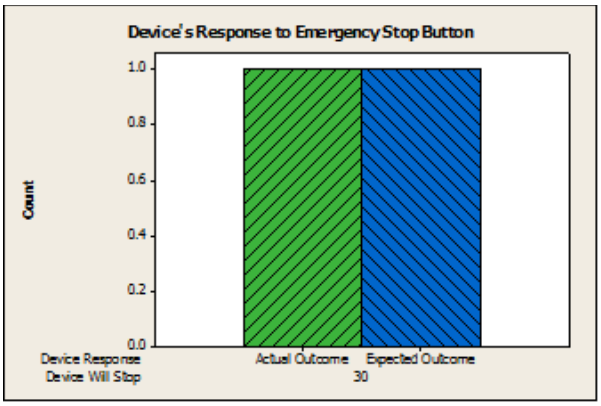

Fig. 5: Prototypes Response to Emergency Stop

The experiment shows that the device was able to respond to the activation of the emergency stop button. The prototype stopped once a signal from the emergency stop button reached the microcontroller which consequently cuts the voltage supply to the motor driver and will lead to the termination of device's operation. This is a critical component since the device will be used primarily by patients. Having this safety feature can prevent untoward incident from occurring.

4. CONCLUSIONS

This study was able to design and manufacture an improved upper limb rehabilitation device. This prototype has the following features:

- Temperature and pulse rate monitors were integrated into the device. Data gathered can provide information which may be used in assessing patient performance in terms of challenge, effort and uneasiness when doing the rehabilitation activity.
- Three rehabilitation activities: Passive, Active-Passive, and Active. These modes are in the form of a game that aims to perform specific actions, which are interpreted by motor displacement and shown as visual feedback, depending on the type of activity being completed. This feature aims to keep the patient motivated and combat boredom when performing rehabilitation activities.
- Capabilities to assess a patient's need for assistance and provide necessary motion support for the patient to perform the rehabilitation activities. This is achieved by incorporating an EMG sensor to detect if the patient's muscles are exerting effort.
- A database system which records quantitative results and graphs for each patient activity, which can be viewed and printed in the form of a report.

5. RECOMMENDATIONS

To improve this study, the researchers recommend these follow-up actions:

- Expand the machine's rehabilitation capabilities by incorporating additional muscle movements, specifically abduction, adduction, flexion, and extension. These motions are also affected by stroke.
- Make the forearm frame's vertical axis adjustable and by fabricating different forearm frames in order to target specific muscles and movements during rehabilitation.
- Integrate a functional electrical stimulation (FES) device. This can help

promote muscle recovery since it is the muscle which is directly targeted.

- Create a rehabilitation device with similar technology for the hands and fingers. Recovering the muscle functions for these body parts are needed in order to properly use an upper limb rehabilitation device with similar forearm frame structure

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