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LOW COST DEVICE FOR ”AT HOME” REHABILITATION AFTER A STROKE EVENT

Mariana CIORAP*, Mihai MUNTEANU, Doru ANDRIȚOI***, Radu CIORAP*****

***”Georghe. Asachi” Technnical University of Iași, Romania**
****Technnical University of Cluj-Napoca, Romania**
*****”Grigore T. Popa” University of Medicine and Pharmacy, Iași, Romania**
mariana.ciorap@gmail.com, Mihai.Munteanu@ethm.utcluj.ro, doru.andritoi@gmail.com, radu.ciorap@bioinginerie.ro

Abstract: *The paper proposes a design solution for a low cost device with feedback for upper extremity rehabilitation after a stroke event. Cerebral vascular accident (CVA) or stroke is one of the leading causes of morbidity and mortality worldwide. CVA is the most important cause of long-term disability in Europe, and demographic changes have led to an increase in both incidence and prevalence of this. Most secondary stroke disability is recovered in a few months, but others may persist for life. The rehabilitation should be started as soon as there is a greater chance of recovery in this early stage. Disabilities get worse and remain permanent over time, which is why is recommended the establishment of a rehabilitation program as soon as possible. Today, the use of virtual reality environments allow patients to perform tasks that mimic real life in rehabilitation clinics, but it tends increasingly more in the future these tasks can be done at home, sending data and receiving feedback from doctors. The devices presented in this paper are not only mechanical devices that allow the movement on a certain direction with predetermined effort degree for the patient, possibly controlled by the force of the muscle activity (EMG), but are innovative devices with the possibility to record a full set of biomedical signals. The patient device can record one or more biomedical parameters such as electrocardiography (ECG), heart rate (HR), electromyography (EMG), non-invasive blood pressure (NIBP), oxygen concentration in the blood (SpO2), movement speed and acceleration, angle of motion of a body extremity, torsion, s.a. according to the physician's prescription and the patient needs. This means that the patient device will be very flexible and can communicate with other medical devices for home use.*

Keywords: tele-rehabilitation, biomedical parameters, stroke, medical devices for home use

1. Introduction

Cerebral vascular accident (CVA) or stroke is one of the leading causes of morbidity and mortality worldwide. In Europe, CVA is the most important cause of long-term disability and demographic changes have led to an increase in both incidence and prevalence of this. Even with optimal care, less than one third of the patients recover completely after stroke. Medical rehabilitation aims to enable people with disabilities to achieve and maintain optimal function of physical, intellectual, psychological and/or social. Medical recovery purposes may extend the initial interventions to reduce disability in complex interventions to encourage active participation. Rehabilitation program after

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CVA consists of all processes that help mental and physical recovery of patients who suffered a stroke and have the potential to promote motor recovery after stroke [1]. Rehabilitation should be instituted as soon as possible to ensure the development of a normal life and must be provided at a high frequency, over long periods of time with an intensity adapted to each patient [2]. Methods of rehabilitation after a stroke vary from person to person, but they have the same goals, acquisition of functional status and independence to provide minimal help from other people.

The rehabilitation of a person implies the existence of a concordance between person and environment in which they live. Tele-rehabilitation, a branch of telemedicine, is providing medical services and remote medical recovery including assessment, treatment and care coordination [3], [4]. In our days, the use of virtual reality environments allow patients to perform tasks that mimic real life in rehabilitation clinics [5], but it tends increasingly more in the future these tasks can be done at home, sending data and receiving feedback from doctors from hundreds of miles distant. The virtual world can create the appearance of opportunity for any person, regardless of where it is located, in fact, at one time. Virtual environments should not only be used to augment current ability but to find tools that enable transfer of the skills and abilities achieved during rehabilitation to function in the "real" world [6].

The best treatment for arm recovery and function has been identified as a top 10 research priority by people with stroke [7] because approximately 77% of people with stroke experience had upper limb dysfunction which impacts adversely on independence with everyday tasks [8].

There are some studies that investigate long-term effects of upper limb activity tracking device providing multimodal feedback on daily arm use [9]. These kinds of devices have the potential to encourage self-administrated training in patients' home environment [9], [10], [11].

2. Materials and methods

The paper presents a ”low cost” device, with feedback, for upper limb rehabilitation at patient's home. There are many solutions for arm rehabilitation, some of them based on EMG control of movement [12], [13], [14], other that use EMG for continuous control of functional electrical stimulation (FES) [15], other based on robotic system [16], [17]. All of these solutions are expensive and request qualified supervising.

Our device is not only a mechanical device that allows the movement on a certain direction with predetermined effort degree for the patient, possibly controlled by the force of the muscle activity (EMG), but is an innovative device with the possibility to record a full set of biomedical signals. The physiological parameters that can be recorded are customised for each patient, making possible a complete monitoring of the disease [18]. The target group is represented by persons with upper limb disability after a stroke event and all of these people have also other disease like diabetes, hypertension or another cardio-vascular disorder. The possibilities to have a wide area of physiological parameters give to the doctors and therapists a real chance to optimise the treatment [19].

2.1. Device for recording physiological parameters

The monitoring device uses custom developed hardware and software applications. Low power amplifiers and transducers are connected to the device, for physiological parameters acquisition. The logical structure of the monitoring system is composed of a network of Parameters Monitoring Device (PMD) that is connected to a Coordinator Device (CD). The Coordinator Device plays the interface role between the PMD network and computer system [20].

It was chosen to record surface EMG from 2 muscle groups, 1 ECG canal and pulse

wave using a photoplethysmography transducers.
For acquiring electromyography (EMG) the MyoWare Muscle Sensor produced by SparkFun was used. This sensor measures the filtered and rectified electrical activity of muscles. For electrocardiography (ECG) signal, the AD8232 SparkFun Single Lead Heart Rate Monitor was used, because is a cost-effective board and give a clear signal. Finally, for pulse wave, the Pulse Sensor Amped, that is a plug-and-play heart-rate sensor, was used. The photoplethysmogram (PPG) is recorded from ear lobe. All this PMD’s are connected to the microcontroller board that is used as Coordinator Device as presented in figure 1.

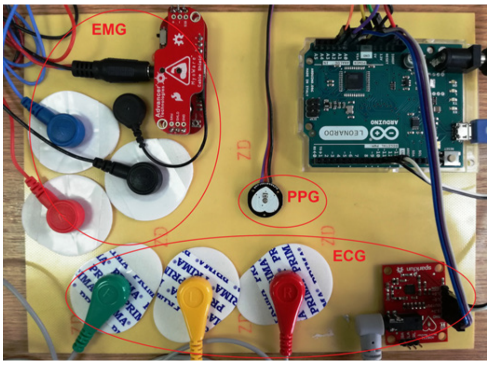

Figure 1: Parameters Monitoring Devices (PMDs) connected to Coordinator Device (CD)

2.2. Device for arm rehabilitation
A mechanical device was designed that can be used for upper limb rehabilitation. This device allows 2 axes movements in horizontal plane. The degree of exercise difficulty is established by physiotherapist at the beginning of recovery procedures and adapted according to patient's progression.
In order to design the device for the upper limb rehabilitation, Autodesk FUSION 360 (the new 3D modelling software offered by Autodesk) was used as a CAD tool. This is one of the most powerful software of his kind that was specially made for working with multiple pieces, easy-to-use, with a friendly interface, all of this integrated in a single cloud-based platform. In figure 2, the design for upper limb rehabilitation design is presented.
Our interest has been focused on designing a low cost and easy-to-use device that can be used by people with disabilities at home, without medical supervision, in order to practice some therapeutic procedures between two treatments at a rehabilitation centre.
The arm rehabilitation device can also be used without the vital parameter monitoring system, but including it provides a complete solution for monitoring the patient's health. This prevents situations where too much effort or too long training severely affects the vital parameters. In these cases, the vital parameter monitoring device generates an alarm signal.

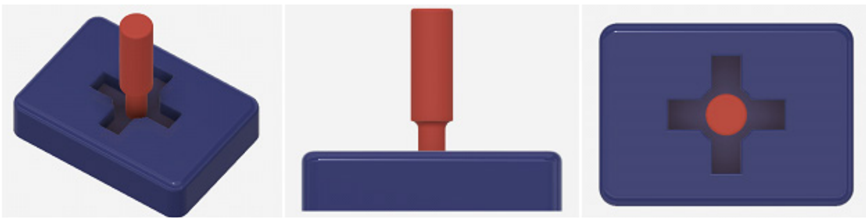

Figure 2: Device for upper limb training

3. Results and discussion
It was tried to establish a connection between the values of the selected physiological parameters to be monitored and the effort made to perform the upper limb rehabilitation exercises. Also, it was intended to provide to the physiotherapist a new set of useful information to personalize and optimize the treatment [20].
The recorded physiological parameters allow analysing the state of the cardiovascular system, because this application refers to the arm rehabilitation of post-stroke. Both PPG and ECG signals

are used for the analysis of heart rate variability during therapeutic procedures.

The photoplethysmogram (PPG) was recorded from ear lobe. A small device was designed, that integrates the pulse sensor using the same CAD tool Autodesk FUSION 360. The result is presented in figure 3.

Figure 3: Device for ear lobe pulse sensor

In figure 4 is presented a sample of PPG signal recorded

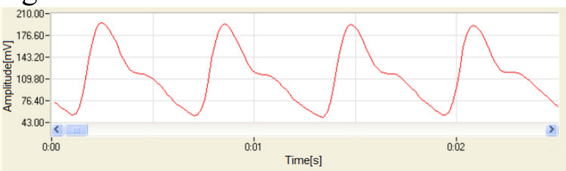

Figure 4: Sample of photoplethysmogam

HRV is considered an important indicator that reflects the individual's ability to adapt effectively to stress and environmental requirements. The HRV analysis was performed both in time and in the frequency domain [21]. An important observation was that HRV varies with the time of day when measurements are made, due to specific factors such as current emotional state, heart rate, and duration of therapeutic procedure.

In figure 5 a sample of the recorded ECG signal is presented and in figure 6 a sample of the EMG signal. All signals are stored on a memory card and all data can be analyzed off-line.

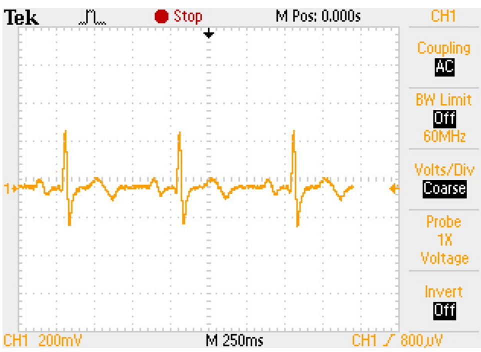

Figure 5: Sample of ECG signal recorded

Figure 6: Sample of EMG signal recorded

EMG signal was used for estimate the muscle fatigue. First, a full-wave rectification of EMG was performed, because in this procedure the entire energy of the signal is retained. Then, an averaging procedure using a low pass filtering was applied. This processed signal represents some correlation with muscle force and it was used as a fatigue indicator.

4. Conclusions

The topic of this paper was chosen in order to offer a solution to the problem of monitoring patients with arm disabilities and to give to them a better solution for their disease management. It was observed that HRV analysis could be a good instrument in evaluating the stress level of patients during rehabilitation procedures.

The advantage offered by this effective and reliable monitoring solution lies in the fact that the human operator intervention is reduced to the minimum; in addition, the cost of implementation and operation is incomparably smaller than the hospitalization.

The future research intends to interconnect this device with a smart phone and develop a "low-cost" virtual reality system for arm rehabilitation.

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