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SEMG Based Study On The Difference In The Muscle Strength Of A Half Paralytic Person Due To Stroke

Abhishek Jha[1],Mrinal Sen[2]
Department of Electronics Engineering, Indian School of Mines, Dhanbad, Jharkhand, India

Department of Electronics Engineering, Indian School of Mines, Dhanbad, Jharkhand. India

ABSTRACT—Surface Electromyography (sEMG) is a technology to measure the bio-potentials across the muscles. The true prospective of this technology is yet to be explored. In this paper, we used a simple and economically constructed sEMG sensor. These sensors were used to determine the differences in the Electromyography (EMG) signal patterns for investigating the loss in the muscle strength of a half paralytic person. Signals have been retrieved from the Flexor carpi radialis muscle of both the arms of a half paralytic person. The sEMG data acquisition is done using the soundcard of a computer, hence reducing the need of additional hardware. Finally, the data is used to analyze the relationship between electromyography and loss of strength due to paralysis. Our results clearly show the difference between muscle strength of the two hands, healthy hand and paralytic hand, of the same half paralytic individual.

KEYWORDS—Surface Electromyography; muscle strength; stroke; paralysis; Flexor carpi radialis muscle.

I. Introduction

Surface electromyography (sEMG) is one of the easy and reliable ways of studying the muscle activity by observing the bioelectrical signals. Its various applications like - diagnosis of neuromuscular abnormalities [1]-[4], in the field of prosthetics [5] and for the study of muscle dynamics [6]-[8]; have made it invaluable for the medical community as well as for the modern technology developers [9]-[13]. Though a lot of work has been done regarding the EMG based study of upper limbs muscles [14]-[16], but very few research have been done regarding the effect of stroke on the muscle activity [17]-[19]. Moreover, very few similar researches have been done in a non-laboratory/ non-ideal environment. Retrieval of EMG signals using sEMG sensors, in a non-ideal environment, is often a challenging task. This is because the amplitude of sEMG signal of a healthy person is of range 10μV to 5000μV and lies in the frequency range 10Hz to 500 Hz [20]. Moreover it has very small SNR and the raw sEMG signal contains interference, also called hum, from 50Hz/60Hz AC power line sources [21]. Due to these reasons some proper precautions should be taken in order to minimize these interference noises. In addition, the sEMG signals become weaker for the muscles of physically challenged persons. In order to study the characteristics of these muscles, in terms of sEMG, some efficient but economic sEMG retrieval circuitry is required. In this paper we are presenting a study on the effect of stroke on muscle activity with the help of economically developed sEMG sensors. The developed hardware has been used to observe the effect of stroke [22] on a patient. sEMG data have been taken from muscles of the patient who had a stroke recently. Another set of data have also been collected from the same patient after a recovery period of

11 months. These data was used to observe the difference in the EMG pattern, due to the stroke, for the same muscle, i.e. Flexor carpi radialis, for the same individual. For observing the difference between the EMG pattern of a hemiparetic patient and a healthy individual, we compared the EMG data of the patient with EMG data of 10 healthy volunteers of same age group. The paper also discuss the observation on the difference between EMG pattern of muscles of two different hands, one normal and other affected by hemiparesis, of same person.

The paper is organized as follows. Section II describes the construction of the developed sEMG sensor. Thereafter, in section III, the methodology of collecting data has been discussed which is followed by the analysis of the data and its interpretation in section IV. Finally, the conclusion is made in section V.

II. Construction

The experimentation employed economically made sEMG sensors, the basic requirement for the extraction of EMG signal from a muscle depends on the following factors; amplification, filtering and processing. The 50Hz interference induces a common mode signal which is stronger than sEMG signal, therefore an amplifier having high CMRR, around 100 [23] was required. In order to fulfill above mentioned criteria, an instrumentation amplifier AD620 was used for this purpose, which is readily available in the market at low cost.

The preamplifier is using instrumentation amplifier AD620 to amplify sEMG signals in the first stage. AD620 has the merits of low power, high accuracy and low noise [23]. The input offset voltage is 50μV max, input offset drift is 0.6 μV/ ºC max and CMRR=120dB (G=10). One of the merits of AD620 is that its gain is resistor-programmed by the impedance that appears between pins 1 and 8. Therefore, to calculate the gain of AD620 the following formulae can be used as in [24].

$$G = 49.4k\Omega / Ro+1 \qquad (1)$$

where, Ro is the resistor between pin 1 and pin 8 of AD620 (see Fig.1) and G is the required gain of the amplifier.

Often G should be large enough because sEMG signals are very weak and prone to other noise. Again, if G is too large, it will make preamplifier get into saturation. By experimentation with different gains, the appropriate gain was found to be G=12 for this experiment. Hence the Ro becomes 4.25kΩ from (1).

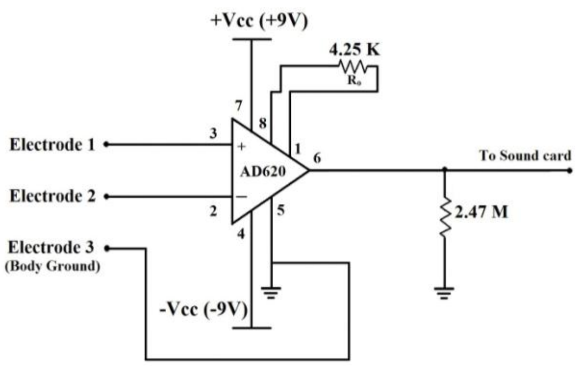

Fig.1 Circuit Diagram for sEMG sensor

A. Electrodes

In our experiment Dry Electrodes are used and the electrode 1 is separated by a distance of 3cm from electrode 2. Electrode 3 is attached to the body ground, usually the bony part. In this experiment, it was the elbow joint.

Fig. 2 Block diagram of the processing

B. Processing

To process the output signal from the instrumentation amplifier we passed it through the sound card of the computer, which is a 16 bit ADC (Fig.2). The digital signal is then processed using custom made MATLAB program.

C. Filtering

The raw sEMG signal contains power line 50Hz/60Hz interference [21] and its harmonics. We, therefore, digitally diminished the 50Hz ± 5Hz frequency harmonics, f_i from (2), in our MATLAB program, which also reduced the cost of the whole system. Since EMG signals are also present at these noise frequencies, we recommend the use of adaptive filters for the noise filtration process. EMG signals lies in the range of 10 Hz to 500Hz and hence, we used another digital bandpass filter in MATLAB, to get the desired frequency range.

$$(50i + 5)\ Hz \le f_i \le (50i - 5)\ Hz \qquad (2)$$

where, $i \in \{1, 2, 3, \ldots, 10\}$.

So the overall set of diminished frequencies, F_D, is given by (3), and the range of frequency used for observation in this experimentation, F_R, is given by (4).

$$F_D = \{f_1, f_2, f_3, \ldots, f_{10}\} \qquad (3)$$

$$F_R = F - F_D \qquad (4)$$

where, $10Hz \le F \le 500Hz$.

III. Methodology

A. Subject's Background:

The Subject who volunteered for this project was suffering from Hemiparesis, due to stroke, in the right portion of the body. She had difficulty in moving her right upper and lower limbs while her left upper and lower limbs were in normal condition. In the recovery period she had undergone the proper medication and physiotherapy as suggested by trained medical practitioners. Stroke or cerebrovascular accident (CVA) is the rapid loss of brain function due to disturbance in the blood supply to the brain. If blood flow is stopped for longer than a few seconds, the brain cannot get blood and oxygen. As a result, the affected area of the brain cannot function, which might result in an inability or difficulty to move one or more limbs on one side of the body. The EMG data was taken twice in the entire experiment. Firstly, 10 days after the impact of stroke, and then after recovery period of 11 months. We also employed 10 healthy volunteers of same age group and of same weight range, in order to obtain the EMG signals for a healthy individual. Further details of the volunteers are given in the Table 1.

TABLE I
VOLUNTEERS' DETAILS

	Hemiparetic	Normal
No. of Volunteers	1	10
Gender	F	F
Age	35-45 Years	35-45 Years
Weight	65 Kg	55-75 Kg
Data Taken	Twice/ Volunteers (i) 10 days after Stroke (ii) 11months after stroke	Once/ Volunteers
Handedness	Right	Right

B. Protocol

The volunteers were instructed and explained to put their arm in two positions; i.e. excited position and relaxed position. For excited position, 'Position 1', the upper body posture was defined as seated with shoulder naturally rotated, elbow flexed at 90º, forming a tight fist while causing isometric contractions in the forearm muscles, whereas, for relaxed position, 'Position 2', fist was loosen causing the forearm muscles to relax, and elbow was kept loosened. The skin above the target muscle was cleaned and the hair was removed from that area in order to decrease the electrode skin impedance. Electrode 3 (Fig.1) was attached to the elbow joint, whereas, electrode 1 and electrode 2 were attached just above the target muscle while maintaining the 3cm separation between both the electrodes. Since the placement of electrode should be proper with respect to the target muscle for getting good sEMG signals [25], we took the help of a trained physiotherapist. Few observations in excited positions were retaken because of some error in data due to dryness in the skin of some individuals. The individuals were given sufficient amount of time before retaking the data so that the excited muscle can be brought down again in the relaxed position to avoid fatigue of the muscles.

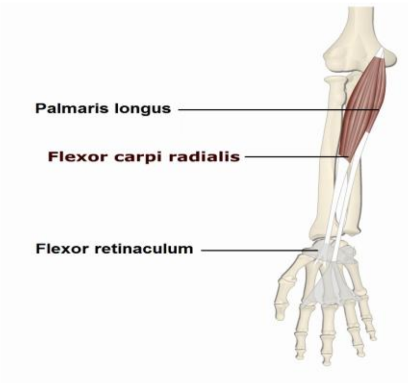

Fig. 3 Figure for Flexor carpi radialis muscle

C. Data Collection

Each volunteer was instructed to first keep her right arm in Position 2, i.e. Flexor carpi radialis in the fully relaxed condition. In this position, 20 samples were taken at an interval of 500ms. The input data was in time domain, therefore those were converted into the frequency domain by taking their Fast Fourier Transform (FFT), and unwanted frequencies were omitted. Frequency response of the sample consisted of frequencies separated by 3.9Hz. Then keeping the sensors at the same place on the arm, 20 samples were taken while the volunteer was asked to keep her muscle (Flexor carpi radialis) in fully excited position by following the Position 1 protocol. Similarly, the data was taken for the left hand in the above mentioned two positions, i.e. 'Position 1 and 2'.

IV. DATA ANALYSIS AND INTERPRETATION

The mean of EMG data of left hand and right hand of 10 healthy individual was compared as seen in Fig 4. This also serves as a reference of a standard EMG pattern for a healthy individual. We can see that the EMG signal for right hand is of slightly higher amplitude in comparison to the left hand for a right handed healthy individual.

The EMG signal of left hand and right hand of a stroke patient just after 10 days of stroke was compared; the pattern can be seen in Fig 5. It can be seen that though the right handed individual should have slightly higher amplitude for right hand EMG signal as compared to that of left hand as seen in Fig. 4, but we find that due to hemiparesis the right hand signal is even lower than that of the left hand for a stroke patient.

After a recovery period of 11 months the improvement in the EMG signal for right hand can be seen in Fig. 6. It can be observed that due to the proper medication and exercises the EMG pattern for stroke patient is approaching that of a healthy individual. The regain of strength in the right arm can be supported from the lessening in the difference of the EMG data from left hand and right hand, as shown in Fig. 6.

We also compared the right hand EMG signals of the stroke patients with the healthy volunteers after the recovery period. We found that the almost recovered patients shows the same typical characteristics in the EMG signal pattern as that of a healthy individual as shown in Fig. 7.

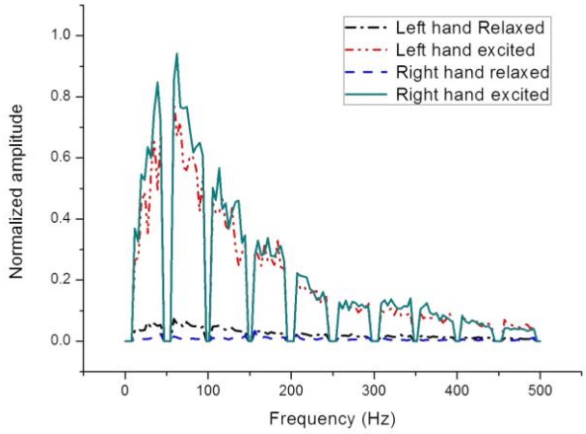

Fig.4 Mean data of Left and right hand EMG signals of 10 healthy individuals

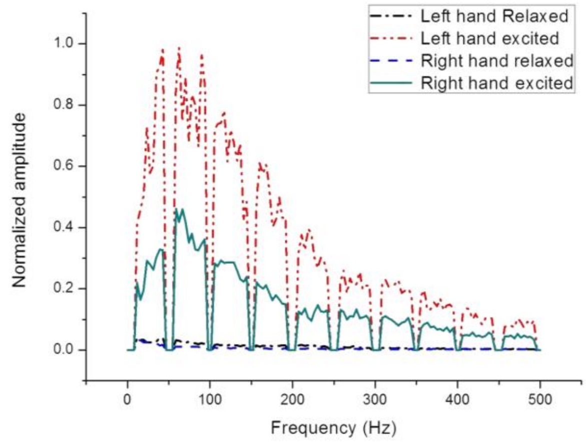

Fig. 5 'Before recovery' EMG signal pattern of a hemiparesis affected stroke patient for both hands

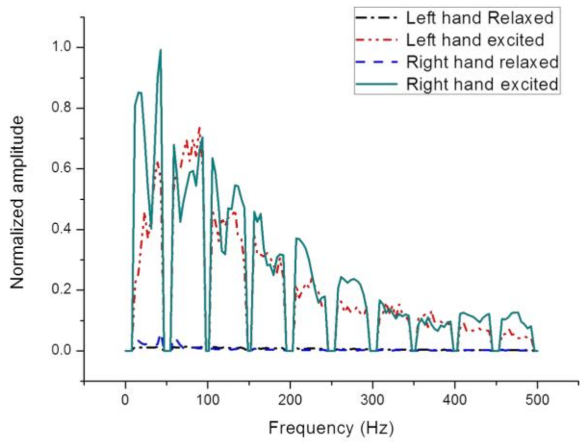

Fig. 6 'After recovery' EMG signal pattern of a hemiparesis affected stroke patient for both hands

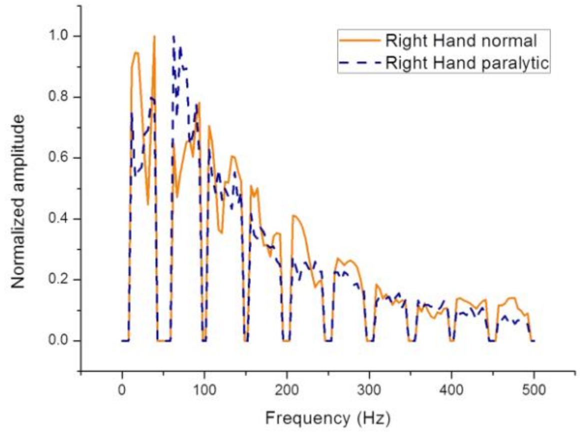

Fig. 7 EMG signal pattern of the right hands of a healthy person a hemiparesis affected stroke patient

In the Fig.4 to Fig.7 on the vertical axis we have the normalized amplitude w.r.t the maximum amplitude in the characteristic EMG pattern and on the horizontal axis we have the frequency in Hertz. The solid line represents the right hand EMG signal when the target muscle was fully excited, following the 'Position 1' protocol; the dashed line represents the data while the target muscle was in fully relaxed position, following the 'Position 2' protocol. Similarly the dashed-dot-dot line represents the EMG signal when the left arm target muscle was fully excited, following the 'Position 1' protocol, whereas the dash-dot line represents the EMG signal when the left arm target muscle was in fully relaxed position, following the 'Position 2' protocol.

A. Relation with Fatigue

We tried to observe the effect of continuous muscle contraction on the EMG pattern for the left hand and right hand of the stroke patient. For this, we took the four set 20 reading in both the position ,following the 'Protocol 1 & 2', in very short interval of time, in such a way the patient didn't have much time to relax her muscle completely . We observed that the rate of loss in strength due to fatigue of muscle is higher for the hemiparesis affected right hand in comparison to the left hand as shown in Fig. 8. This result also supports the fact that individual affected from hemiparesis tend to get fatigue if subjected to prolonged exercise or longer use of affected muscle. In the Fig. 8 on the vertical axis we have normalized amplitude, and on the horizontal axis we have the number of attempts after which the reading was taken. The red bars are for the data from hemiparesis affected right hand while the blue bars are for the unaffected left hand of the same individual.

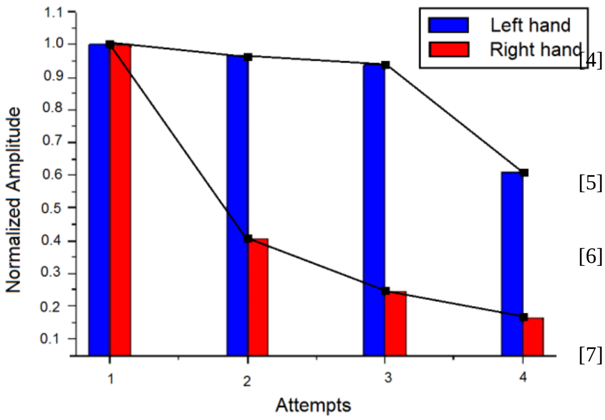

Fig. 8 Change in the muscle strength with the number of observation during prolonged muscle activity for both the hands of a hemiparesis affected stroke patient

V. CONCLUSION

In this paper, a simple and economic sEMG sensor has been developed for analyzing EMG patterns. Different circuit parameters and constraints of non-ideal environment have been discussed to improve the circuit performance. Digital filter is used for noise removal from the raw EMG signal and hence reducing the cost of overall setup. The circuit has been used for acquisition of data from muscles of a stroke patient who have been affected from Hemiparesis. The differences in the EMG signal strength of left hand and right hand of a healthy and a stroke patient, before and after recovery period, has been observed. The effect of hemiparesis on the rate of loss of strength on prolonged muscle activity has also been observed and a remarkable difference between the affected limb and the unaffected limb can been seen from the obtained results.

The concept of using a low cost market available instrumentation amplifier for EMG signal analysis can be immensely useful for developing portable medical devices, which could serve as a testing device for the stroke patients and medical practitioners to observe the recovery of hemiparesis affected muscles. Moreover, the work can also be extended to create the EMG database of the major muscles of affected limbs, which can be used for understanding the muscle dynamics of a hemiperatic patient and hence developing healing/curing aids for the affected stroke patients.

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