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Development of Electromyography Signal Signature for Forearm Muscle

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Abstract

Electromyography (EMG) measures muscle response or electrical activity in response to a nerve's stimulation of the muscle. EMG is generally acquired through surface and needle or wire electrodes. The needle or wire electrodes are usually used by clinicians in a clinical setting. This paper concentrates on surface electromyography (sEMG) signal that is acquired in a research laboratory since sEMG is increasingly being recognized as the gold standard for the analysis of muscle activation. The sEMG can utilized for establishing signal signature for forearm muscles that becomes an important input in development of rehabilitative devices. This paper discusses the establishment of sEMG signal signature of female and male subjects for forearm muscles such as extensor carpi radialis, flexor carpi radialis, palmaris longus and pronator teres based on movements such as wrist extension and flexion, hand open and close, and forearm supination and pronation. This was achieved through the use of Butterworth Bessel, Elliptic and Chebyshev filters. The sEMG signal signature could be useful in the development of rehabilitation device of upper extremities.

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Keywords: Electromyography; signal signature; forearm muscle; rehabilitation; filtering

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1. Introduction

There are increasing number of people that are affected by stroke nowadays. In 2010, worldwide prevalence of stroke was 33 million, with 16.9 million people having a first stroke. Stroke was the second-leading global cause of death behind heart disease, accounting for 11.13% of total deaths worldwide[1]. About 795,000 people have a stroke every year. Stroke causes 1 of every 20 deaths in the U.S. Stroke is a leading cause of disability[2]. In Malaysia, stroke is one of the top five leading causes of death after ischemic heart disease, septicemia, malignant neoplasms, and pneumonia as shown in Figure 4. Since 2005, the percentage of deaths attributed to stroke in general hospitals has ranged from 6·6% to 8·4%. As the life expectancies in Malaysia for males and females were 72 and 76 years old, respectively, this accounts for an average of 5·5 crude death rates per 1000 population[3]. Muscular dystrophy, arthritis and regional pain syndrome are also major cause of disabilities of stroke patients[4, 5].

Task oriented stroke rehabilitation promote the motor recovery and cerebral organization of patient after stroke[6, 7]. However the availability of such training session are limited in hospital and rehabilitation centre[8]. Robotic rehabilitation provides intensive training without tiring and possible to enhance the therapy beyond the abilities of therapist. The robotic rehabilitation utilizes the surface electromyography signals (sEMG) as control input to estimate the magnitude and direction of torque for the robotic joint of exoskeleton[9]. Researchers have done several works ranging from the use of sEMG to developing models to estimate torque based on force produced by the muscle contractions that can be utilized in the rehabilitation devices[10-15].

The main objective of the research is the establishment of sEMG signal signature of female and male subjects for forearm muscles such as extensor carpi radialis, flexor carpi radialis, palmaris longus and pronator teres based on movements such as wrist extension and flexion, hand open and close, and forearm supination and pronation. Hence, this paper presents the findings of a study on sEMG processing using Butterworth Bessel, Elliptic and Chebyshev filters. The sEMG signal signature could be useful in the development of rehabilitation device of upper extremities.

2. Materials and Methods

2.1 Recording EMG Data

The tools required for the experimental work are Delsys Trigno Wireless System[16]. The sEMG acquisition process flow is illustrated in Fig. 1.

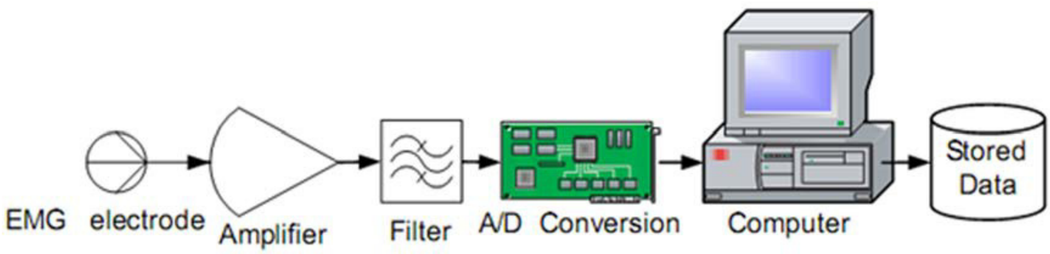

Fig. 1. sEMG acquisition process flow from raw input signal to output stored data[16]

The sEMG electrodes are very important for recording EMG signals. The differential amplifier is used to detect potential differences between two electrodes and cancel outside noise. Then, the signal is filtered by using different type of filters such as Butterworth, Bessel, Chebyshev and Elliptic. Thereafter, the filtered signal is further processed using analysis software[16].

2.2 Methods

Five healthy male subjects and three healthy female subjects (range: 20-25 years) volunteered for the study after providing institutionally approved written informed consent. The procedure started with recording of each test subject's weight and height. The subject will be asked to perform six different arm movements (wrist flexion, wrist extension, hand close, hand open, forearm supination and forearm pronation) as shown in Fig. 2.

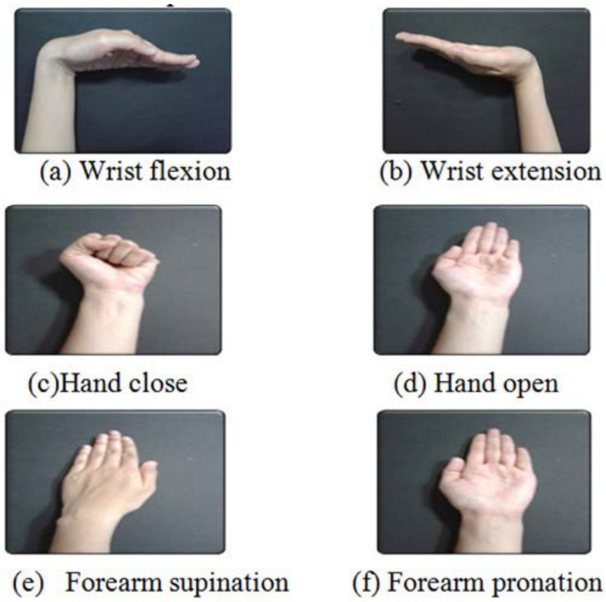

Fig. 2. Six different movements in arm

Table 1 shows list of movements in forearm and the associated muscles. Before proceeding with the experiment, initially, an antiseptic alcohol swab is to clean the subject's skin from dust or sweat. Then, the surface electrode is placed on top of the skin of the appropriate muscle to be tested. The placement of the sensor on the subject's skin is shown in Fig. 3. Then, the subject would start with wrist flexion, hold for five seconds and rest for five seconds. Then, the process is repeated for other movements.

Table 1. List of arm movement and associated muscles

Body part	Movement	Muscles
Wrist	Extension	Extensor carpi radialis
	Flexion	Flexor carpi radialis
Hand	Close	Palmaris longus
	Open	Palmaris longus
Forearm	Supination	Pronator teres
	Pronation	Pronator teres

Fig. 3. Placement of the electrode on the subject's forearm

The acquired raw signal is filtered at the different representative filters such as Chebyshev, Elliptic, Butterworth and Bessel with band pass filter corner frequency at 1 Hz to 500 Hz using EMG Works software[16]. The signal taken is limited to 20 second with 320 samples (in voltage). Then, Root Mean Square (RMS) is chosen for feature extraction before proceeding to thresholding process. In this experiment, RMS is selected because; only positive side of raw signal is needed. Then, the experiment is carried out with threshold process in order to get the muscle activation. The database in Table 2 displays the experimental parameters.

Table 2. Experimental parameters

Sampling frequency (Hz)	2000 Hz
Types of filter	Chebyshev, Elliptic, Butterworth and Bessel filter
Basic filter types	Band pass filter
Order (N)	4
Corner frequency 1 (Hz)	1 Hz
Corner frequency 2 (Hz)	500 Hz

3 Results and Discussion

Fig. 4 shows the sample raw muscle signals detected by the Delsys sensor for wrist flexion and extension (WFWE), hand open hand close (HOHC) and forearm supination and pronation (FSFP). The data are from Test Subject #1. The signal are recorded for 20 seconds and it is filtered using four different filters with a band pass filter at 1Hz to 500 Hz to allow and lower and higher frequency. The recorded data are set to the same order (N) to facilitate comparison across samples.

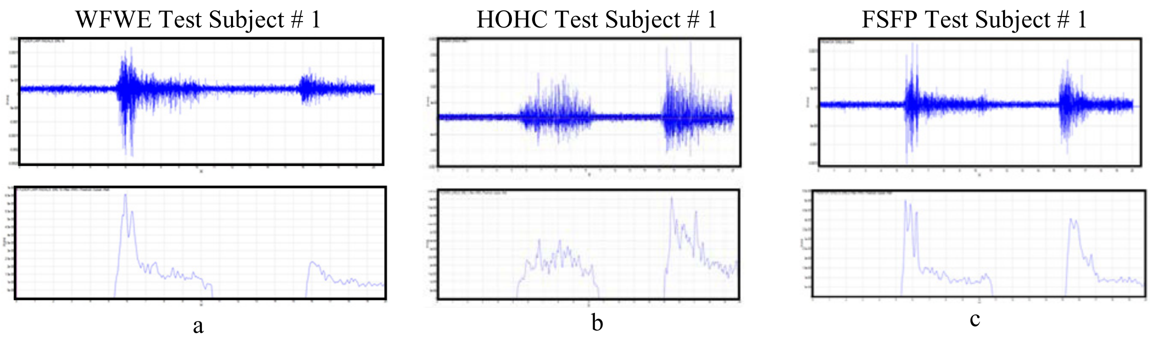

Fig. 4. Sample of raw signal, filtered signal and muscle activation for Test Subject 1

The results for six movements such as wrist flexion, wrist extension, hand close, hand open, forearm supination and forearm pronation for female subjects are illustrated graphically in Figs 5 to 7.

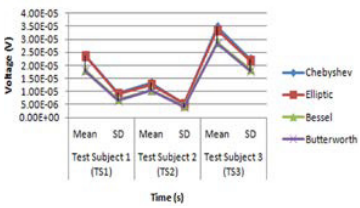

Fig. 5. Female wrist extension & flexion

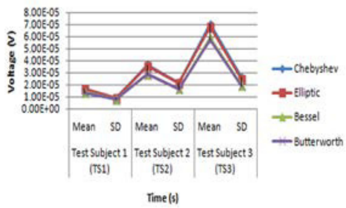

Fig. 6. Female hand open & close

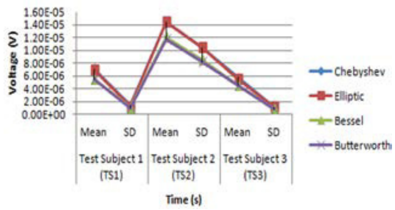

Fig. 7. Female forearm supination & pronation

From Fig 5, it can be seen that the Butterworth filter produces the lowest standard deviation (SD) for Test Subject 1 (TS 1) with 6.69µV, followed by Test Subject 2 (TS 2) with 4.08µV and Test Subject (TS 3) 3 with 0.18µV for female wrist extension & flexion movements. The results obtained in Fig 6 for female hand open & close movements are similar as in Fig. 5 where Butterworth filter produces the best performance, followed by Bessel, Elliptic and Chebyshev filters respectively. Fig. 9 shows that Butterworth filter and Bessel filter is the most appropriate filter with the lowest value of SD with TS1 (1.08µV), TS2 (8.17µV) and TS3 (8.27µV) for female forearm supination & pronation movements. Hence, it can be deduced that Butterworth filter is the best filter among other three (Bessel, Elliptic and Chebyshev) filters for all movements.

The results for six movements such as wrist flexion, wrist extension, hand close, hand open, forearm supination and forearm pronation for male subjects are illustrated graphically in Figs 8 to 10.

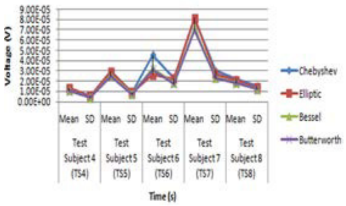

Fig. 8. Male wrist extension & flexion

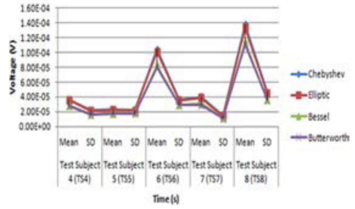

Fig. 9. Male hand open & close

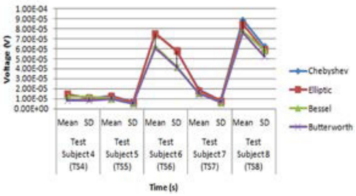

Fig. 10. Male forearm supination & pronation

The results obtained for male group is identical with the result for female group when it can be seen from Fig. 8 where Butterworth and Bessel filters produce the lowest SD. The Test Subjects 4 until 8 (TS4 until TS8) produce the smallest SD for Butterworth filter where the SD value for TS4 is 4.08µV, TS5 is 7.35µV, TS6 is 1.77µV, TS7 is 2.3µV and TS8 is 0.12µV for female wrist extension & flexion movements. In Fig. 9, Butterworth filter produces the best filtering techniques and followed by Bessel, Elliptic and Chebyshev for male hand open & close movements. Similarly, from Fig. 10, it can be seen that Butterworth and Bessel filters produce the performance male forearm supination & pronation movements. Overall, the Butterworth filter is found to be the best among the other three (Bessel, Elliptic and Chebyshev) filters for all movements.

The comparison within and across the female and male grouping for movements of wrist extension & flexion, hand open & close and forearm supination & pronation shows that the Butterworth filter outperforms other filters based on the standard deviation measurements. Based on the results, the filtration of sEMG signals for hand, wrist and forearm muscles such as Extensor carpi radialis, Flexor carpi radialis, Palmaris longus, Palmaris longus, Pronator teres and Pronator teres could employ only Butterworth filters without carrying out extensive work using other filters in future.

The findings show that there exists a different amplitude values for the processed EMG data where the males exhibited higher amplitude compared to females. Hence, this research has shown that different sEMG signal signature for forearm muscles could be established for females and males separately. However, since the sample size is small, the research findings can be construed as preliminary results. Further research by carrying out the experimental work with more subjects (male and female) is necessary to derive a definitive conclusion.

4 Conclusion

This paper has discussed the establishment of sEMG signal signature of female and male subjects for forearm muscles such as Extensor carpi radialis, Flexor carpi radialis, Palmaris longus, Palmaris longus, Pronator teres and Pronator teres based on movements such as wrist extension and flexion, hand open and close, and forearm supination and pronation. This was achieved through the use of Butterworth Bessel, Elliptic and Chebyshev filters. This sEMG signal signature could be useful in the development of rehabilitation device of upper extremities.

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