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Validation test on thresholds for wheelchair power-assist system activation using population data

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Abstract

Power-assist wheelchair consist of DC motors to ease the propulsion for upper limb impairment person. Surface electromyography (sEMG) is one of methods to activate it. The purpose of this study was to investigate the threshold for Motor Unit Action Potential (MUAP) to activate the power-assist system. MUAPPEAK for contact and recovery phases for 3 participants were collected to be used in validation test to find the most suitable threshold. The threshold are based on mean and standard deviation (SD) of the population data. Result shows no suitable threshold for participant 1, mean for muscle group BIC & TRI for participant 2 (8.77% TP and 0% FN) and participant 3 is fit to both mean and SD for EXT & FIX. As a result, there is no single threshold that fit to all person. Dynamic thresholds or additional threshold determination methods are required to ameliorate the system.

Index Terms: *Motor Unit Action Potential (MUAP), sEMG, Power-assist wheelchair, contact phase, recovery phase, Arduino*

I. INTRODUCTION

Electromyography (EMG) is a signal that can be acquired directly from targeted muscle or on the skin surface using needle electrode, fine wire electrode or surface electrode, respectively, can be considered as a superposition of sequences of MUAPs [1]. MUAP's amplitudes, firing rate and shapes providing valuable details that is useful for application in rehabilitation and biomedical activities [2, 3].

Intramuscular EMG widely tested on single MUAP due to high selectivity of detection technique which is capable of targeting one single fiber. At the same time, surface electromyography (sEMG) is used to quantify and classify a few muscular activities without harming the person [4]. This kind of advantages bring good impacts in recreational, biomedical applications, clinical diagnosis, rehabilitation and sport where the installations or preparations is uncomplicated. And now, sEMG-based power-assist wheelchair developed to ease the mobility of upper limb impairment person. Power-assist wheelchair operated on torque available on market as in Figure 1.

Severe upper limb impairments would cause mobility problem that need an assistive device for independently moving. Researchers and physiotherapist has investigated and agreed the application of powered wheelchair improve the independent mobility [5]. But most of upper limb impairments patient facing difficulty to maneuver around due to stiffness of the muscles to propel forward [6]. Here is where a system to activate the power-assist is most needed. Muscle sequence analysis based on MUAP is a well-known method to investigate and recognize activities done by targeted muscles. But the suitable threshold for power-assist activation are not well understood yet to differentiate types of activity between contact and recovery phase [7]. Contact phase is where mechanical power delivered to the handrim to move forward and recovery phase is reposition the arm to repeat the contact phase [8]. The main purpose of this study was to investigate the MUAP peak values during push and recovery phase for normal and healthy

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participants. This understanding has important implications for implementing a method to determine suitable threshold for sEMG-based power-assist wheelchair in helping the mobility of upper limb impairment patient.

Figure 1: E-Motion M15 Power-Assist wheelchair

II. METHOD

A. Participants

Manual wheelchair was adopted to collect and record MUAP activities during recover and contact phases. 3 participants were recruited to be involved in the research and consent letter has been given to those who are agreed to participate. Mean ± SD: age, 22.4 ± 0.6 years; height, 168.2 ± 13.5 cm; weight, 62.7 ± 10.8 kg. Experiments conducted at Universiti Kuala Lumpur Malaysia France Institute.

B. Experimental Design

Validation test conducted for 50 seconds consist of 5 contact and 5 recover phases. Each phase allocation time is 5s. Participants are allowed to perform one activity in one phase. In contact phase, they must propel forward and for recovery, return their hands back to starting point of contact phase. This cycle repeated for 5 times. Participants are given 12 minutes of practice time to get used with propulsion method and timeline as in Figure 2.

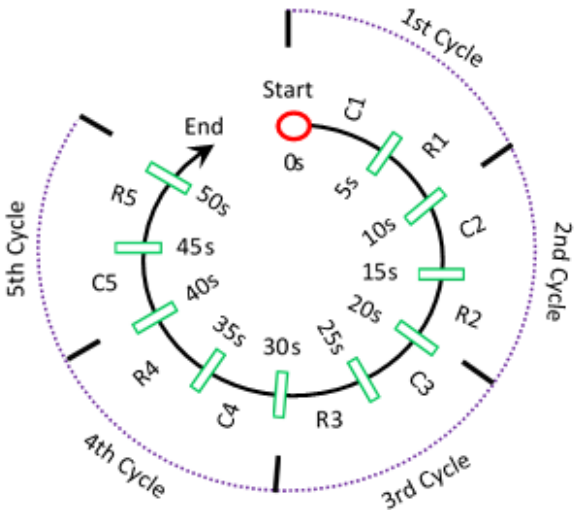

Figure 2: Timeline for Validation Test (C = Contact Phase, R = Recovery Phase).

Data Acquisition

4 sEMG Myoware muscle sensors (Figure 3 (a)), biomedical pads Ag-AgCl (Figure 3 (b)), an Arduino UNO microprocessor (Figure 3 (c)) and Matlab software were used conducting the experiment as in Table 1. In human arm, there are 4 major muscle groups, Biceps Brachii (BIC), Triceps Brachii (TRI), Extensor Carpi (EXT) and Flexor Carpi (FIX) as shown in Figure 4. On each of these 4 muscles were placed a sEMG sensor to record MUAPs activity during arm flexion and extension in contact and recovery phase. SENIAM which is a sEMG for the non-invasive assessment of muscles was used as a guideline for sensors placement location on targeted muscle [9].

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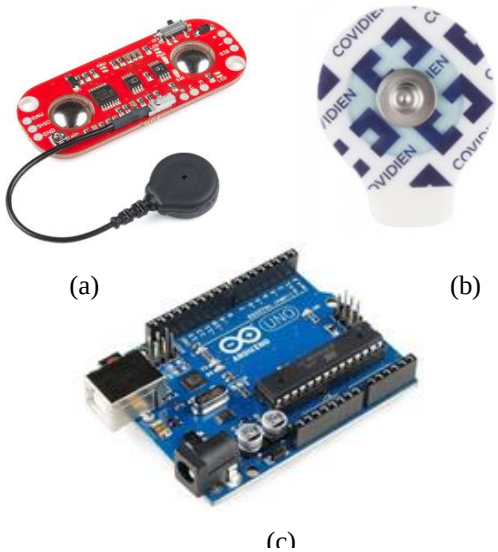

Figure 3: Hardware Used in This Research

Table 1: List of hardware and software

NO	ITEM	QUANTITY
1.	Myoware muscle sensor	4
2.	Biomedical pad	12
3.	Arduino UNO microprocessor	1
4.	Matlab	1

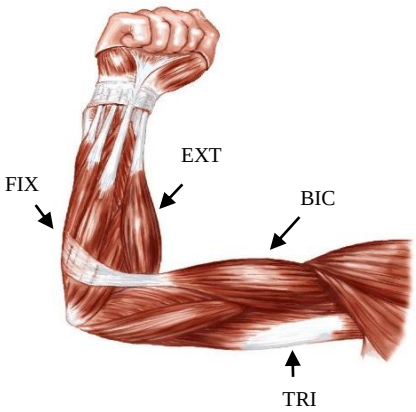

Figure 4: Musculoskeletal Model of Human Arm

Data acquisition flow as per explained in Figure 5 is where MUAPs sensed by each electrodes sent to Myoware muscle sensor to filter and amplify into 1024-bit system by Arduino UNO microprocessor. Then, MUAP converted into range of 1-5 Voltage for plotting into Matlab software for monitoring and storing the data for further analysis. After MUAP converted into 1-5 V, pattern recognition based on threshold obtained from 13 participants to indicate the power-assist system. The threshold determined from mean, SD and CI from population data of 13 participants. If

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MUAP value is over than threshold, digital signal "1" send to power-assist system and all the data monitored from Matlab.

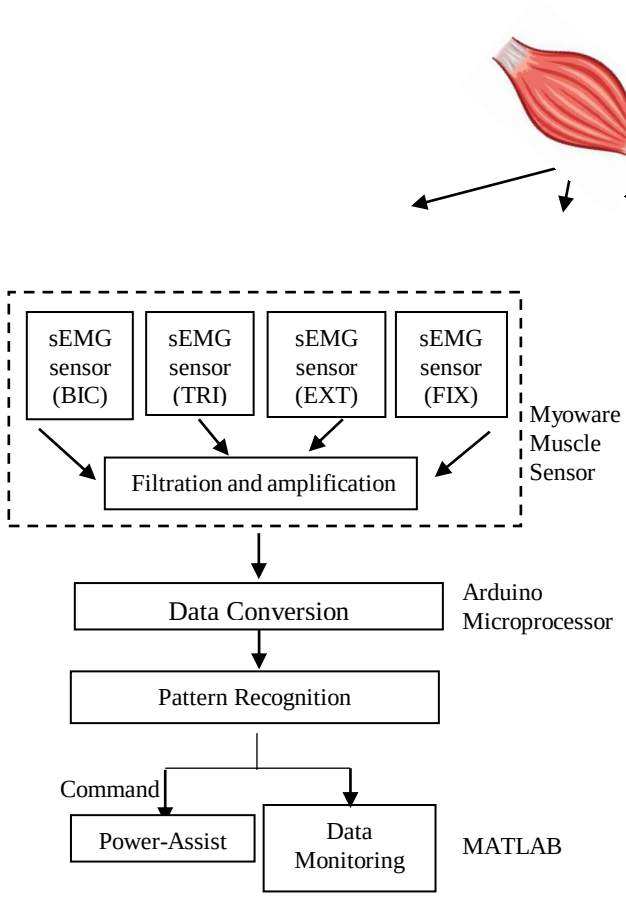

Figure 5: sEMG Data Acquisition for Validation Test

D. Threshold Values

Population data collection for mean ± SD as in Figure 6. It shows that $MUAP_{PEAK}$ in contact phase is higher than recovery phase. Propelling forward required higher MUAP to command muscles to contract and produce higher propelling force due to participant weight compared to recovery phase is where they has to move their hand only to repeat the contact phase. Consequently, lower MUAPs are produced for recovery phase. Table 2 are the values applied in validation test to find the best threshold for each participants.

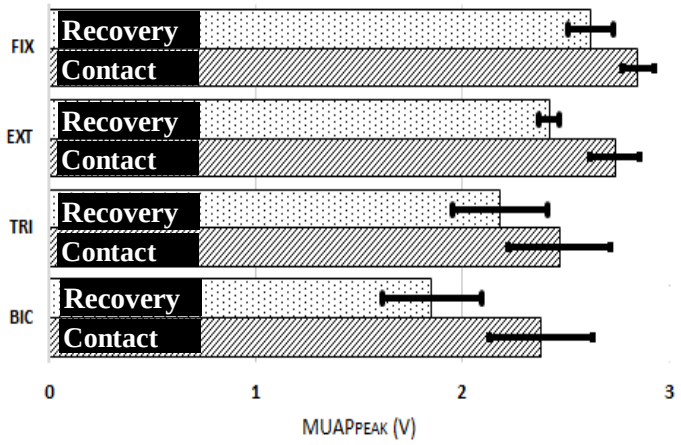

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Figure 6: Population [illegible] ± SD for 13 participants

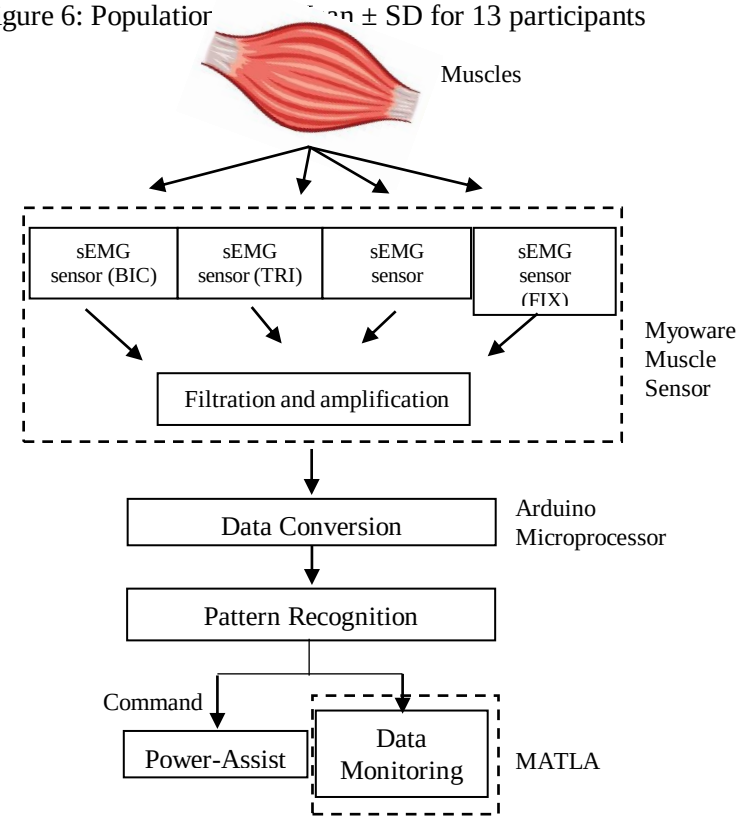

Figure 6: sEMG Data Acquisition for Validation Test

Table 2: Threshold values for Validation Test

	BIC (V)	TRI (V)	EXT (V)	FIX (V)
MEAN	2.376	2.351	2.743	2.846
SD	2.623	2.640	2.861	2.926

E. Assessment Method

Misclassification matrix is a table that is often used to describe the performance of a classifier on a set of test data for which the true values are known as in Figure 7. There are 4 parts in the matrix and for this research, True Positive (TP) and False Negative (FN) used for assessment of which threshold are the best. TP is where MUAP value is over the threshold and power-assist system supposedly to switch on at right time (contact phase). However, FN happens when it is switched on at wrong time which is in recovery phase that expected to remain off. Power-assist system should switch on if participant propel forward and not to when their hands return to starting point for contact phase.

In each phase, allocation time is 5s and participants are allowed to do only 1 activity based on which phase they are now either contact or recovery. Average stroke time is around 0.4 – 0.5s [8, 10] and 10% is selected for maximum TP values for contact phase. Meanwhile, FN is selected which is has 0%. Evaluation will be on opposing muscles group because of it would performing opposite movement as one muscle group is contracting, the opposing is lengthening. It will be BIC and TRI, meanwhile EXT pairing with FIX

	Predicted +	**Predicted -**
Actual +	True Positive (TP)	False Negative (FN)
Actual -	False Positive (FP)	True Negative (TN)

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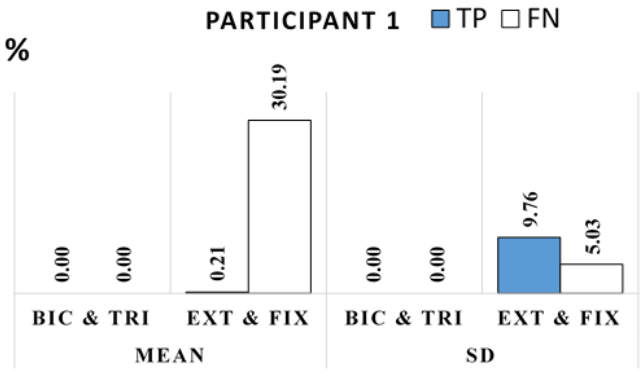
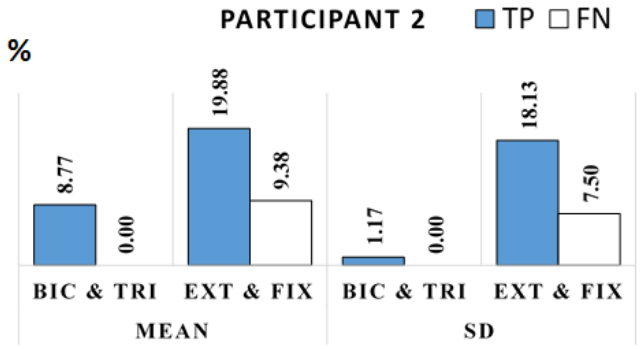
Figure 7: Misclassification Matrix

III. EXPERIMENT RESULT

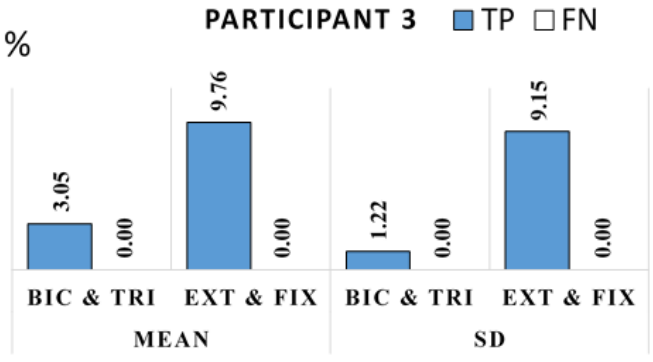
Figure 8 and Table 3 show validation test result for 3 participants and TP, FN values are in percentage. Participant 1, TP value that meet the condition is in SD for EXT & FIX muscle group only. But, the FN value (5.03%) is quite high means that power-assist system switched on in recovery period. Participant 2, there are two TP values that is below 10% which are mean for BIC & TRI and SD for BIC & TRI. EXT & FIX for both mean and SD are exceeded 10%. 0% FN brings a good sign that these two thresholds are suitable for participant 2. FN participant 3 is 0% for all thresholds and TP are below 10% where satisfy the conditions.



(a)



(b)



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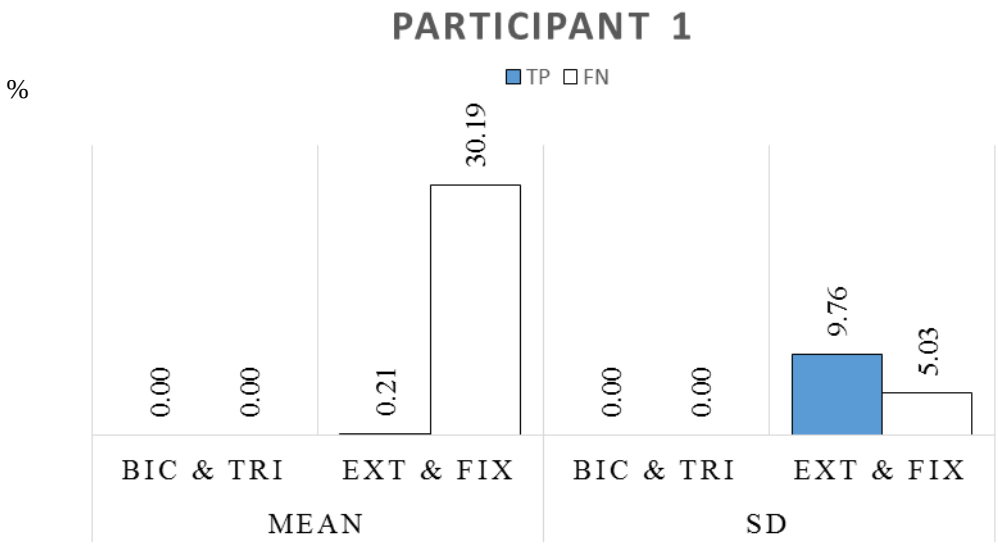

Table 3: TP and FN Result for Each Participants

Participant		1		2		3	
Misclassification Matrix		TP (%)	FN (%)	TP (%)	FN (%)	TP (%)	FN (%)
MEAN	BIC & TRI	0.00	0.00	8.77	0.00	3.05	0.00
	EXT & FIX	20.73	30.19	19.88	9.38	9.76	0.00
SD	BIC & TRI	0.00	0.00	1.17	0.00	1.22	0.00
	EXT & FIX	9.76	5.03	18.13	7.50	9.15	0.00

IV. CONCLUSION

The same value of threshold implemented in the research, different result were obtained from all 3 participants for TP and FN value. No threshold suit to participant 1 even though TP value of SD for EXT & FIX is 9.76% due to FN is more than 0%. FN value show how many time power-assist system switched on in recovery and it's dangerous when that time it should remain off. It could harm wheelchair user by activating the system without user's intention to move forward. Meanwhile, 0% of TP demonstrate that power-assist didn't switched on when it's supposedly to assist the user. Consequently, no threshold is applicable to participant 1 and other threshold determination method is needed to overcome this problem.

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For participant 2, EXT & FIX for mean and SD dissatisfied FN condition but BIC & TRI is 0% in both thresholds. TP value for BIC & TRI in mean 8.77% and SD is just 1.17%. In this case, mean's threshold for BIC & TRI is selected for participant 2 because of 1.17% is too low and has possibility that power-assist didn't turn on in all contact phases. Implemented threshold seems fit the best to participant 3 when all of it satisfied the requirements. Due to small TP's value of BIC & TRI for mean and SD, these two threshold can be neglected and further analysis is needed to choose either mean or SD for EXT & FIX is the best by looking result in each contact phases. As in Figure 10, both shows TP were appeared in all 5 contact phases and no difference can be seen between it. In this case, both threshold can be selected for participant 3.

As result above, there is no one threshold that is suitable for all participants. Different participant, different threshold that would works perfectly for them and here is tasks for researchers to investigate more on threshold determination method to improve robustness of this system to cater more users in the future.

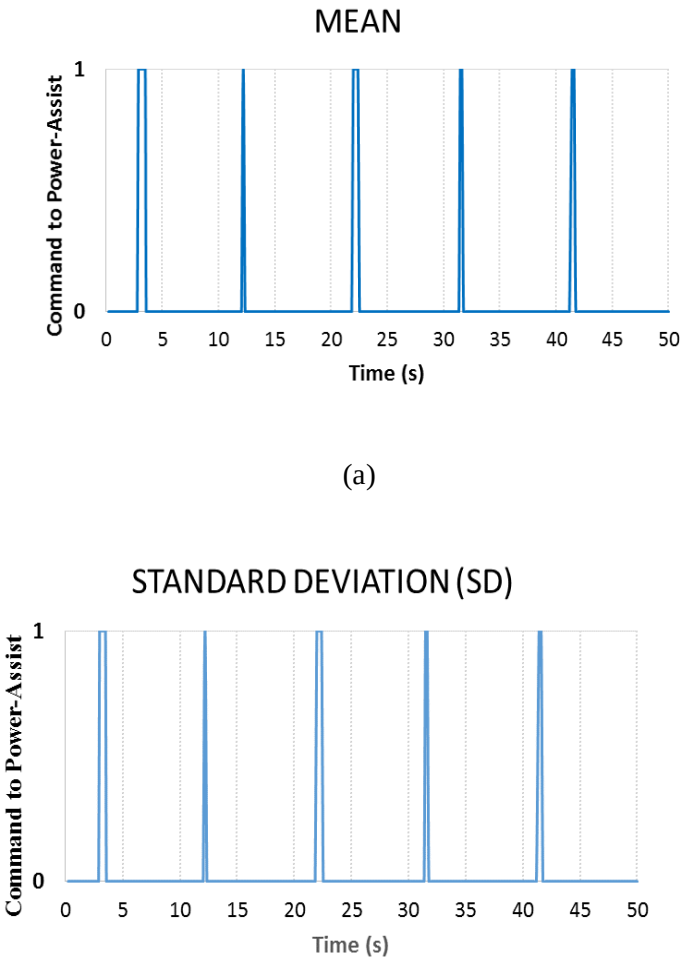

Figure 9: Signal Sent to Power-Assist System for Mean and SD

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