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Effect of an Acupuncture Stimulation on Human Body Stamina Improvement based on Statistical Electromyography Analysis

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ABSTRACT

The acupuncture therapy has been known since thousands years ago in China as the TCM (Traditional Chinese Medicine). One of the main benefits of this therapy is as a function of accelerating recovery in muscle fatigue due to physical activity during resting the body for a certain time. Unfortunately, clinical proofs as in modern medicine or through the stages of analytical laboratory relatively still lack. Therefore, in this paper we consider a method to explore acupuncture therapy which has been known can improve the human body stamina based on Electromyography (EMG) measurement as the main source of quantitative analysis.

In this paper, EMG is used as a source information that will represent the characteristic of biceps muscle fatigue from initial condition up to recovery condition. Initial condition described that volunteers will be treated a physical stimulation on 5 kg static load exercise. Recovery condition described that all volunteers will be separated into two groups, where the first group obtained acupuncture treatment and the second group did not. Then, bioelectricity from muscle measured as analysis of EMG comparison between two groups. Furthermore, the effect of acupuncture therapy will be evaluated quantitatively by this EMG data conversion into statistical data analysis; i.e. Power Spectral Density (PSD) and Median Frequency (MF).

Keywords: Electromyography, acupuncture, Power Spectral Density, Median Frequency.

Mathematics Subject Classification: 62J12, 62G99

Computing Classification System: I.4

1. INTRODUCTION

Acupuncture is a traditional China medication (TCM) that has been used thousands years ago. Although well accepted in the mainstream of medical care throughout East Asia, it is considered an alternative medical system in much of the Western world. Currently, active research has been carried out to reveal its relation to modern biology, chemistry and physics and therapeutic effectiveness (Ernst et al., 2007). Some efforts have been given in order to find more understanding the anatomy

and physiology of acupuncture points, the healing concepts and behaviour as well as the medical mechanism (Ahn et al., 2008). It is still in the part of controversy in bringing together with conventional medicine. However, the effort to show the therapeutic effectiveness using modern sciences is still growing up rapidly.

In this paper, we introduce local acupuncture therapy referred to GI acupuncture. GI acupuncture created by Gunawan Ismail (GI), Indonesian acupuncturist who combine the technique between acupuncture and massage. The unique of GI acupuncture therapy is only stimulates simple acupuncture points of human body without reducing the therapeutic effectiveness. Hence, this simple acupuncture simplified as GI acupuncture will be easy to learn by ordinary people who want to learn of this traditional medication.

The used of acupuncture on the human stamina improvement by doing physical activity have been studied (Liz Tough, 2006). The aim of this paper is to observe how the GI acupuncture stimulation can improve the stamina or human body endurance based on quantitative parameter. In particularly, the GI acupuncture was used on the human biceps muscle which is subjected to do simple physical exercise activity, i.e. raising the load of 5 kg for a period time. The response physiologies detected from the volunteers from the muscle electrical signals or called electromyography (EMG). The EMG data will represent the change characteristics of human muscle after given stimulation of GI acupuncture. Furthermore, based on De Luca, 2002; the effect of acupuncture therapy will be evaluated quantitatively by this EMG data based on Power Spectral Density (PSD) and Median Frequency (MF) and conversion into statistical data analysis. The paper extends the previous version of the paper appeared in Farida et al., 2011.

2. Acupuncture

Even tough acupuncture came from China, but its name came from Latin, *acus* mean needles and *pungere* mean puncture. Archeologists are believed that acupuncture has begun from 3000 BC ago, but stones as device, not needles, and named *bian shi*. *Bian shi* is not only found in China, but also in Korean, Japan, Eurasian and Mongolian (Y.T. Ma and Z.H. Cho, 2005).

Acupuncture therapy has certain point (called acupoints) that used to insert needle into body. These point were believed to be holes that allow entry into channels and could provide a gateways to influence, redirect, increase, or decrease body‘s vital substance-Qi-thus correcting many of the imbalances. Acupuncture could help body in controlling stress and curing injury by stimulate the release of various hormones. Therefore, the effectiveness of acupuncture is variety depend on patient self healing value which also make variety in how long patients recovery even for the same disease.

The acupuncture therapy uses needles which penetrate to the soft muscle of human body. The needle penetration will build the homeostasis mechanism and increased the self healing (Chiang et al.,

1973). Homeostasis is a concept based on a condition to defence the physical and chemical condition which relatively constant in the internal environments.

The process of the acupuncture therapy in the human body will be divided into two parts, there are central and peripheral. The central mechanism is due to needle penetration on acupuncture points which is the points of the nerve peripheral. Needle penetration will be activating the nerve which connected to the some particular body systems, and will send the information to the brain which connected to the immunity systems and cardiovascular systems also normalize the physiology activity of all the body. The mechanism of peripheral on the needle penetration is the trigger reaction of the body physiology, including the increasing sensitivity of the body and healing the damaged muscle.

The acupuncture are the physical therapy which coordinating the brain and the peripheral nerve. Then, the acupuncture did not medicate a special disease but more balancing the body function as whole systems. As a physiological therapy, the effectiveness of acupuncture depends on the ability of the disease to be recovered, and depend of the value potentially different self healing of the patients. Using the acupuncture therapy on one patient can be recovered from their suffering, but one other patient maybe cannot (Y.T. Ma and Z.H. Cho, 2005).

2.1. Acupoints

The efficiency of acupuncture therapy depends on the effective points to be penetrated. The acupoints connected to the main anatomy structure by the peripheral nerve. The points are closed to the nerve cells and aorta which also surrounding by the little nerve cells. The modern neuromuscular medication named these points as trigger points, motor points, or derma points. All of the points have the same characteristics that will show illness senses and discomfort due to the reaction of nerve sensitivity. Although, it is almost 70% acupoints to be trigger points, but the trigger points and the acupoints is not the same Trigger points' tendon (Y.T. Ma et al., 2005). The acupoint which used in this experiment shown in Figure 1.

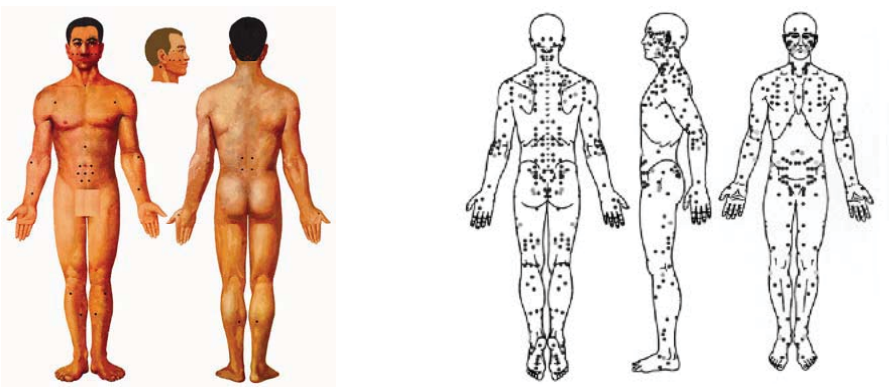
Figure 1. Acupoints

2.2. GI acupuncture

There are several of types of acupuncture that has used in Indonesia. GI acupuncture is the simplest one which made by consolidation of traditional China Medicine (TCM) and Indonesia traditional medicine (ITM) that has developed by Drs. Gunawan Ismail who has been practicing acupuncture for more than 30 years in several medical clinics in Jakarta and Bandung. Many positive testimonies of the patients who suffer diseases are reported from GI acupuncture therapy patients. The GI acupuncture is a much more simplified acupuncture therapy as it is compared by the Chinese Traditional Acupuncture (TCM), so there will be easy to be studied by therapists who have studied the basic of GI acupuncture (Farida et al., 2009).

GI acupuncture has 7 main acupoints that known as 2-3-2 points which function is to neutralize organ dysfunction in human body. These points are the 2 of left and right *Tien Ie* points, the 3 of left and right *Tien Su* and *Kuan Yu* points at the stomach, and left and right *Tsu San Lie* points.

- The penetration on *Tien Su* and *Kuan Yu* points (stomach) is to activate the immune systems through increasing the conductivity of the nerve. These points are the primary homeostasis systems.
- *Tsu San Lie* points (leg) are the points that were very effective to the premix nerve, which is the system in the body on the diaphragm form
- *Tien Ie points* (neck) are points which connected to the systems that influence the twelve cranial nerve center.



(a) (b)

Figure 2. The comparison acupoint between GI acupuncture (a) and Traditional China (b)

These points could be add in other acupoints that has connected to the symptoms of disease if it necessary. Needles are injected trough the skin with certain depth, so it could reach the neuron or tissue that related to organ dysfunction neutralization. It took about 60 minutes for GI acupuncture therapy.

3. Electromyography Signals

Electromyography(EMG) signal comes from nervous electric activity when muscles contract or relax. Amplitude range of EMG signal is between 0-10 mV (peak to peak) or 0-1,5mV (rms). The frequencies which are detected by skin electrode are about 0-500 Hz, with dominant frequency in the range of 50-150 Hz (Farida et al., 2007). The amplitude of EMG signal is random. However, the frequency components between 0-20Hz are disposed of the unit motor of the muscle. The EMG signals are influenced by physiological factors, anatomic and technical. EMG signal is affected by *noise*, they are electromagnetic radiance (50-60 Hz), *motion artifact* and instability because the randomness of unit motor activation phase. These effects caused by these various factors which need to be controlled with proper detection methods in order to obtain good measurement results. Generally, Block diagram of EMG measurement shown in Figure 3.

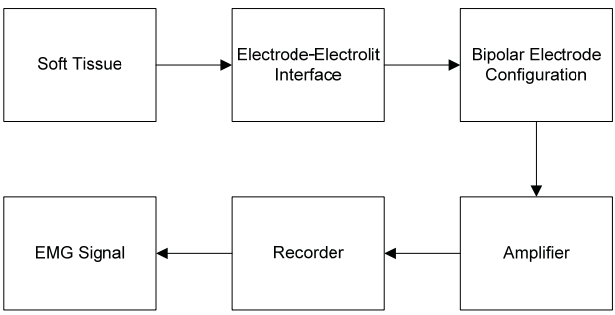


Figure 3. Block diagram of EMG measurement

3.1. Detecting and Filtering the EMG Signals

EMG signal triggered by the activity of motor unit on the line muscle fibers. EMG signal spreads on the muscle and goes through the muscle surface and the tissue, before it is recorded by the electrode. The tissue and the skin serve as a low pass filter and the interface electrode-electrolyte acts as a high pass filter. EMG signal represented by variable **m** and noise represented by variable **n**.

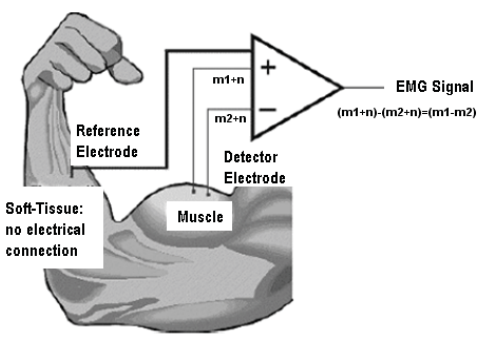


Figure 4. Bipolar Electrode and Differential Amplifier

If the surface of metal electrode is in contact with the electrolyte, it will spontaneously generate an electrical surface which will be influenced by half-cell potential. The layers are called Electrical Double Layer (EDL) which has thickness of order 1 – 20 nm. The EDL layers draw the ion in opposite charge with the layer and repelled the ion of the same charge. The EDL possesses the electrode to have the capacitive characteristics and the impedance (De luca, 2002).

3.2. Processing and Interpretation EMG Signals

Some parameters used to analyze the EMG signal so as to obtain information that has a physical representation. Figure 5 is a sample of the recording EMG signals which unprocessed (raw signal).

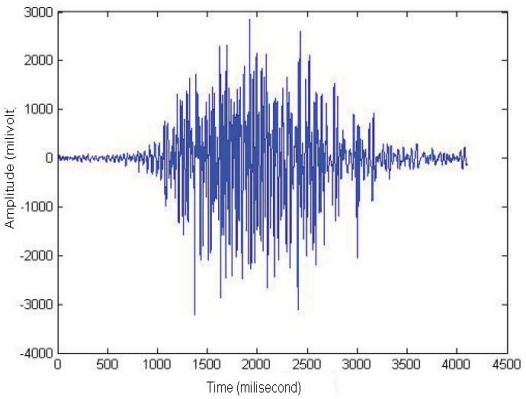


Figure 5. The Raw Signal EMG

The interpretation of EMG signal can be done on a time domain which is amplitude represented on RMS values. Often, the EMG parameters can be analyzed by a statistical analysis, such as the mean (μ) and the variance (σ) of the piece of data

$$\mu = \sqrt{\frac{\sum_{i=1}^{N} x_i}{N}}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (x_i - \mu)^2}{N}}$$

The other approach of interpretation of EMG signal can be done on frequency domain. In the research, analysis of the EMG signal is done using Analysis Time-Frequency (TFA) that represented on equation:

$$P_{xx}(t,f) = \sum_{-\infty}^{\infty} x(k)w(k-t)e^{-j2\pi fk}$$

where: P_{xx} *(t,f)* are the power spectral density of the t is time period and for frequency f, *x(k)* are the raw signal), *w(k-t)* are the windows function with t step. Thus, Median Frequency (MF) and Power Spectral Density of the EMG signal (data) could be analyzed.

3.2.1. Power Spectral Density

The estimation of the power spectral density (PSD) is separated for duration of time and frequency, which will be separated to be a piece of data based on the time duration. In this research used Welch's periodogram method to get estimated PSD. Welch's method is a modification of Bartlett method, which making the pieces of data that overlap each other (Salehuddin et al., 2011). Figure 6 illustrates the signal truncation of the raw EMG signal to be a K, L, M, N, O and P piece of signal, each has 5 seconds duration and The estimated PSDs are counted for all frequencies of the piece of data (see Figure 7), and to be averaging on the span of frequency tracking which is called mean PSD.

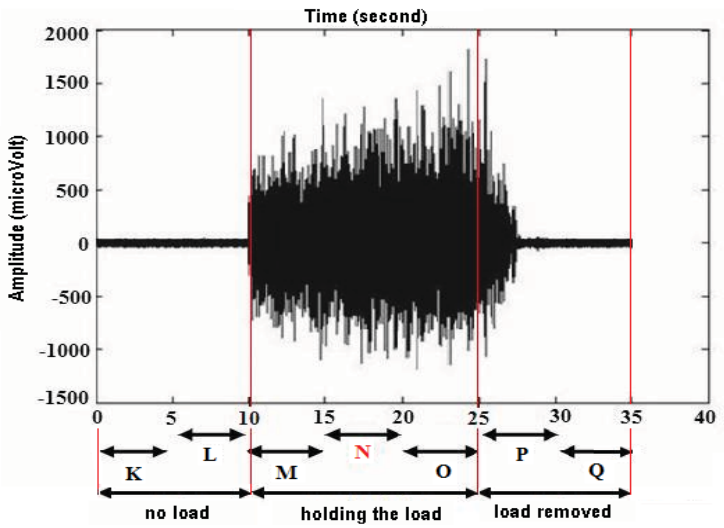


Figure 6. The Raw Signal EMG grouped into 7 segments piece of data

The Mean PSD value is used to investigate muscle fatigueness. In the muscle that experience tiredness, the frequency will be decreased and the Mean PSD will be increased. These are caused by the product of the increased of recruiting the unit motor of the muscle (Hagbarth and Macefield, 1995; Tarata, 2003).

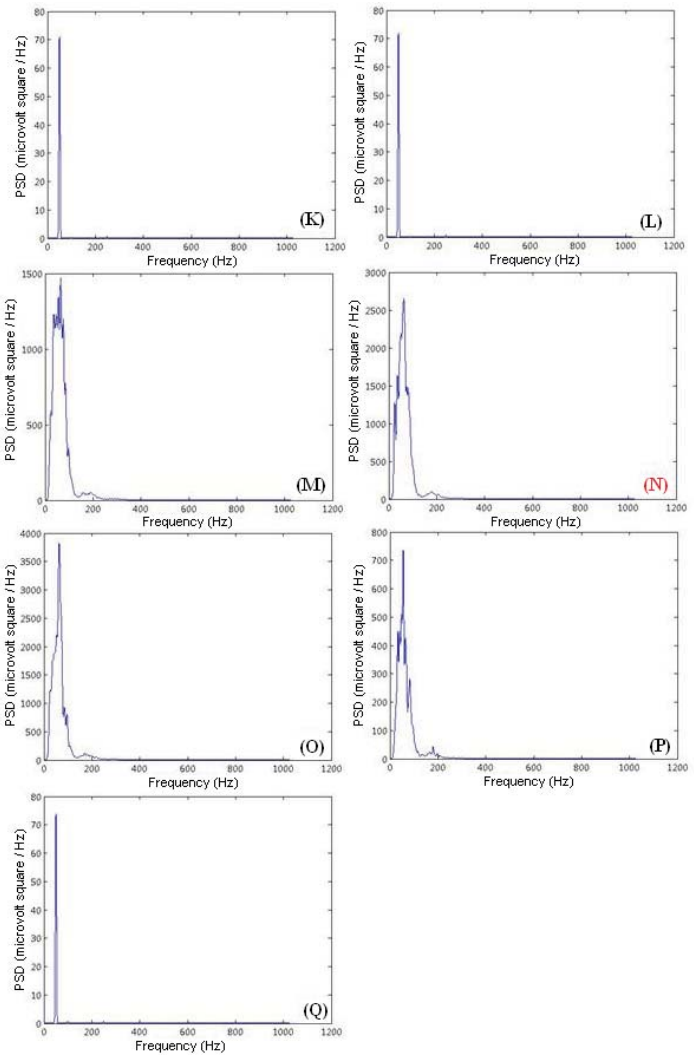


Figure 7. Graphic of PSD estimation value for each piece of data

3.2.2. Median Frequency (MF)

Median Frequency (MF) is the frequency that separates PSD in two parts and has the same power. MF will be used to determine the fatigue muscle index. The MF lean will be decreased if the muscle is going to be more worn out. This is caused by the change of central individual nerve motoric activity (Mann, 1983). The Mean PSD and MF will be calculated for every sub session of all the EMG data. These values will be used to account for the effect on the muscle for every sub session. MF formulated as follow:

$$\int_{0}^{f_{med}} S_m(f)\,df = \int_{f_{med}}^{\infty} S_m(f)\,df$$

where:

$S_m(f)$: PSD from EMG signal

f_{med} : MF from EMG signal

f : frequency (Hz)

3.2.3. Absolute Value

The absolute value of the power can then be used to determine muscle activation, i.e. when the muscle activation start up and the muscle will be contracted until the contraction is ended. The absolute value will be increased with the time of contraction. This is caused by the increased of the number of muscle motor unit that synchronizes. Absolute value formulated as follow:

$$m_{absolut} = \sum_{t}^{t+T} |m(t)|$$

dengan:

$m(t)$: Raw EMG signal

T : Duration when absolute value counted

t : Time (second)

4. MEASUREMENT AND ANALYSIS OF EMG SIGNALS

Experiment involved 8 volunteers were separated into two groups.

a. First Group

   The aim experiment for this group is focus on determine the characteristics of the biceps muscle fatigue when raise a 5 kg load and hold for a duration time. This group consist of 4 healthy men, i.e. A (28 years), B (22 years), C (22 years) and D (24 years).

b. Second Group

   The aim experiment for the last group is focus on determine the effect of acupuncture stimulation as biceps muscle fatigue recovery after raise a 5 kg load and hold for a duration time. This group consist of 4 healthy men, i.e. E (22 years), F (21 years), G (22 years) and H (22 years).

Figure 8. (A) Relax Positions (B) Holding a load position

Table 1: Experimental Procedure

Volunteers	No Acupuncture			Length of time (hours)	Acupuncture Stimulation		
	Session 1	Lapse of time between sessions (rest time)	Session 2		Before Acupuncture	Lapse of time between sessions (rest time)	After Acupuncture
A	6 sub session	15' rest	6 sub session	-	-	-	-
B	6 sub session	20' rest	6 sub session	-	-	-	-
C	6 sub session	30' rest	6 sub session	-	-	-	-
D	6 sub session	45' rest	6 sub session	-	-	-	-
E	6 sub session	15' rest	6 sub session	3	6 sub session	15' ac	6 sub session
F	6 sub session	15' rest	6 sub session	24	6 sub session	15' ac	6 sub session
G	6 sub session	30' rest	6 sub session	24	6 sub session	15' ac +15' rest	6 sub session
H	6 sub session	45' rest	6 sub session	24	6 sub session	15' ac + 30' rest	6 sub session

The whole procedure of experiments is given in Table 1. Every sub session consists of 10 seconds relax, 15 seconds holding the load and 10 seconds back to relax. Lapse of time between sub sessions is 2 minutes. The illustration is shown in Figure 8.

The results of EMG data recorded is processed by power spectral analysis to find the value of the estimated PSD and MF, and rectified to determine the absolute value. In this experiment, EMG data has a sampling frequency of 2048. Each sub sessions recorded in the duration of 35 seconds. To find the estimated value of the PSD, EMG signals in the time domain is divided into 7 segments piece of data, in 5 seconds, as illustrated in Figure 6 and Figure 7. PSD estimated value for each piece of data then averaged across frequencies from 0-1024 Hz, hereinafter referred to as the mean PSD. The mean PSD and MF in any sub session taken for analysis is the result of the data in seconds to 15 to 20 (segment of data N), because the data on this range time is the most stable and not affected by motion artifact when lifting weights (segment of data M) and off load (segment of data O), as shown in

Figure 9. The stability segment of data N also can be seen from the standard deviation of absolute value which smaller than the segment of data M and O. For example, in one session volunteer B in session 1, sub session 3, the segment of data N has a standard deviation of 41.04, 120.42 for volunteer M and 67.45 for volunteer O.

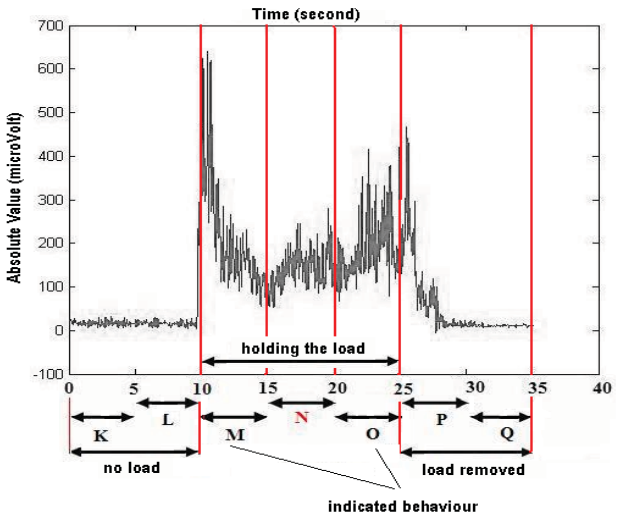


Figure 9. Data Segmentation of EMG Signal

5. STATISTICAL AND ANALYTICAL RESULTS

Data from the calculation of mean PSD and MF for the first group is shown in Figure 10-13. Then, some parameters can be determined i.e. the average value, change and percentage change from session 1 to session 2, and the standard deviation. This data will be used to analyze the effect of rest periods on characteristics of the biceps muscle fatigue. For the second group is shown in figure 15-18. Then, this data will be used to analyze the effect of the break after give acupuncture stimulation as the characteristics of the biceps muscle recovery.

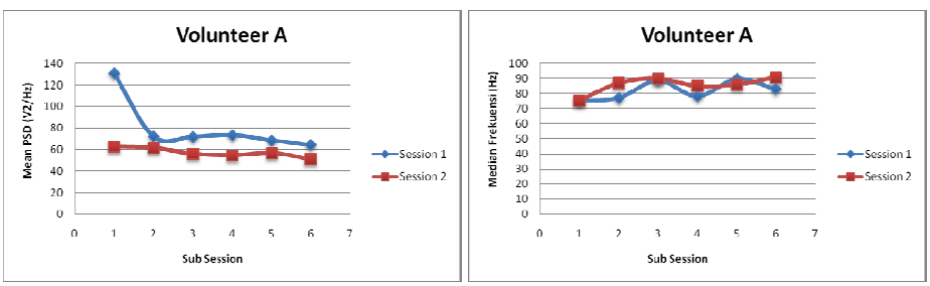


Figure 10. Mean PSD and Median Frequency in First Group for volunteer A

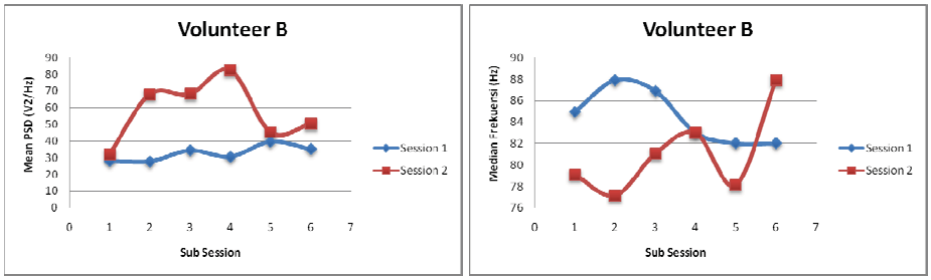


Figure 11. Mean PSD and Median Frequency in First Group for volunteer B

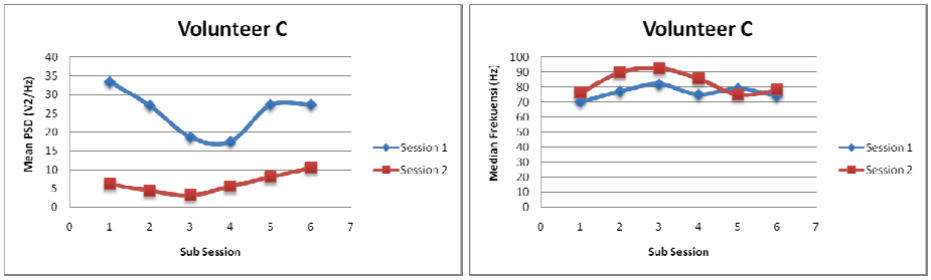


Figure 12. Mean PSD and Median Frequency in First Group for volunteer C

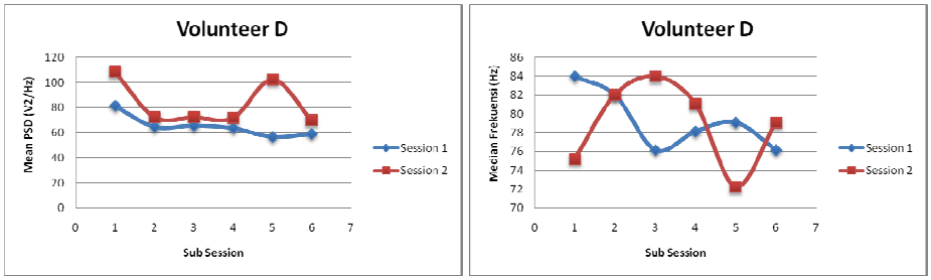


Figure 13. Mean PSD and Median Frequency in First Group for volunteer D

Figure 10-13 show the tendency of the transformation mean PSD and MF for all volunteers in the first group on the different session. The results show that the PSD value tends to increase while the MF value tends to decrease which indicate the muscle fatigue is increase. For the detail, Volunteer B and D indicated that muscle recovery condition characterized by decline trend of the mean PSD and by the ascending trend of the MF. In the other hand, Volunteer A and C have not seen any improvement in the condition of biceps muscle which is subjected to static load. The absolute value for each sub session without comparison to other sub session for volunteers showed an increase value over the duration of the contraction. This condition is shown in Figure 14.

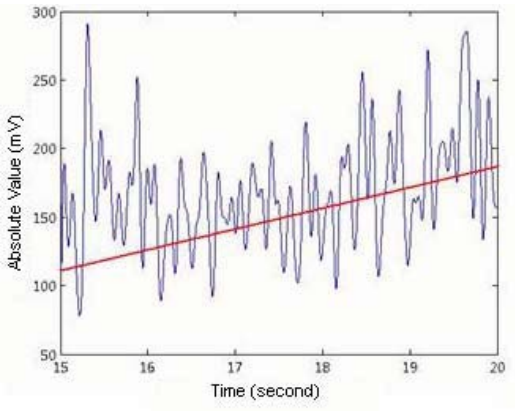


Figure 14. Graphic of absolute value for volunteer B Session 2, Sub Session 1

From all the volunteers in the first group who have different rest periods seen that the effect of the break is not always proportional to the recovery of the biceps muscle. Because the recovery of muscle co-influenced by the vitality of each volunteer at the time of doing experiment.

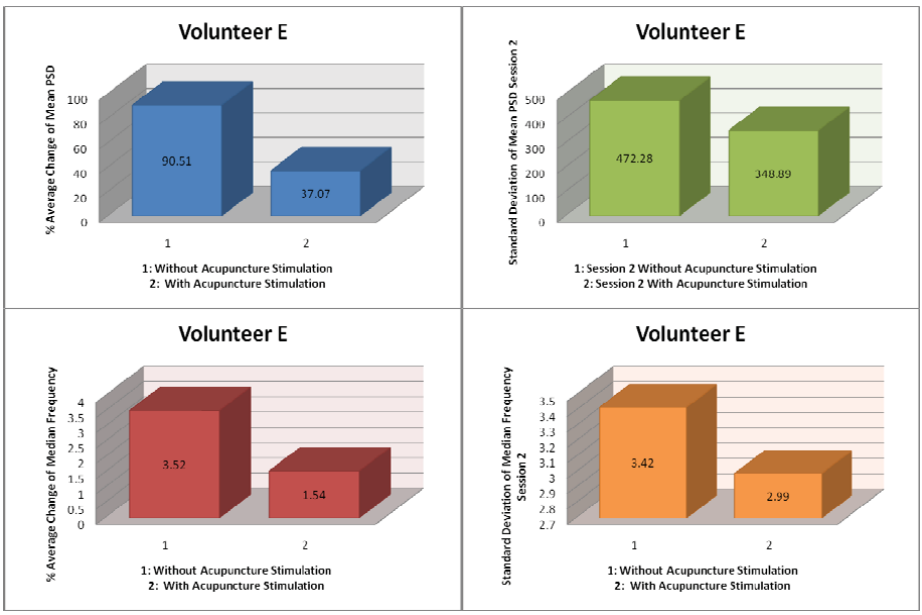


Figure 15. Percentage Average Change of Mean PSD and its Standar Deviation; and Percentage Average Change of Median Frequency and its Standar Deviation for volunteer E

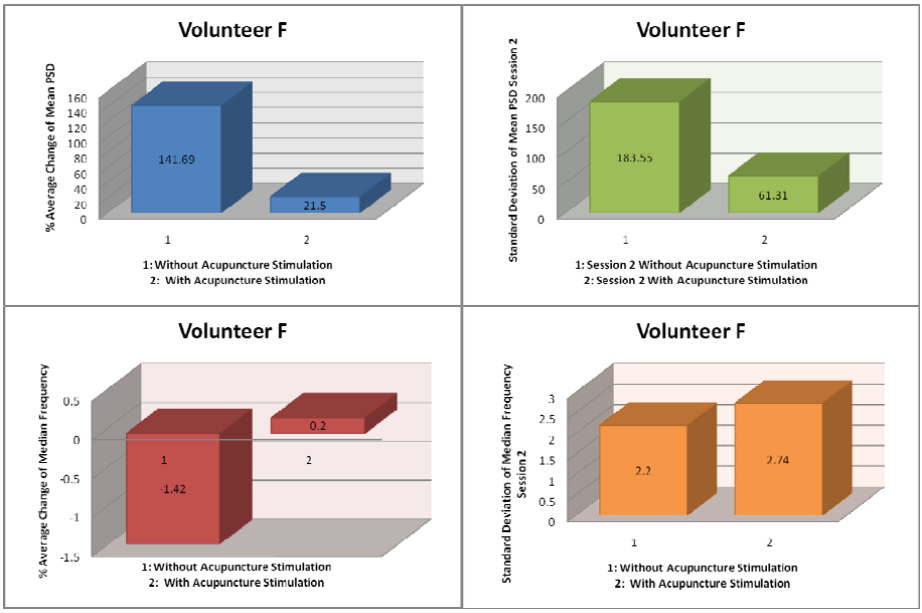


Figure 16. Percentage Average Change of Mean PSD and its Standar Deviation; and Percentage Average Change of Median Frequency and its Standar Deviation for volunteer F

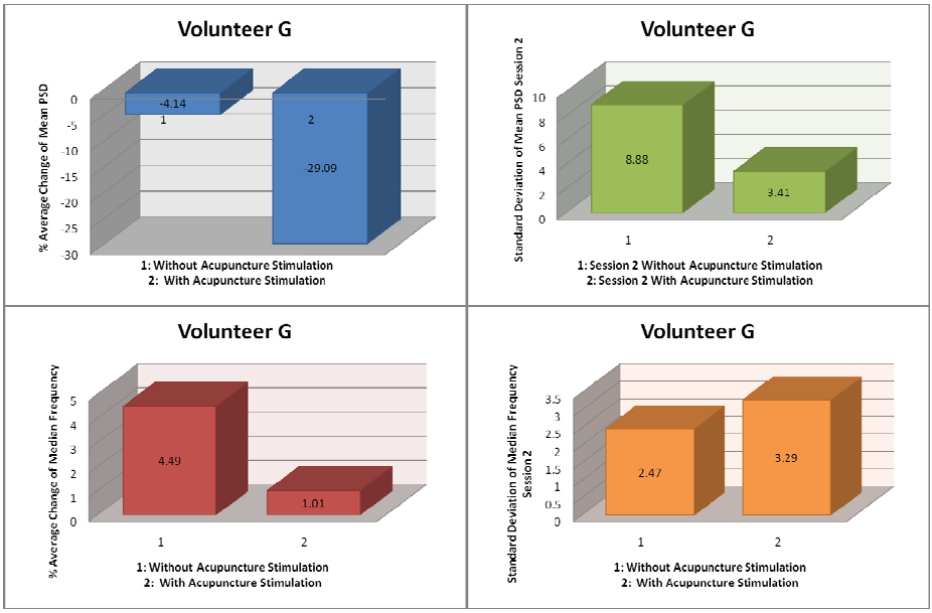


Figure 17. Percentage Average Change of Mean PSD and its Standar Deviation; and Percentage Average Change of Median Frequency and its Standar Deviation for volunteer G

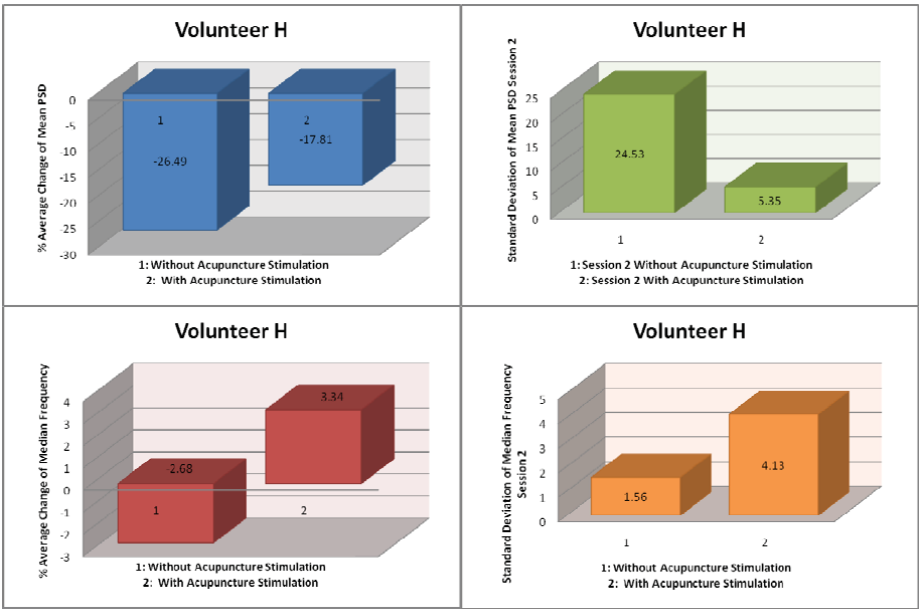


Figure 18. Percentage Average Change of Mean PSD and its Standar Deviation; and Percentage Average Change of Median Frequency and its Standar Deviation for volunteer H

Chart Column in Figure 15-18 shows percentage average change of Mean PSD and its Standard Deviation; and also Percentage Average Change of Median Frequency and its Standar Deviation for all volunteers in the second group. These figures can be tabulated and summaried in Table 2.

Table 2: Percentage average change of Mean PSD, MF, and its standard deviation

Volunteer	Percentage averga change of Mean PSD Session 1 to Session 2 (%)		Percentage averga change of MF Session 1 to Session 2 (%)	
	Without Acupuncture	Before and After Acupuncture Stimulation	Without Acupuncture	Before and After Acupuncture Stimulation
E	90.51	37.07 (< Without Acupuncture)	3.52	1.54 (< Without Acupuncture)
F	141.69	21.50 (< Without Acupuncture)	-0.98	0.16 (Down Without Acupuncture, Up With Acupuncture)
G	-4.14	-29.09 (> Without Acupuncture)	4.49	1.01 (< Without Acupuncture)
H	-26.49	-17.81 (< Without Acupuncture)	-2.68	3.34 (Down Without Acupuncture, Up With Acupuncture)
	Standard Deviation of Mean PSD in Session 2		Standard Deviation of MF in Session 2	
	Without Acupuncture	Before and After Acupuncture Stimulation	Without Acupuncture	Before and After Acupuncture Stimulation
E	472.28	348.89 (< Without Acupuncture)	3.42	2.99 (< Without Acupuncture)
F	183.55	61.31 (< Without Acupuncture)	2.2	2.74 (> Without Acupuncture)
G	8.88	3.41 (< Without Acupuncture)	2.47	3.29 (> Without Acupuncture)
H	24.53	5.35 (< Without Acupuncture)	1.56	4.13 (> Without Acupuncture)
Information: Positif value shows percentage increasinga and vice versa.				

For example, Figure 16 shows that on volunteer F, acupuncture had a positive influence such as reduction the percentage value of the increase mean PSD and reduction the standard deviation value of mean PSD as well as increase MF value and its standard deviation.

The recovery of the biceps muscle which is subjected to a 5 kg static load marked downward trend in mean PSD value as well as in its standard deviation. It showed a tendency to decrease and stabilize muscle power output. In addition, there is an increasing trend of the MF and its standar deviation. This is most likely caused by changes in the activation of centralized individual motor neurons and properties that acupuncture stimulates the brain to activate the body's defense system around the point of insertion as well as become trigger of the body's physiological reaction in the surrounding penetration area in improving the body's sensitivity and repair damaged tissue.

From all the volunteers in the second group who have different rest periods seen that the acupuncture therapy is give positive effect on biceps muscle recovery for volunteer F, then followed by volunteer G and volunteer H. For volunteer E, generally, the acupunture theraphy has not shown a positive effect significantly. It indicates information that break time after give acupuncture stimulation is not always proportional to the biceps muscle recovery, because acupuncture has a certain response time for optimal influence.

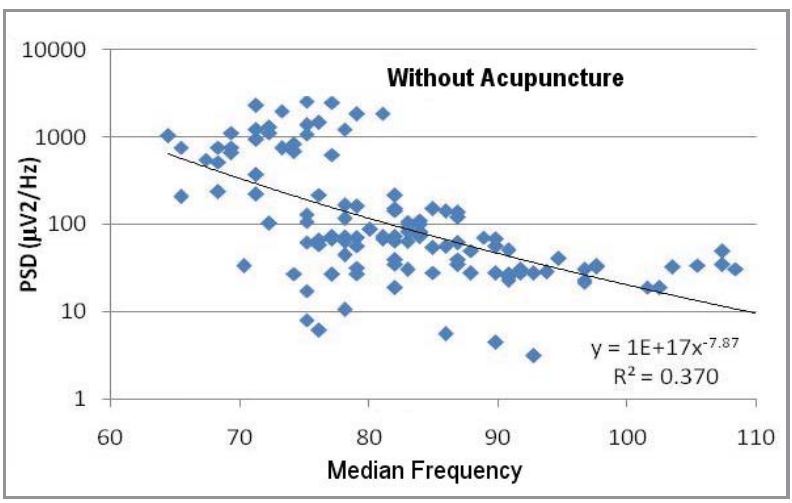


Figure 19. PSD and MF correlation for all volunteers without acupuncture stimulation

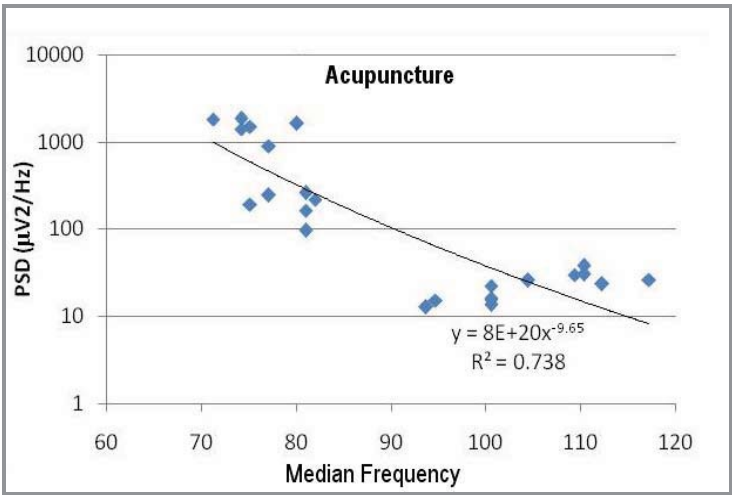


Figure 20. PSD and MF correlation for all volunteers with acupuncture stimulation

The Mean PSD and MF of the EMG signals of all volunteers, when they are raising a 5 kg load are correlated as shown in Figure 19. The hypothesis has proved that if the muscle is tired, the power of muscle to burden a load will be rise. This can be observed from the increasing of the PSD and decreasing of MF of the EMG. The curve presented by Fig 19-20, shows that volunteers that had stimulated by acupuncture give a better correlation coefficient between PSD and MF.

6. CONCLUSIONS

The result of the experience and testimonial of subjects who were treated by acupuncture therapy are showed that the positive response of increased the human stamina due to acupuncture. However, this is not supported by evidence from modern science perspectives. In this paper, the testimonial has been clarified by observing the EMG signals. In general, response of the muscle fatigue is the PSD value tends to increase while the MF value tends to decrease. The results show that the acupuncture on the biceps of volunteers can increase the MF and decrease the PSD of the human EMG of the biceps. The effect of exercise will be dominantly observed if the resting time between exercises is long enough. The power used by the muscle to exercise with the same load is decreased detected from PSD of the muscle, while the MF rises which also means that the subject's stamina on doing exercise are increased. Acupuncture stimulation for increasing stamina shown significant effect if a time interval between the revocations of needle acupuncture with physical exercises in between 15-30 minutes, with the optimal effect on the time interval 30 minutes.

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