

## Investigation of lower limb's muscles activity during performance of *salat* between two age groups

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### ABSTRACT

Muscles play an important role in the movement of limbs. They undergo contraction to straighten or to bend a joint for the limbs to move. There are many factors that can affect muscle activity. Age could be one of the possible factors affecting muscle activity. The purpose of this study was to investigate the lower limb's muscles activity during performance of *salat* between two age groups. The lower limb's muscles investigated were Gastrocnemius (GAS), Biceps Femoris (BF), Tibialis Anterior (TA) and Rectus Femoris (RF). The postures involve are standing, bowing, prostrating and sitting. The electromyography (EMG) signals of the muscles were measured using the technique of surface EMG (sEMG). The signals were acquired by using Delsys Bagnoli™ Desktop sEMG system and EMGworks®. Ten healthy subjects from two age groups were recruited in this study. The first group consists of five males aged between 20 to 29 while the second group consists of five males aged above 40. The raw EMG signals acquired were analyzed and the EMG envelopes were developed using MATLAB. The averaged RMS values of EMG for each muscle were also calculated. Analysis of variance (ANOVA) of the EMGs was obtained by using F-test. Further investigation of the variance was performed by using Tukey comparison. From the results, the most active muscle during the performance of *salat* is BF while the less active muscle is GAS for both age groups. The statistical result show that there is no difference in the muscle activity pattern between the two age groups but there is significant difference among the muscles investigated.

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## 1. INTRODUCTION

*Allah Subhana-hu wa Ta'ala* has ordained for all muslims to worship Him by performing *salat* (prayer) five times a day. In addition to spiritual act, *salat* comprises of prescribed physical postures that are obligatory to be performed. These postures are standing, bowing, prostrating and sitting. However, it may be permissible for those who are sick, disable and old to dispense with such performance of the prescribed postures, nonetheless, being devoted muslims, they have this innate desire to strive for the perfection of such. *Salat* has many benefits for body health, among others it can improve blood flow and muscle fitness of disabled geriatric persons [1], heart rate and blood pressure [2] as well as standing balance control [3].

*Salat* involves performing specific postures which in turn requires coordination between muscles activities and limb motions. Relationship between lower limbs motions and muscles activities were studied by [4], [5] while [6], [7] reported results of upper limbs motions with muscles activities. In addition, [8], [9] analyzed both upper and lower limbs muscles activities in association with limb motions. These studies

studied the muscles activity during postures and movements in salat and compare it with the specific physical exercises, for example, takbeeratul-ihram and stretching exercise [6], prostration and squat exercise [5] and bowing and unilateral plantar flexion exercise [4]. These postures and movements in salat if carried out regularly can give the same benefit as performing physical exercises. It shows that salat not only limited to an act of worship, but it also includes physical movement whereby it could be adopted as alternative to rehabilitation program and daily physical exercises.

Muscle activity can be measured when a skeletal muscle undergoes a contraction. There are three types of muscle contraction, namely concentric, eccentric and isometric. During a muscle contraction, an electrical current is generated which represents the neuromuscular activities that can be measured through electromyography (EMG) technique either using surface electrodes (non-invasive) or needles electrode (invasive). The muscle activity can be analyzed by using raw EMG signal. Sometimes, the raw EMG signal is further processed as rectified EMG or EMG envelope to enhance the signal to facilitate the analysis. The EMG signal obtained can be processed into a muscle envelope by using root mean square (RMS) calculation [4], [5] or rectification and filtering [10] to smoothen the noisy signal. Špulák et. al [11] have developed EMG envelope to detect muscle activity onset and cessation during walking and cycling while Zhou et. al [12] have developed EMG envelope to analyze tibialis anterior muscle during walking in different terrain. It shows that muscle envelope has been used for analysis of various muscle activity in various movements.

Age could be one of the possible factors affecting muscles activity. Schmitz et. al [13] investigated lower limb's muscle activation pattern during walking between healthy young and older adults. While Franz and Kram [14] investigated lower limb's muscle activity and coactivity during uphill and downhill walking for various walking speeds in young and old adults. Many studies have investigated whether age factor has any effect on muscle activity, but none has investigated this factor in performance of salat. Therefore, this study focuses on investigating lower limb's muscles activity namely Gastrocnemius (GAS), Biceps Femoris (BF), Tibialis Anterior (TA) and Rectus Femoris (RF) during performance of postures in salat between two age groups. The postures involve are standing, bowing, prostrating and sitting.

## 2. METHODOLOGY

The method for this study can be divided into three major parts namely data acquisition process, EMG envelop development and statistical analysis as shown in Figure 1. In the data acquisition process, the EMG signal of the desired muscles was acquired and recorded from healthy subjects during performance of salat. Next, the EMG signals obtained were high pass filtered, rectified and then filtered by using a 4th order Butterworth low pass filter by using MATLAB to develop EMG linear envelope. In the statistical analysis part, the analysis of variance using F-test was performed and Tukey method was used for further investigation of the variance of the muscles activity.

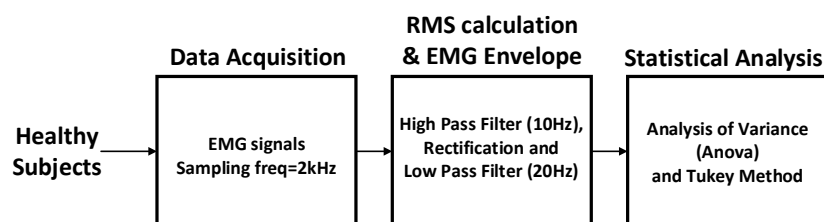


Figure 1. Methodology of the lower limb's muscles activity study

### 2.1. Data Acquisition Process

Ten healthy subjects were recruited in this study. They were five males aged between 20 to 29 for Group 1 and five males aged above 40 for Group 2. The subjects were briefed on the study protocol before the data collection was carried out. A surface EMG (sEMG) was used as a technique to measure and collect the EMG data from the subject's specified muscles using Delsys Bagnoli™ Desktop sEMG system powered by a 9V battery and EMGworks®. The laptop was disconnected from the main AC power supply during the data collection. The lower limb muscles involved were Gastrocnemius (GAS), Biceps Femoris (BF), Tibialis Anterior (TA) and Rectus Femoris (RF). Firstly, the skin surface was cleaned up by using an alcohol swab. The skin must be clean and in a dry condition before electrode placement. Next, the electrodes of the sEMG were placed on the skin surface of the desired muscles to collect the EMG signal. The placement of the sensor electrodes and the reference electrodes are as shown in Figure 2.

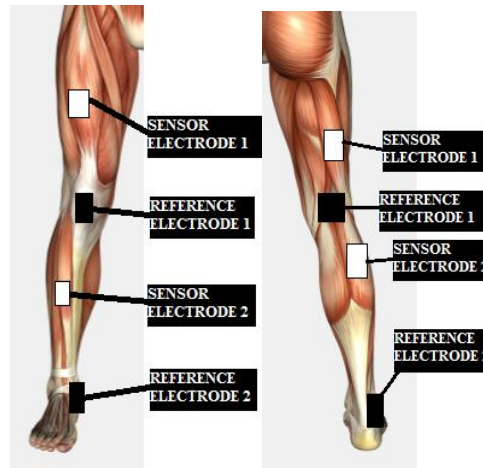


Figure 2. Placement of sensor and reference electrodes (left: anterior and right: posterior view)

After the electrodes have been placed at the desired muscles, the subjects were asked to perform postures in salat namely standing, bowing, sitting, and prostration as shown in Figure 3 to measure the EMG signal of the muscles. These postures were performed in sequence which complete for one rakaat in salat and each posture was performed for about five seconds. The sequence of the postures performed is as shown in Figure 4. The EMG signals during the transition between the postures were also measured. Frequency content of surface EMG measurement mostly lies from 400-500 Hz [15]. Therefore, the minimum sampling rate is 1 kHz (twice of the maximum frequency content). In this study, 2 kHz sampling rate was used to obtain more information from the signal. The subjects were asked to repeat the same procedure for three times to obtain the average EMG signal.



Figure 3. Postures in salat: 1) standing, 2) bowing, 3) prostration and 4) sitting

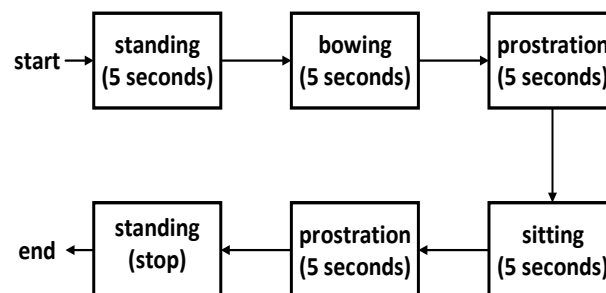


Figure 4. The sequence of postures performed for data collection

## 2.2. EMG Envelope Development

A few steps were taken to develop linear EMG envelope. Firstly, the raw EMG signals were filtered using a high pass filter with a cutoff frequency of 10 Hz to reduce the noise and motion artifact in the EMG signals as shown in Figure 5.

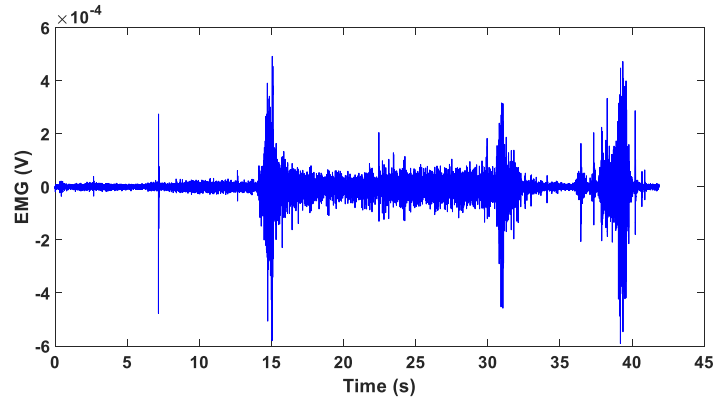


Figure 5. EMG signal of TA muscle after high pass filter

Next, the filtered EMG signals were used for the RMS calculation of the EMG and rectified by taking the absolute value of the signal. The rectified EMG signal is as shown in Figure 6.

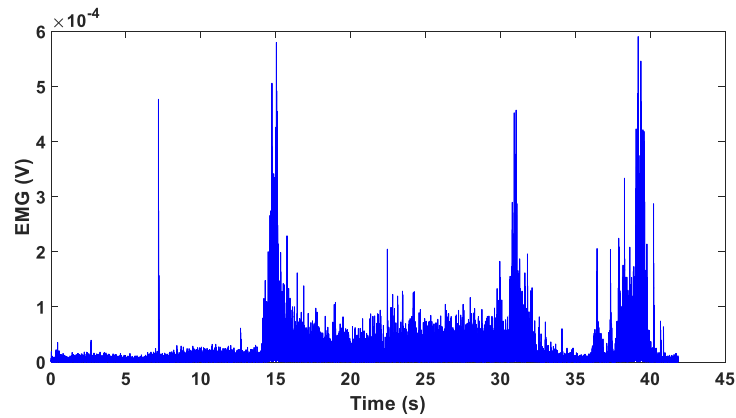


Figure 6. EMG signal of TA muscle after rectified

Finally, the signals were filtered by using a 4th order Butterworth low pass filter with a cutoff frequency of 20 Hz to obtain the muscle activity envelope as shown in Figure 7.

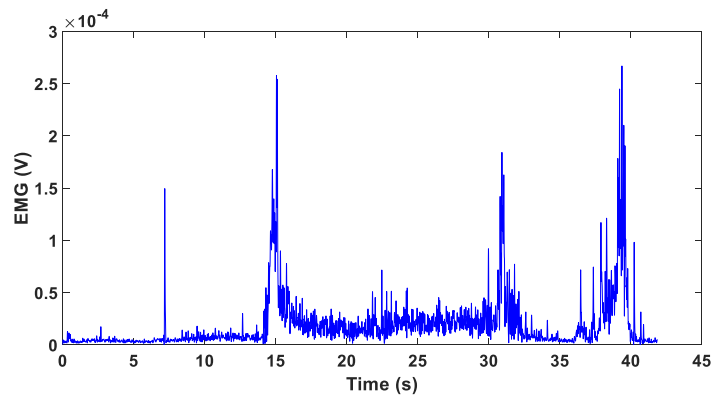


Figure 7. Linear EMG envelope of TA muscle for the postures and transitions in salat

### 2.3. Statistical Analysis of the Muscle Activity

Analysis of variance (ANOVA) is a useful method for judging the statistical significance of the factors in the investigation. Minitab software was used for the computational of the F-value. As discussed by [16], [17] the primary assumption in applying ANOVA is that the response is normally distributed. The variance of the response is divided into the variance that can be attributed to the investigated characteristic or factor and the variance that can be attributed to the randomness in the response. These two assumptions may be validated.

After the EMG envelopes of the signals were successfully developed, analysis of variance was employed to compare three or more means in the study. Hypothesis testing was used to evaluate the possible differences among the means. The null hypothesis ( $H_0$ ) for this test is that the means are all alike using the F distribution. The alternative hypothesis ( $H_a$ ) is that at least one of the means is different from the rest. With the F-test, all the means were compared simultaneously. Even though one is comparing three or more means in the use of the F-test, variances were used in the test instead of mean [16], [17]. The test statistic F was computed as follows:-

$$\text{Mean square between, MSB} = s_B^2 = \frac{\sum n_i(\bar{X}_i - \bar{X}_{GM})^2}{k-1} \quad (1)$$

GM denotes the grand mean of all values in the samples. X represents the measurements of muscle activity (voltage) according to the four different types or groups of muscles.  $\bar{X}_i$  is the mean of no.  $i$  group,  $S_i^2$  is the variance of no  $i$  group,  $k$  is the number of groups and  $n_i$  is the sample size of no.  $i$  group.

$$\text{Mean square within, MSW} = S_W^2 = \frac{\sum (n_i-1)s_i^2}{\sum (n_i-1)} \quad (2)$$

$$F_{stat} = \frac{s_B^2}{s_W^2} \quad (3)$$

With the F-test, two different estimates of the population variance are made. The first estimate is called the between group variance, and it involves finding the variance of the means. The second estimate, the within group variance is made by computing the variance using all the data and not affected by differences in the means.

The Root Mean Square, RMS value for each signal was calculated. The equation of RMS is as shown in 4.

$$RMS = \sqrt{\frac{\sum X_N^2}{N}} \quad (4)$$

The standard deviation, S and variance, S2 of each group according to the respective muscle were calculated. The equation of standard deviation is as shown in 5. Where  $\mu$  is the mean of the population and N total number of sample sizes of the group,  $N = n_1 + n_2 + \dots + n_k$ .

$$S = \sqrt{\frac{\sum (X_i - \mu)^2}{N-1}} \quad (5)$$

## 3. RESULTS AND DISCUSSION

The results are presented in two sections. The first section presents the EMG envelope of muscles activity during performance of salat for the two age groups. While the second section of the results presents the statistical analysis of the muscles activity during performance of salat between two age groups.

### 3.1. Results for EMG Envelope Development

Figure 8 and Figure 9 show the muscle activity envelope of all four muscles TA, BF, GAS and RF during the performance of salat for Subject 2 (Group 1) and Subject 3 (Group 2), respectively. From the figures, its show that all the four muscles are involved during the performance of salat (one rakaat), but the muscles activity varies between postures and the muscles activity in Group 1 is more prominent compared to Group 2.

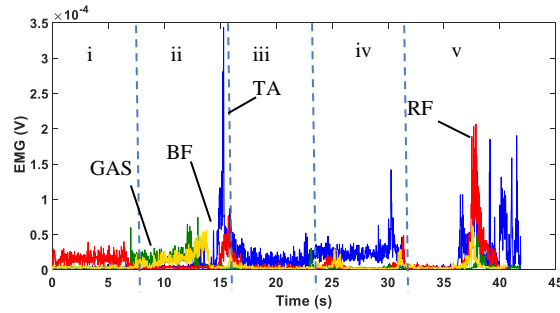


Figure 8. TA, BF, GAS, RF muscle activity envelope during performance of salat (Subject 2-Group 1). (i-standing and transition between standing to bowing, ii-bowing and transition between bowing to prostration, iii-prostration and transition between prostration and sitting, iv-sitting and transition between sitting and prostration and v-prostration and transition between prostration and standing)

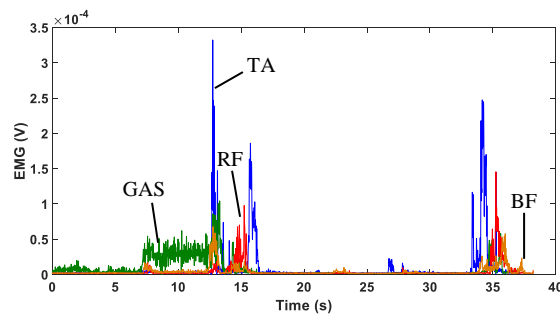


Figure 9. TA, BF, GAS, RF muscle activity envelope during performance of salat (Subject 3-Group 2)

RF is active during standing to assist the knee extension (the first six seconds in Figure 8). GAS becomes active during bowing to maintain stance in the bowing position (between eight to twelve seconds in Figure 8 and 9) while BF is active in order to prevent hyperextension of the knee during bowing (between eight to twelve seconds in Figure 8). TA is active throughout prostration and sitting to dorsiflex the ankle. RF and BF are seen to be slightly activated during sitting to flex the hip and the knee, respectively. All four muscles are active during the transition from bowing to prostration approximately at 15s and from prostration to standing at the last few seconds.

The RMS of each muscle and its equivalent  $\ln$  for all the subjects in Group 1 and 2 were calculated and the results are tabulated in Table 1 and 2, respectively. As can be seen in the tables, some of the RMS values (in bold) have a big difference within the subjects of the same group of the same muscle. Variation in resistance of individual subjects that depends on the skin and underlying tissue [18] may be contributing to this difference. Skin preparation is very important whereby the hair should be removed and conductive gel should be applied to the skin before electrode can be placed on the muscle for EMG measurement. Other than that, variation in joint angle may displace the right electrode position along the muscle fibers with respect to innervation and tendon zone and resulting in large bias estimation of EMG amplitude and spectral [19].

Table 1. Voltage RMS and The  $\ln$  Equivalent for Each Muscle for Subjects in Group 1

Muscle	Voltage	Subject				
		1	2	3	4	5
TA	$V_{rms}$ ( $\mu V$ )	31.92	119.79	29.65	21.96	16.33
	$\ln V_{rms}$	-10.35	-9.03	-10.43	-10.73	-11.02
GAS	$V_{rms}$ ( $\mu V$ )	5.63	17.46	17.61	7.50	5.20
	$\ln V_{rms}$	-12.09	-10.96	-10.95	-11.80	-12.17
RF	$V_{rms}$ ( $\mu V$ )	14.16	13.61	24.97	12.69	14.96
	$\ln V_{rms}$	-11.17	-11.20	-10.60	-11.27	-11.11
BF	$V_{rms}$ ( $\mu V$ )	216.30	14.15	13.45	17.91	15.17
	$\ln V_{rms}$	-9.03	-11.17	-11.22	-10.93	-11.10

Table 2. Voltage RMS Aand The Ln Equivalent for Each Muscle for Subjects in Group 2

Muscle	Voltage	Subject				
		1	2	3	4	5
TA	$V_{rms}$ ( $\mu V$ )	<b>61.37</b>	29.82	26.36	35.75	27.70
	$\ln V_{rms}$	-9.70	-10.42	-10.54	-10.24	-10.49
GAS	$V_{rms}$ ( $\mu V$ )	14.40	17.00	8.59	18.40	14.00
	$\ln V_{rms}$	-11.15	-10.98	-11.66	-10.90	-11.18
RF	$V_{rms}$ ( $\mu V$ )	15.70	13.30	<b>47.90</b>	13.90	17.10
	$\ln V_{rms}$	-11.06	-11.22	-9.95	-11.18	-10.98
BF	$V_{rms}$ ( $\mu V$ )	37.70	36.90	<b>87.60</b>	10.40	12.30
	$\ln V_{rms}$	-10.19	-10.21	-9.34	-11.47	-11.31

The averaged RMS values of each muscle for each group were calculated and plotted as shown in Figure 10. As depicted in Figure 10, the muscle that is the most active during the performance of salat for Group 1 is BF. Meanwhile, the less active muscle during the performance of salat for Group 1 is GAS. The same results obtained for Group 2, the most active muscle during the performance of salat is BF and the less active muscle during the performance of salat is GAS.

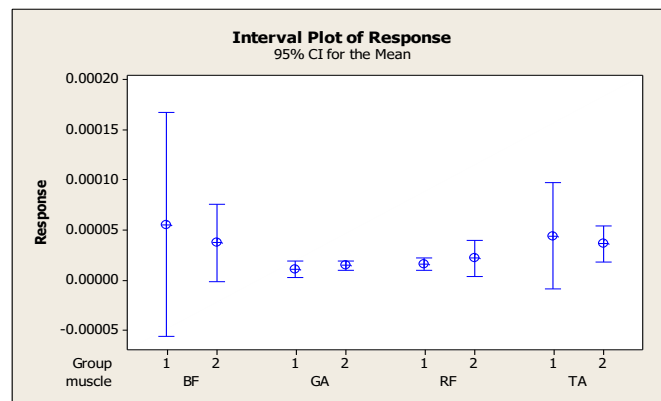


Figure 10. Mean RMS Value of Each Muscle for Group 1 and 2

There are many other factors that may be affecting the results of the study. One of the factors is that the transitions between postures of a person are different from another. It may affect the reading of EMG signals during data acquisition. The height and weight of a subject may also affect the EMG signals during data acquisition. Another factor that might be contributing to the difference in the reading of EMG signal is the physiques of the subject. Collecting data from a muscular subject might be easier than collecting data from a non-muscular subject. The muscles of the non-muscular subjects can be hard to be detected and the muscle might be enclosed by fat that causes unwanted noises and motion artifact. Therefore, a further study that considers all of the factors mentioned above needs to be conducted to obtain a set of data that is more accurate.

### 3.2. Results for Analysis of Variance

A natural logarithm transformation of the data was made to meet the assumptions of normality and constant variance. The standard analysis of variance (ANOVA) result is summarized in Table 3. Since the F-critical value  $f_{0.05,1,35} = 4.08$  is larger than the F-statistic, there is no evidence to reject  $H_0$  and its p-value ( $p = 0.289$ ), this indicates that there is no difference in the mean outputs between the age groups at the 5% level of significant. Examination of the ANOVA Table 3, the muscles revealed that there is very strong evidence that the different type of lower muscles is statistically significant. They significantly influence the response (voltage). Since p-value ( $p = 0.002$ ) is less than  $\alpha = 0.05$ , the null hypothesis is rejected. Thus, there is a difference effect among the mean muscles. The F-test statistic shown in Table 3 is 6.06 with,  $df_1 = 3$  and  $df_2 = 35$  degrees of freedom. Using the critical value approach with  $\alpha = 0.05$ , the null hypothesis is rejected when F-statistic exceeds the critical value of 3.84. We have sufficient evidence to suggest that at least one of the four means is different from one of the others. The F-tests showed that the muscle activity pattern between the different type of lower muscles is statistically significant. BF appears to have the largest effect as compared to the rest of the effects.

Although all the four muscles are involved during the performance of postures in salat, there was statistically significant difference among the muscles. This can be seen in Figure 8 and 9 whereby different muscles activity are needed to perform different postures in salat.

Table 3. ANOVA for *ln* Mean (Voltage)

Source of Variance	DF	Seq SS	Adj SS	Adj MS	F	P
Group	1	0.4257	0.4257	0.4257	1.16	0.289
Muscle	3	6.6613	6.6613	2.2204	6.06	0.002
Error	35	12.8307	12.8307	0.3666		
Total	39	19.9177				

DF=degree of freedom, Seq SS=Sequence Sum of Square, Adj SS=Adjusted Sum of Square, Adj MS=Adjusted Mean Square

The R2 and the R2 (adjusted) values are 35.5% and 28.5%, respectively. This means that the model could explain about 28.5% variability in the response about the mean voltage. Approximately about 64.5% of the response variability is not explained by the model. This may be indicating that factors not considered in the experiment are important. Potentially, if these variables or factors are added to the model, the model would describe more of the variability in the response. Some of the factors mentioned earlier might be contributing to this response. In addition, the actual time taken by the subject for each posture may be a potential parameter, psychological state of the subjects and which salat is concerned need to be considered.

Next, further investigation was conducted to determine which means are different from the others. Pairwise comparison was selected by Tukey Method and 95.0% Confidence. From the results GAS differ significantly from TA and BF but GAS and RF does not differ significantly from each other so is TA and BF. These results are shown in Table 4.

Table 4. Tukey Comparison

Muscle	N	<i>ln</i> Mean	Grouping
TA	10	-10.30	A
BF	10	-10.60	A
RF	10	-10.97	A B
GAS	10	-11.38	B

Where means that do not share a letter are significantly different. Therefore BF gives maximum response whereas GAS mean is less. The adequacy of the fitted model for response EMG voltage is assessed by plotting the residuals against the fitted values as shown in Figure 11. The figure shows that the residuals are met. Although the normality is not quite met, the samples have equal size and sample size is 40.

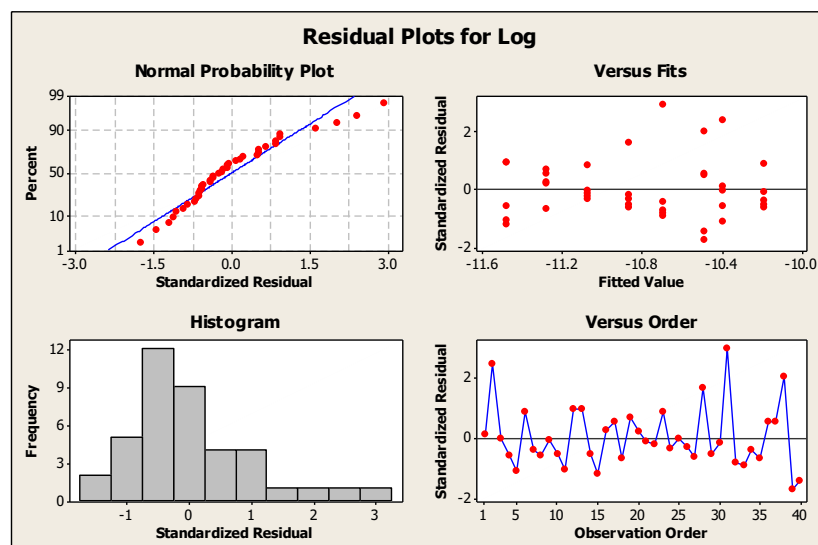


Figure 11. Residuals versus fitted of *ln* mean(voltage) and normality test



#### 4. CONCLUSION

All four lower limb's muscles TA, GAS, RF and BF are involved in the performance of salat. Different postures in salat requires different muscles activity involvement. Age does not affect the muscle activity pattern during performance of salat.

Further studies can be done to ensure the accuracy of the result by considering the other potential factors that might affect the reading of EMG signals and more subjects should be recruited and replication principle to be adopted in the experiment.

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