Analysis of Muscle Contraction on Pottery Manufacturing Process Using Electromyography (EMG)

Hartomo Soewardi¹ and Amalia Azka Rahmayani²

¹Senior lecturer of Industrial Engineering Department, Islamic University of Indonesia, Yogyakarta
²Graduated Student in Industrial Engineering Department, Islamic University of Indonesia, Yogyakarta

Abstract. One of the most common problems in pottery manufacturing process is musculoskeletal disorders on workers. This disorder was caused by uncomfortable posture where the workers sit on the floor with one leg was folded and another was twisted for long duration. Back, waist, buttock, and right knee frequently experience the disorders. The objective of this research is to investigate the muscle contraction at such body part of workers in manufacturing process of pottery. Electromyography is used to investigate the muscle contraction based on the median frequency signal. Focus measurements is conducted on four muscles types. They are lower interscapular muscle on the right and left side, dorsal lumbar muscle, and lateral hamstring muscle. Statistical analysis is conducted to test differences of muscle contraction between female and male. The result of this research showed that the muscle which reached the highest contraction is dorsal lumbar muscle with the average of median frequency is 51.84 Hz. Then followed by lower interscapular muscle on the left side with the average of median frequency is 31.30 Hz, lower interscapular muscle on the right side average of median frequency is 31.24 Hz, and lateral hamstring muscle average of median frequency is 21.77 Hz. Based on the statistic analysis result, there were no differences between male and female on left and right lower interscapular muscle and dorsal lumbar muscle but there were differences on lateral hamstring muscle with the significance level is 5%. Besides that, there were differences for all combination muscle types with the level of significance is 5%.

1. Introduction
Pottery manufacturing industry in Indonesia is one of strategic industries that have contributed to government income and also provide the big opportunity of employment [8]. In 2009, there were 441 pottery shop and 2,367 workers that always increase in every year [2]. This enhancement was also followed by an increasing in production and marketing [6]. In pottery manufacturing, the workers must work effectively in 7 hours for a day which they did it repetitively and used a static posture for long duration. This condition will cause musculoskeletal disorders that are impairments of body structures especially in muscles, joints, tendons, ligaments, nerves, bones or localized blood circulation system [3].

According to a preliminary study that was conducted to workers in pottery manufacturing industry showed that 28.3% of workers experienced a complaint at back, 53.5% at waist, 51.7% at buttock, and 48.3% at right knee. This fact describes a problem on musculoskeletal system. But, how deep of this
problem occur is still questionable. Thus, it is important to analyze this state in detail based on muscle contraction study. On the preview research, the researcher already used electromyography to analyze the muscle contraction but not for pottery workers. So, the objective of this research is to analyze muscle fatigue by using electromyography.

2. Research method
Experimental study was conducted in the ergonomics laboratory to record signal of muscle contraction.

2.1. Subjects
Fifteen university students, which consist of 8 males and 7 females who had an average age of 20-22 years old, were participated. This subject was selected for experiment based on two criteria that are healthy and no physical disability.

2.2. Apparatus
The tools that used in this research were electromyography (EMG ME3000P8) where its function was to record the signal of muscle contraction. A set of personal computer was used to display the raw signal recorded and Megawind 700046 software version 2.4 (Mega Electronics, Ltd.) was also used to transform the raw signal into median frequency signal. The signal was identified by electrodes as sensor that it was adhered on the skin.

2.3. Design of Experiment
Each participant in a sitting position on the floor as comfortable as possible. Participant was sit in front of the pottery maker with 30 cm in distance with position of two hands and right leg parallel to the pottery maker (Fig 1.(a)). And Fig 1.(b) show the placement of electrodes on skin of the body part.

![Fig 1. (a) Design of experiment and (b) placement of electrodes](image)

The placement of electrodes were based on Reference [1], where the location of lower interscapular on the left and right side (Fig 2.(a)) was at inferior medial border of the scapula on an oblique angle, approximately 5 cm down from the scapular spine. For the dorsal lumbar muscle (Fig 2.(b)), the two electrodes are placed at the T-10 level and L-3 level of the spine, approximately 2 cm lateral from spine over the muscle belly. And the lateral hamstring muscle (Fig 2.(c)) may be placed parallel to the muscle in the center of the back of the thigh, approximately half the distance from gluteal fold to the back of the knee.
Fig 2. (a) Lower interscapular muscle on the left and right side, (b) dorsal lumbar muscle, and (c) lateral hamstring muscle.

2.4. Task
The participants were instructed to make product from clay using pottery maker where the left hand take the clay and then directed to the pottery maker. While the right hand manufactures the clay into a pot and right leg twisted the pottery maker. At the same time, the muscle contraction was recorded.

2.5. Experimental procedure
The experiment was conducted in the ergonomics laboratory. Before doing the experiment, pilot study was conducted to determine locations of electrodes at the contracted muscles. Each participant was given 5 minutes to do exercise to make familiar with the task. The real experiment was conducted to identify the muscle contraction data by using electromyography for 15 minutes each participant. So, the total time of experiment for each participant is 20 minutes. After completing the experiment, the recorded signals as array signal were transferred into median frequency signal using Megawin software based on the formulation as follow:

\[
\int_{0}^{MF} P'(f) df = \int_{MF}^{\infty} P'(f) df = \frac{1}{2} \int_{0}^{\infty} P(f) df
\]

where \( P(f) \) is the power spectrum density. This transformation is done to change in the time domain into the frequency domain.

2.6. Data analysis
Statistical analysis was used to determine the differences for each muscle contraction between female and male by using Wilcoxon and independent sample t-test based on a value of median frequency. Normality test was used to determine which one the appropriate test at 5% of significance level.

3. Result and discussion
3.1. Analysis of electromyography signal
Table 1 showed the result of average of median frequency signal for lower interscapular muscle on the left side (LIL), lower interscapular muscle on the right side (LIR), dorsal lumbar muscle (DL), and lateral hamstring muscle (LH). One period of time was 20 seconds for experiment for each female and male respectively.

|                | Average of Median Frequency (Hz) |
|----------------|----------------------------------|
|                | LIL    | LIR    | DL     | LH     |
| Female         | 30.98  | 21.74  | 55.65  | 15.47  |
| Male           | 31.62  | 30.75  | 48.02  | 28.06  |
### Average of Median Frequency (Hz)

|       | LIL | LIR | DL  | LH  |
|-------|-----|-----|-----|-----|
| Female| 30.98 | 21.74 | 55.65 | 15.47 |
| Male  | 31.62 | 30.75 | 48.02 | 28.06 |
| Average| **31.30** | **31.24** | **51.84** | **21.77** |
| St. Dev| 3.72 | 2.20 | 2.98 | 3.30 |

Median frequency is half of the total spectrum energy of the muscle [5]. Thus, the median frequency signal can be used as a valid indicator to determine muscle fatigue [7]. The decrease in the median frequency indicates a fatigue in the muscle [4].

Fig 3 presents a graph of average of the median frequency signal for contraction of each muscle type during 49 periods for both males and females.

![Graphs of median frequency](image)

**Fig 3.** Median frequency graph of (a) lower interscapular muscle on the left, (b) lower interscapular muscle on the right, (c) dorsal lumbar muscle, and (d) lateral hamstring muscle.

The change in the graph describes contraction of the muscle. Decrease in the median frequency shows that the muscle starts to not be able to contracted. It means the fatigue will be occurred. Otherwise, the muscle will increase in contraction. This state will also cause the fatigue in long period.

Fig 3 (a) shows that contraction of the lower interscapular (left) muscle in the first four periods was decreased. It because no activity was done by the muscle, but the contraction is still took place for holding the position of left hand. At fifth period until 49th period, the contraction was increase. It means that the muscle works harder than before. So, the fatigue will be happen immediately.

While Fig 3 (b) shows that the contraction of lower interscapular (right) muscle in fourth period until the end of period was decrease. It means that the muscle start to be active for works. So, this decrease indicates there was a symptom of fatigue. And by the same token for dorsal lumbar muscle (Fig 3 (c)) and lateral hamstring muscle (Fig 3 (d)). However, the dorsal lumbar muscle has the highest median frequency of 51.84 Hz (see Table 1). Meanwhile the lower interscapular (left) muscle is 31.30 Hz, lower interscapular (right) muscle is 31.24 Hz, and lateral hamstring muscle is 21.77 Hz.

This condition can occurred because dorsal lumbar muscle has function for holding the sit and movement of waist for long period. And the lower interscapular (left) muscle has function for take the clay into the pottery maker. While the lower interscapular (right) muscle has function to form a pot, and lateral hamstring muscle to twisted the pottery maker.

#### 3.2. Statistical analysis

Table 2 show the result of normality test between male and female. While table 3 show the result of normality test both male and female. The significance which less than 0.05 means that the data was not normal and if the data more than 0.05 then means normal.
Table 2. Result of Normality Test between Male and Female

| Muscle (M)          | Sig | Sig | Muscle (F)          |
|---------------------|-----|-----|---------------------|
| Lower Interscapular (left) | 0.000 | 0.000 | Lower Interscapular (left) |
| Lower Interscapular (right)    | 0.062 | 0.200 | Lower Interscapular (right) |
| Dorsal Lumbar        | 0.200 | 0.200 | Dorsal Lumbar        |
| Lateral Hamstring    | 0.200 | 0.200 | Lateral Hamstring    |

* P (0.000) < 0.05  
P ≥ 0.05

Table 3. Result of Normality Test both Male and Female

| Muscle          | Sig |
|-----------------|-----|
| Lower Interscapular (left) | 0.000 |
| Lower Interscapular (right)  | 0.000 |
| Dorsal Lumbar    | 0.200 |
| Lateral Hamstring | 0.002 |

* P (0.000) < 0.05  
P ≥ 0.05

Table 4 shows the result of independent t-test for all the muscles between male and female. For lower interscapular (left) muscle, lower interscapular (right) muscle, and dorsal lumbar muscles show that there were no differences on muscle contraction between male and female. It means that three muscles work with the same load for both workers. While the lateral hamstring muscle shows that there was difference on muscle contraction between male and female. It means that there was different load when muscle works where the contraction for female was bigger than male.

Table 4. Result of Independent Sample T-test

| Muscle (left) | Sig |
|---------------|-----|
| Lower Interscapular | 0.566 |
| Lower Interscapular (right) | 0.531 |
| Dorsal Lumbar   | 0.027 |
| Lateral Hamstring | 0.000 |

* P (0.000) < 0.05  
P ≥ 0.05

Table 5 shows the result of Wilcoxon test for testing differences in muscle contraction on some combination of muscle types. From the result, all of the combination of muscles show that there were differences in muscle contraction. This can occurred because each muscle has different function for making pottery.

Table 4. Result of Wilcoxon Test

| Muscle              | Sig |
|---------------------|-----|
| Lower Interscapular (left) | 0.013 |
| Lower Interscapular (right)  | 0.000 |
| Lower Interscapular (left) Vs Lower Interscapular (left) | 0.000 |
| Lateral Hamstring    | 0.000 |
4. Conclusion
Based on the analysis, it can be concluded that:
1. The muscle which reached the highest contraction is dorsal lumbar muscle with the average of median frequency is 51.84 Hz. Then followed by lower interscapular muscle on the left side with the average of median frequency is 31.30 hz, lower interscapular muscle on the right side average of median frequency is 31.24 Hz, and lateral hamstring muscle average of median frequency is 21.77 Hz.
2. There were no differences in muscle contraction for lower interscapular on the right and left side and dorsal lumbar muscle between male and female, but there was a difference significant muscle contraction on lateral hamstring muscle at 5% of significance level.
3. There were differences of muscle contraction for among the combination muscle types at 5% significance level.

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Author biographies

**Hartomo Soewardi** is a senior lecturer of Industrial Engineering Department, Faculty of Industrial Technology, Islamic University of Indonesia, Yogyakarta-Indonesia. Currently he is Ph.D in Engineering Design and Manufacture. His teaching and research interest are industrial ergonomic design, product design, management and quality design. His email address is hartomo@uii.ac.id

**Amalia Azka Rahmayani** is a graduated student in Department of Industrial Engineering, Faculty of Industrial Technology, Islamic University of Indonesia. She was born in Jakarta, December 5th 1992. Her email address is azkamalia@gmail.com