ELECTROMYOGRAPHY ANALYSIS ASSOCIATED WITH PROLONGED STANDING IN METAL STAMPING INDUSTRY

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ABSTRACT: Many jobs in metal stamping industry require workers to perform in standing position. Standing is a practical working position when the workers are lifting heavy products, and pushing or pulling excessive loads because those jobs require a stable position and large degree of freedom. However, if the workers perform the jobs continuously in standing throughout the working hours, they may be experience muscle fatigue. The objective of this study such as to measure the myoelectric levels (μV) exerted by the left and right erector spinae, left and right tibialis anterior. The myoelectric levels in the muscles were measured using surface Electromyography (sEMG). Ten production workers from a metal stamping industry participated as subjects for sEMG measurement. Out of which, five workers from metal stamping process lines and another five from handwork section. The muscle activity of the subjects was measured for 5 hours and 45 minutes of continuous standing during beginning of workday, middle of workday, and end of workday from Monday to Wednesday. Results of comparison found that the two groups of workers show significant difference (p-value < 0.05) in myoelectric level in the right erector spinae, right gastrocnemius, and left tibialis anterior during the beginning of workday. However, the two groups of workers did not show any significant difference in myoelectric level during the middle of the workday and end of the workday. It can be concluded that muscle activity of the workers was determined by the work load and duration of standing. This study suggests that anti fatigue mat and micro breaks should be provided to the workers to reduce muscle fatigue.

KEYWORDS: *Prolonged Standing, Muscle Activity, sEMG, Stamping Process, Handwork Section.*

1.0 INTRODUCTION

Standing can be hypothesized as a flexible position because it is easy for moving and having large degree of freedom. Standing can be classified by two types; dynamic and stationary postures. Dynamic standing is a position in which a person intermittently walks while he or she is performing the activities. On the other hand, stationary standing is a position in which a worker does not walk, but at standstill [1]. In industrial workplaces, numerous processes jobs are recommended to be performed in standing position. For example, standing position is commonly practiced for manufacturing works such as welding and machining processes. In addition, standing is preferred when the workstation does not allow the workers to comfortably position their legs under the working table due to insufficient clearance. For instance, operating a lathe machine or metal stamping machine is impossible to do in sitting position because the design of the machines does not provide adequate space for the workers to position their legs under the machine. However, when the workers spent more than 50% of the total working hours during a full work shift in standing position, they are considered to be exposed to prolonged standing [2].

sEMG is one of the scientific instruments that has been applied to quantify muscle activity of workers while performing tasks in prolonged standing [3-9]. It quantifies the effort level of muscle in terms of myoelectric levels, expressed in micro volt (μV) corresponding to contraction of the muscles while handling the work load. For instance, if the myoelectric levels are high, it means that the muscles are exerting high effort while performing the particular tasks. There is very minimal study explored the effects of prolonged standing on muscle activity been conducted to metal stamping workers in Malaysia [10]. As a consequence, there is a limitation of information in designing a proper work-rest schedule and safe workstation design for workers in metal stamping industry.

The purpose of this study is to quantify the effort level exerted by the left and right erector spinae, left and right tibialis anterior, and left and right gastrocnemius muscles among two groups of workers (metal stamping process lines and handwork section) while performing tasks in prolonged standing. Additionally, the muscle effort level of these groups was compared to find out which group exerted more effort in the muscles while performing the tasks.

2.0 METHODS

A metal stamping company situated in Malaysia was selected to perform the data collection. In the production department of the company, all workers are males and national citizenship. They worked in two shifts based on a 12-hour shift schedule. In addition, there are two main work departments namely stamping process lines and handwork section. The stamping process lines produced metal stamped parts for vehicle assembly, while the handwork section performed restoration on the products from the metal stamping process lines. All processes jobs in both sections require workers to stand because the nature of jobs are repetitive, frequent movement, and large degree of freedom. In addition, the workers at the stamping process line are exposed to mechanical vibration due to high impact between plungers of stamping machine and die. The cyclic load transfers its vibration to the workers' body through the machine foundation and thus poses whole-body vibration (WBV).

Ten production workers were recruited as subjects in the study. Among them, five workers were selected from the metal stamping process lines, and another five were recruited from the handwork section. The selected subjects represented more than 80% of the total production workers of both departments. To fulfill the basic requirement of this study, only workers who performed processes jobs in prolonged standing and no injuries for the past 12 months were allowed to participate in the experimental work. Demographic of the selected workers from both metal stamping process lines and handwork section are described in Table 1.

All subjects were given a written consent using procedures approved by the Research Ethics Committee of Universiti Teknologi MARA. At the end of experiment, each subject was given a token of appreciation for their participation.

Table 1: Demographic of the workers

Criteria	Metal stamping mean (SD)	Handwork mean (SD)
Gender	male	
Age (year)	24.3 (2.1)	24.6 (4.8)
Body mass (kg)	56.6 (9.3)	60.5 (10.8)
Height (m)	1.67 (0.08)	1.68 (0.08)
Work experience	4.0 (2.4)	4.3 (3.7)

2.1 Surface Electromyography

A surface Electromyography (sEMG ME3000P4, MEGA Electronics, Finland) and MegaWin Software were used to record, store and analyze all the data regarding muscle activity of the workers. The measurements of muscle activity were conducted based on real time monitoring. All electrodes were connected to a data logger and the electromyography levels from the data logger are monitored through lap top screen using wireless networking. The sEMG electrodes were attached conscientiously to the subject's skin to measure the activity in the six muscles: left and right erector spinae, left and right tibialis anterior, and left and right gastrocnemius. In the measurement and analysis of standing jobs, the selected muscles are suggested by the established guidelines [11] and a recent review article [12]. To ensure the sEMG protocols were complied, especially on the attachment of electrodes on respective muscles, a physiotherapist was consulted before the evaluation is carried out. Setting of SEMG system during the measurement is based on Surface EMG for the Non-Invasive Assessment of Muscles (SENIAM) [13]. The settings are as follows:

- EMG electrodes: surface electrode Ag/AgCl, 20 mm diameter,
- Distance between electrodes: 25 mm,
- Skin preparation: cleaned,
- Common Mode Rejection Rate (CMMR): 110 dB,
- Filter: Band pass filter (85 Hz – 500Hz), and
- Sampling rate: 1000 Hz.

Before beginning the test, the personal particulars of the subject were recorded in MegaWin Software, and the subject was given sufficient time to get enough practice to familiarize with the sEMG instruments. The subject was also informed that he has to perform the task at his own pace and should immediately report any feeling of pain or discomfort so that the measurement can be terminated. After all the measurement settings are ready, the subject can now start to perform his task. Figure

1 shows the placement of the sEMG electrodes to measure fatigue in the selected muscles.

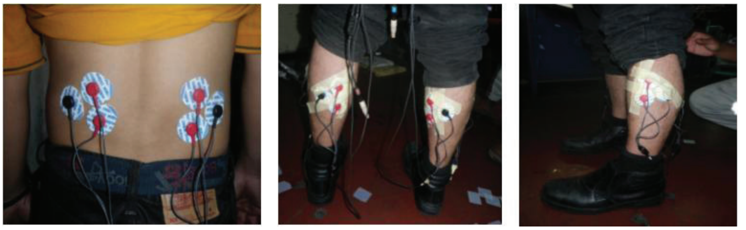

Figure 1: Surface electrodes (Ag/AgCl) are attached over the erector spinae muscles (lower back), gastrocnemius muscles (posterior legs) and tibialis anterior muscles (anterior legs)

In a workday, all muscles were concurrently measured for 5 hours and 45 minutes of continuous standing to quantify the effort level exerted by the muscles. The sEMG measurements were conducted for 1 hour and 15 minutes of standing at the beginning of the workday (9:00 a.m to 10:15 a.m), 2 hours of standing at the middle of the workday (10:30 a.m to 12:30 p.m), and 2 hours and 30 minutes of standing at the end of the workday (2:00 p.m to 4:30 p.m) for three consecutive workdays from Monday to Wednesday. Fifteen minutes of morning break and 90 minutes of lunch break were provided at the beginning of the workday and middle of the workday respectively.

The output parameter from the sEMG measurement is myoelectric levels that are expressed in micro volt (μV). Statistical analyses associated with descriptive and comparative analysis were used to interpret the data. In the statistical analysis, p-value < 0.005 is defined as significant difference.

3.0 RESULTS

Table 2 presents the minimum (min), mean, maximum (max), and standard deviation (SD) of myoelectric levels (μV) in each muscle for two groups of workers during beginning of workday. For workers in metal stamping process lines, the lowest myoelectric level was detected in the right gastrocnemius muscle (11.4 μV); meanwhile the highest myoelectric level was identified in the left gastrocnemius muscle (14.4 μV). In handwork section, the lowest myoelectric level was recorded in the right gastrocnemius muscle (12.8 μV); meanwhile the highest myoelectric level was quantified in the right erector spinae muscle (25.9 μV). The t-test (Paired Two Sample for Means) with $\alpha = 0.05$ was performed to find any significant difference in myoelectric levels in each muscle for two groups of workers. The two groups of workers show significant difference (p-value < 0.05) in myoelectric level in the right erector spinae, right gastrocnemius, and left tibialis anterior, as tabulated in Table 2.

Table 2: Myoelectric levels at beginning of workday
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	Metal stamping process lines			Handwork section			*P-value*
Muscles	min	mean	max	min	mean	max	
ES(L)	12	13	15	12	13.6	15	0.30
ES(R)	12	13.2	14	14	15.6	18	0.04*
GS (L)	13	14.4	16	14	15.2	16	0.24
GS (R)	11	11.4	12	12	12.8	14	0.005*
TA (L)	10	11.8	14	12	13	14	0.03*
TA (R)	13	14.2	15	14	15.6	17	0.13

* : Significant difference (p-value < 0.05)
ES (L): Left erector spinae
ES (R): Right erector spinae
GS (L): Left gastrocnemius
GS (R): Right gastrocnemius
TA(L): Left tibialis anterior
TA(R): Right tibialis anterior

Table 3 presents the minimum (min), mean, maximum (max), and standard deviation (SD) of myoelectric levels (μV) in each muscle for two groups of workers during middle of workday. For workers in metal stamping process lines, the lowest myoelectric level was detected in the left erector spinae muscle (14.4 μV); meanwhile the highest myoelectric level was identified in the right tibialis muscle (17.6 μV). In handwork section, the lowest myoelectric level was recorded in the left erector spinae muscle (14 μV); meanwhile the highest myoelectric level was quantified in the right tibialis anterior muscle (18 μV). The t-test (Paired Two Sample for Means) with $\alpha = 0.05$ was performed to find any significant difference in myoelectric levels in each muscle for two groups of workers. The two groups of workers did not show any significant difference in myoelectric level, as tabulated in Table 3.

Table 3: Myoelectric levels at middle of workday

	Metal stamping process lines			Handwork section			*P-value*
Muscles	min	mean	max	min	mean	max	
ES(L)	12	14.4	16	7	14	18	0.85
ES(R)	15	16	17	14	16.8	19	0.41
GS (L)	16	17.4	19	15	17.4	19	1.0
GS (R)	13	14.2	16	13	14.4	16	0.85
TA (L)	13	14.8	18	13	14.8	17	1.0
TA (R)	15	17.6	20	16	18	20	0.78

* : Significant difference (p-value < 0.05)

ES (L): Left erector spinae
GS (L): Left gastrocnemius
TA(L): Left tibialis anterior
ES (R): Right erector spinae
GS (R): Right gastrocnemius
TA(R): Right tibialis anterior

Table 4 presents the minimum (min), mean, maximum (max), and standard deviation (SD) of myoelectric levels (μV) in each muscle for two groups of workers during end of workday. For workers in metal stamping process lines, the lowest myoelectric level was detected in the left tibialis muscle (11.4 μV); meanwhile the highest myoelectric level was identified in the left gastrocnemius muscle (17.8 μV). In handwork section, the lowest myoelectric level was recorded in the right gastrocnemius muscle (16.4 μV); meanwhile the highest myoelectric level was quantified in the left tibialis anterior muscle (23.2 μV). The t-test (Paired Two Sample for Means) with $\alpha = 0.05$ was performed to find any significant difference in myoelectric levels in each muscle for two groups of workers. The two groups of workers did not show any significant difference in myoelectric level, as tabulated in Table 4.

Table 4: Myoelectric levels at end of workday

	Metal stamping process lines			Handwork section			*P-value*
Muscles	min	mean	max	min	mean	max	
ES(L)	12	15.2	18	15	18.5	21	0.15
ES(R)	11	16.2	19	14	17.8	22	0.37
GS (L)	14	17.8	20	15	20	23	0.32
GS (R)	11	14.8	17	12	16.4	19	0.40
TA (L)	10	14.4	17	23	23.2	48	0.03
TA (R)	14	17.6	21	15	20.4	24	0.36

* : Significant difference (p-value < 0.05)
ES (L): Left erector spinae
GS (L): Left gastrocnemius
TA(L): Left tibialis anterior
ES (R): Right erector spinae
GS (R): Right gastrocnemius
TA(R): Right tibialis anterior

4.0 DISCUSSION

This study has conducted an analysis of muscle activity of production workers in a metal stamping company. In the company, there were metal stamping process lines and handwork section. Both work departments required workers to perform jobs in standing for prolonged time periods. All workers worked on a 12-h shift schedule. Workers at the metal stamping process lines worked day shift only; meanwhile, workers at the handwork section worked both day and night shifts. It was observed that the workers spent about 80% of the working hours in standing (only sitting during breaks) throughout the 12-h working period. This is due to the activities at both work departments required the workers to move frequently with large degree of freedom. For instance, workers at the metal stamping process lines have to reach the workpieces from the pallet on the floor and feed the workpieces to the stamping machine, synchronize with the machine speed. Thus, the process would be practicable in standing as it requires frequent movement. On the hand, workers in handwork section were assigned to perform repair and restoration works on the products that produced by the metal stamping process. Hence grinding and knocking processes using manual method are the major activities at the handwork section. Similar to metal stamping process lines, all workers at the handwork section performed the jobs in standing position because they have to move in large degree of freedom, especially while performing grinding process on huge products.

This study observed that muscle fatigue occurred particularly in the lower back (erector spinae muscle), posterior leg (gastrocnemius muscle), and anterior leg (tibialis anterior muscle) due to above mentioned working conditions. Furthermore there were complaints of fatigue in those body parts from the workers of metal stamping process lines and handwork section [14]. Through sEMG measurement, this study identified that the average of myoelectric levels (μV) in the muscles of handwork section workers are higher than workers of metal stamping lines during beginning, middle and end of the workday. This study believed that different of myoelectric levels occurred when the postures of workers in the handwork section were deviated significantly from neutral position especially when they performed the grinding and knocking processes in bending, extension, forward and side flexion thus placed more stress in the back and lower extremities.

Another interesting finding in this study is the trend of myoelectric levels among the working sessions. Based on the results obtained, this study observed that the myoelectric levels of muscles during the beginning of the workday are slightly lesser than middle of the workday. Consequently, the myoelectric levels of muscles during the middle of the workday are lesser than end of the workday. This is due to duration of performing work in standing position. The job tenure and measurement of muscle activity during beginning of the workday took 1 hour and 15 minutes; 2 hours of standing during middle of the workday and 2.5 hours during end of the workday. This study pointed that duration of standing can influence the myoelectric levels. When a worker is standing in a long period of time, static contraction of muscles can occur particularly in the back and legs. Due to static contraction, performance of the muscles may decrease and this condition can lead to discomfort and muscle fatigue [15].

This study proposes ergonomics control measures to reduce the risk level of prolonged standing. One of the best solutions is alternating the standing with sitting. As opposed to standing, sitting is a much less strenuous posture because it requires fewer muscles to be contracted to stabilize the body. In addition, when the processes jobs are performed in sitting position, the loading on the upper limbs will be uniformly distributed through the seat pan [16], hence reduces the loading on the lower limbs. However, sitting in long periods of time is also not good for the health. This can be done using a sit-stand stool. It enables a worker to perform jobs in sitting as well as standing position. Moreover, the sit-stand stool is equipped with a foot rest to provide comfort to the worker's legs. Also, it can be rotated 360 degrees so that the worker can reach the materials without twisting their body and consequently enlarge the degree of freedom to do the jobs.

Besides, application of anti-fatigue mat on the standing area can absorb pressure in the workers' feet due to hard standing floor [17-18]. Alternatively, providing a soft shoe-insole can reduce fatigue in the feet due to body mass and workload while performing processes jobs in prolonged standing [19]. Furthermore, administrative controls such as providing micro breaks in the working hours can be applied to minimize muscle fatigue due to prolonged standing. It has been proven that providing breaks in the working hours can minimize risk of leg swelling due to prolonged standing [20-21]. The advantage offered by the micro breaks is that the time interval and the foods taken by the workers during the breaks can refresh their energy and reduce fatigue due to previous work activities [14].

5.0 CONCLUSION

This study has performed muscle activity measurement in the left and right erector spinae, left and right tibialis anterior, and left and right gastrocnemius of workers at metal stamping process lines and handwork section in a metal stamping company. All workers performed their tasks in standing position for prolonged time periods. The measurements of muscle activity were conducted at three working sessions: beginning of workday, middle of workday, and end of workday. During beginning of workday, the two groups of workers show a significant difference in myoelectric level in the right erector spinae, right gastrocnemius, and left tibialis anterior. On the other hand, the two groups of workers did not show any significant difference in myoelectric level during the middle of the workday and end of the workday. Therefore, this study concluded that muscle activity of the workers was determined by the work load and duration of standing. This study suggests that anti fatigue mat to be positioned on the floor surface. Alternatively, providing micro breaks throughout the working hours can reduce muscle fatigue due to prolonged standing.

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