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Experimental Tests of Effect of Vertical Lifting Height, Horizontal Distance, and Lifting Method on Muscle Activation Value Generated Using Electromyography

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Abstract

In industry, manual lifting activities certainly involve muscles and generate risks if done improperly. There are problems in the form of complaints from industrial workers on manual lifting activities that are carried out in a less ergonomic manner. This study aims to determine the effect of lifting factor variables on the resulting level of muscle activation. Three factors were used i.e. lifting method factor, horizontal distance factor and vertical distance factor. Each factor has two factor levels to produce eight combinations. 10 male subjects participated in this study. Previous research that has been done manually is by calculating the pulse resulting from a lifting activity according to a specified frequency. In this study, monitoring of muscle activity was carried out automatically using an instrument called Electromyography (EMG) at three points of the hand muscles, namely the biceps brachii muscle, triceps brachii muscle, and brachioradialis muscle. The results indicated the best combination based on the value of muscle activation on the biceps brachii muscle, triceps brachii muscle, and brachioradialis muscle which respectively include combination 2 (M1-H2-V1) with a significance value of 0.002, combination 6 (M2-H2 -V1) with a significance value of 0.000 and combination 2 (M1-H2-V1) with a significance value of 0.013. The resulting combination of the best lifting factors can be used as a reference and recommendations for the ideal lifting posture and conditions for workers in minimizing possible injuries.

1. INTRODUCTION

Lifting activities, especially manual lifting which is generally carried out as a daily activity that involves the physical, is defined as art, science, and work which includes handling, moving, packing, storage and supervision and controlling of a material and all its scope (Knudson, 2007). The activities of manual material handling have been identified as the cause of the highest risk of musculoskeletal disorders (MSDs) if these were not done properly. There are several risk factors for a person experiencing MSDs in terms of work include awkward body postures when doing work, lifting workloads, long duration of working time and repetitive movements and grip of workers, namely the tools used. Based on research by Bridger (2003), there were 87% of MSDs in workers, which in fact had a fairly high incidence. That study shows that there are complaints on the parts of the worker's body in manual material handling activities which are quite high. The types of complaints that exist are ranging from the common ones, namely aches, stiffness, swelling, numbness, cramps, heat to pain. The number of complaints experienced indicates the need for evaluation and analysis of aspects that affect the lifting activities, starting from the lifting method, distance, load weight, assistive devices, and others.

The lifting methods commonly used in industrial activities are the squat lift, straddle lift, knee high lift and stoop lift. The lifting activity on the squat lift is recommended for people with knee injuries, while the stoop lift relies on torso movement. Each variant of the method can be adapted to the characteristics of the workpiece to be lifted and the work to be performed. Therefore, we want to know the difference in loading on the muscles from the methods commonly used in manual material handling activities, namely the squat lift and the stoop lift. In addition to the lifting method, there are other factors that affect muscle performance in manual material handling activities, including the horizontal distance and vertical distance formed. The horizontal distance is the distance between the operator and the material to be lifted while the vertical distance is the distance the material is moved before starting the lift to the end of the lift. It is necessary to know the effect of the distance of the lifting distance on the effort required by the operator which affects the resulting muscle performance so that the optimal distance can be known in carrying out ergonomic lifting thereby reducing the risk of injury. This study was conducted to measure and compare the level of muscle activation produced through a combination of factors and factor levels. Through experiment, we try to find the best combination that minimizes muscle performance that can cause MSDs injuries so that muscle and joint tissue injuries that may be experienced due to repetitive activities can be prevented or minimized in such a way shape.

2. METHODOLOGY

2.1 Experimental Subjects

For this study, 10 males aged between 25 to 55 years (young to retirement age group) whose daily work involved physical activity were participated. For subject's selection, this study used predetermined criteria referring to Holland & Wainer's research (2013). The subjects were in physically and mentally health during experiment.

2.2 Factors and Factor Levels

According to previous research by Surata (2013) related to manual material handling work, it is known that the methods of lifting weights that are generally used are the squat lift and stoop lift methods. In a lifting activity, there is a distance between the load and the operator which is called the horizontal distance as well as the distance to be moved which is called the vertical distance. Tests on these variables aimed to determine their effect on the response variable studied, namely the level of muscle activation produced in manual material handling activities in different treatment combinations. This study used three factors namely lifting method (M), horizontal distance (H) and vertical distance (V) (see Figure 1 and Figure 2). For each factor, two level factors were used: squad lift (M1) and stoop lift (M2), 27 cm (H1) and 37 cm (H2) for horizontal distance and 45 cm (V1) and 75 cm (V2) for vertical distance.

2.3 Research Instruments

In this study, the Electromyography (EMG) was used to monitor muscle activity. EMG is a process of recording the electrical activity of the muscles so that it can be determined whether the muscles are contracting or not (Lehto & Landry, 2013). Electromyography (EMG) is part of Biomedical Engineering. The EMG signal has a frequency range at dominant energy between 20 – 500 Hz, with an amplitude between 0 – 10 mV. Research on EMG generally utilizes electrical signals contained in the human body as control input for a system that takes EMG signals resulting from muscle activity that provides information about the state of the muscles.

2.4 Procedures

Prior the study, the male subjects were selected through a set of criteria. The subjects were informed the aim of the study and how the experiment would be conducted. Subsequently, we prepared the instruments and workstations for lifting activities. Before experiment, the points of the body of subjects were cleaned to facilitate the detection of EMG signals. The electrodes were placed on the body parts being studied and then the experiment was conducted according to factor and level factor being determined. Subjects performed the random combination of the task (see Figure 3).

2.5 Data Analysis

Raw surface Electromyography data were filtered first with a Digital filter using the Infinte Impulse Response type and Band-pass filter = 85 – 500 Hz on the Data Lite application. The filtered data was then rectified. Rectification is the process of integrating EMG signals so that only positive signals are taken. In this study full-wave rectification was carried out, in which all EMG signals were absolute so that signals with negative values became positive. The rectified data were then normalized using RMS (Root Mean Square) with a time window of 250 mS. The filtered data in the Data Lite application were then tested statistically. For the data analysis, we referred to the previous study (Yanto, 2020; Yanto & Lu, 2015). The statistical tests used in this study were the normality test for each factor studied, the homogeneity test, the One Way ANOVA (Analysis of Variances) test, and the ANOM (Analysis of Means) test. Conclusions were drawing according to statistical test results. The results were obtained to determine the combination of factors and factor levels which provide the most significant influence and minimize injuries that may arise.

3. RESULTS

Based on the results of the raw signal graph shown in Figure 4, each combination has a different response. The more fluctuating the muscle response that is formed on the graph, the greater the resulting level of muscle activation. Conversely, the flatter the response that is formed on the graph, the smaller the level of muscle activation generated. The resulting level of muscle activation affects the work of the muscles, namely how much contraction occurs during lifting.

Table 1 shows the EMG raw signal data sheet for respondent 1 which shows the results of the three muscles when the lifting activity is carried out. The results of the normality test for all combined data on muscle activation values for the biceps brachii muscle, triceps brachii muscle, and brachioradialis muscle of the left and right hands have a value greater than the significance level of 0.05. With this it can be concluded that all data on muscle activation values for each combination for the biceps brachii muscle, triceps brachii muscle, and brachioradialis muscle of the left and right arms are normally distributed. After all data on muscle activation values are said to be normally distributed, the statistical test can be continued with the ANOVA test to determine whether there are significant differences between factors and treatment combinations.

The ANOVA test of all existing combinations showed significant results for certain factors. These significant factors were then further tested using the ANOM test. Based on the results of the ANOM test for the biceps brachii muscle, the best combination of factors and factor levels that produce the optimal level of muscle activation. The lower the level of muscle activation that is formed, the better the effect for the muscles. This is because the lower the level of muscle activation produced, the less the risk of injury that may arise from the lifting activities carried out. For the M1 lifting method (squat lift), the recommended vertical distance is V1 (45 cm) when combined with the horizontal distance H1 (27 cm) and V2 (75 cm) which can be combined with H1 (27 cm) and H2 (37 cm) because the two horizontal distances do not produce a significant difference for M1 (squat lift) and V2 (75 cm). Furthermore, for the M2 lifting method (stoop lift), the recommended vertical distance is V1 (45 cm) which can be combined with H1 (27 cm) and H2 (37 cm) because the two horizontal distances do not produce a significant difference for M2 (stop lift). lift) and V1 (45 cm).

Based on the results of the ANOM test for the triceps brachii muscle, it is known that the combination of factors and the best factor level that produces the optimal level of muscle activation. The lower the level of muscle activation that is formed, the better the effect for the muscles. This is because the lower the level of muscle activation produced, the less the risk of injury that may arise from the lifting activities carried out. For the M1 lifting method (squat lift), the recommended vertical distance is V1 (45 cm) when combined with the horizontal distance H2 (37 cm) and V2 (75 cm) when combined with the horizontal distance H1 (27 cm). Furthermore, for the M2 (stoop lift) lifting method, the recommended horizontal distance is H1 (27 cm) which can be combined with V1 (45 cm) and V2 (75 cm) because the two vertical distances do not produce a significant difference for M2 (stoop lift). lift) and H1 (27 cm). In addition, the combination of factors and factor levels recommended for the M2 lifting method (stop lift) is the horizontal distance H2 (37 cm) and the vertical distance V1 (45 cm). These results can be seen in Figure 4.37 which shows the effect of the interaction of factor combinations and factor levels that produce low muscle activation values which are marked on a graph that crosses the lower decision limit.

Based on the results of the ANOM test for the brachioradialis muscle, the best combination of factors and factor levels that produce the optimal level of muscle activation. The lower the level of muscle activation that is formed, the better the effect on the muscles. This is because the lower the level of muscle activation produced, the less the risk of injury arising from the lifting performed. For the M1 lifting method (squat lift), the recommended vertical distance is V1 (45 cm) when combined with the horizontal distance H2 (37 cm) and V2 (75 cm) when combined with the horizontal distance H1 (27 cm). Furthermore, for the M2 (stoop lift) lifting method, the recommended horizontal distance is H1 (27 cm) which can be combined with V1 (45 cm) and V2 (75 cm) because the two vertical distances do not produce a significant difference for M2 (stoop lift). lift) and H1 (27 cm). In addition, the combination of factors and factor levels recommended for the M2 lifting method (stop lift) is the horizontal distance H2 (37 cm) and the vertical distance V2 (75 cm).

Figure 1.
Illustration for lifting method: M1 and M2.

Figure 2.
Illustration for horizontal distance (H1and H2) and vertical distance (V1 and V2).

Figure 3.
Illustration of a subject performed the task in the experimen

Table 1.
Sample EMG Raw Signal Datasheet

Squat Lift (M1)							
45 cm (V1)	Lifting frequencies	37 cm (H2)					
		Biceps Brachii Muscle		*Triceps Brachii Muscle*		*Brachioradialis Muscle*	
		Root Mean Square - Mean (mV)		*Root Mean Square - Mean* (mV)		*Root Mean Square - Mean* (mV)	
		Kiri (M19558)	Kanan (M19580)	Kiri (M19579)	Kanan (M19567)	Kiri (M19562)	Kanan (M19572)
	1	0,068	0,109	0,023	0,025	0,073	0,089
	2	0,06	0,109	0,019	0,019	0,06	0,09
	3	0,061	0,091	0,027	0,022	0,06	0,087
	4	0,07	0,099	0,025	0,018	0,07	0,081
	5	0,068	0,1	0,02	0,018	0,064	0,084
	6	0,072	0,102	0,021	0,018	0,063	0,091

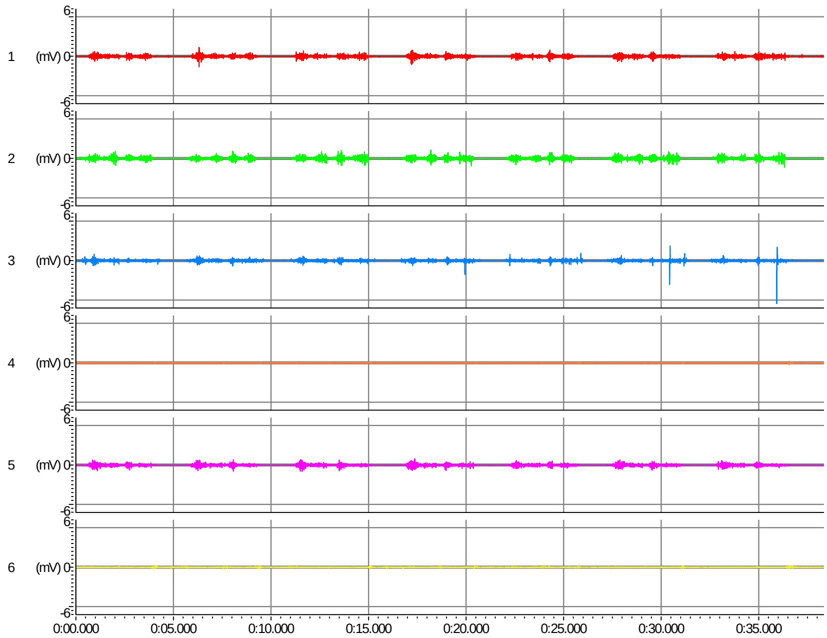

Figure 4.
EMG Raw Signal Results

4. DISCUSSION

The development of the learning process can be realized in various ways, one of which is the design of a study by modernizing the learning media used. One of the new learning instruments or media that is being developed at the Ergonomics and Work System Design Laboratory (PSK&E) of the Atma Jaya Industrial Engineering Study Program is Electromyography (EMG). Electromyography itself is a tool used to evaluate and record the electrical activity generated by skeletal muscles in the human body. Generally, electromyography is used to study muscle and nerve tissue (Turker & Sozen, 2013). At Atma Jaya Catholic University itself, research using Electromyography can be said to be a new thing because its use is still very rare. Previously, this tool was used in research conducted by Taruna (2022) with the research title "Design of Movement Analysis Practicum Modules with Electromyography for TIN 209 Subject - Work System Design & Ergonomics Practicum". The use of the Electromyography tool in the final assignment research is as a medium in designing a practicum module with an experiment that functions as a guide for practicum implementation. This research is a new thing, namely the use of the Electromyography tool in experimental tests which is influenced by the independent variable which gives output to the response variable, namely the level of muscle activation produced.

Based on research conducted on the three muscles, the best combination for each muscle can be identified. In the biceps brachii muscle, it was found that the best combination of lifting factors that produced the lowest muscle activation value was combination 2 (M1-H2-V1) with a significance value of 0.002. In the triceps brachii muscle, it was found that the best combination of lifting factors that produced the lowest muscle activation value was combination 6 (M2-H2-V1) with a significance value of 0.000. Then, for the brachioradialis muscle, it was found that the best combination of lifting factors that produced the lowest muscle activation value was combination 2 (M1-H2-V1) with a significance value of 0.013. The resulting combination of the best lifting factors can be used as a reference and recommendations for the ideal lifting posture and conditions for workers in minimizing possible injuries supports previous researchers (Nagacholie, 2010; Ashriyah *et al*., 2020; Taruna, 2022).

5. CONCLUSION

Based on the research conducted, there are differences in muscle responses produced in the three muscles studied, namely the biceps brachii muscle, triceps brachii muscle, and brachioradialis muscle. There is a significant influence of the lifting method factor on the resulting level of muscle activation because the significance value generated using the Minitab software is less than the significance level used of 0.05 for the three muscles studied. There is a significant influence of the horizontal distance factor on the resulting level of muscle activation because the significance value generated using the Minitab software is less than the significance level used of 0.05 for the three muscles studied. Then, there is a significant influence of the vertical distance factor on the resulting level of muscle activation because the significance value generated using the Minitab software is less than the significance level used of 0.05 for the biceps brachii muscle and triceps brachii muscle. Meanwhile, for the brachioradialis muscle, the resulting ANOVA test results showed an insignificant effect because the significance value generated using the Minitab software was worth more than the significance level used at 0.05.

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