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Development of the Strength Level on Arm for Indonesian People in Lifting Activity

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Abstract. Lifting is one of manual material handling activity that involves the whole part of a body. This activity is significant to contribute musculoskeletal disorder specifically on arms. It is because the arms are a major strength to lift objects. However, many people do not know the capability of their arm so that the task designed does not comply with the limitation of workers. Thus, it is required to determine a level of strength on arms. The objective of this study is to develop the strength level of arms for Indonesian people based on musculoskeletal contraction. An experimental study is conducted in the ergonomics laboratory. 24 males and 24 females was participated in this study which consists of three different ethnics. They are sixteen participants of Ethnic A, sixteen participants of Ethnic B and sixteen participants of Ethnic C. A case study of lifting consists of 4 positions of object. They are 38 cm in height, 50 cm in height, 85 – 115 cm in height for forming 90 degrees of the elbow and 100 cm in height. Back lift technique was implemented. An Electromyography is used to investigate muscle contraction on arms. Statistical analysis is done to test the hypothesis. The result of this study shows that the arm strength level for Indonesian workers has significant differences between males and females among difference Ethnic. For male, Ethnic A has 28.82% - 79.28% of MVC, Ethnic B has 17.74% - 58.67% of MVC, and Ethnic C has 22.13% - 68.67% of MVC. For female, Ethnic A has 28.28% - 84.63% of MVC, Ethnic B has 24.47% - 70.98% of MVC, and Ethnic C has 24.24% – 75.67% of MVC.
Keywords: Arm strength, Lifting activity, Musculoskeletal, MVC, Electromyography

1. Introduction

Based on data from the U.S. Bureau of Labor Statistics in 2015, approximately 31% (356,910 cases) of overexertion injury claims were caused by lifting and lowering of load. It affects injuries and illnesses by part of the body, in which 31.1% in upper extremities, 23.1% in lower extremities, 16.6% in back, 11% in multiple parts, 8.2% in head and 10% in all other parts of body. From 31.1% (358,890 cases) with injuries or illnesses to upper extremities, 143,900 cases involved the hands and 92,850 cases involved the shoulder.

Lifting is one of manual material handling activity that involves the whole part of a body. However, this activity is significant to contribute musculoskeletal disorder on arms when lifts the heavy load [1], [2]. Ref. [3] reported that heavy task had four times greaterprevalence of lumbar insufficiency, three times greater prevalence of recurrent attacks of lumbago and two times greater prevalence of pronounced sciatica than light jobs. The position of the load when lifting objects is also another factor affecting stress on arm and spine because of it configurated unnatural posture as well as a heavy moment on arm [4].The effective moment arm is related to an increase muscular contraction effort [5].

The muscle contraction occurs to improve limb stiffness and joint stability [6], [7]. To describes the muscle contraction around the arm area, it requires to quantify and analyze the muscle activity of the biceps brachii (BB) musclebased on Electromyograph (EMG) activities. It is believed that the quantity of static strength a muscle depends on the length muscle at the position of contraction[8]. Furthermore, [9], [10], [11] mentioned that a force of the static strengthwill be affected by gender, age, and posture of the subject.

EMG is a tool to identify the quantities of signal amplitude of muscle activity, especially those from deep muscles and has been used in several studies related to activity of hand [12], [13]. The EMG describes arm muscle movements within postural task [14].

The objective of this study is to investigate and develop the strength level of arms for Indonesian people based on musculoskeletal contraction by using Electromyography.

2. Method

2.1. Subject

Forty-eight university students (24 males and 24 females) was participated in this study. They are 8 males and 8 female participants respectively for Ethnic B, Ethnic A, and Ethnic C. Their age is in range between 19 to 23 years. And they had sport activities for 1 - 2 times per week and had no chronic medical history of musculoskeletal disorder on arms.

2.2. Apparatus

The main tool in this study is Electromyography (Lab Quest 2: Vernier Tech & Soft, Texas, USA) to investigate muscle contraction on arms. Raw signal from the EMG recorded by attaching electrodes on hand cleaned with an alcohol swab and normalized into a percentage data of Maximum Voluntary Contraction (MVC). A set of personal computers is used to present the raw EMG using Logger Pro Software. While, the experiments performed using an arm-leg and back dynamometer for as a trigger of muscle contraction.

2.3. Experimental Design

Experiment was conducted in Ergonomic Laboratory. Each participant stands in front of an arm-leg and back dynamometer. It requires 2 minutes for setting the equipment while 15 seconds for real experiment (5 seconds for relax, 5 seconds for reach maximum effort, 5 seconds calm down) [14]. There are 4 positions used in this study. They are 38 cm in height, 50 cm in height, 85 – 115 cm in height for forming 90 degrees of the elbow and 100 cm in height. Back lift technique was implemented. Figure below show the experiment design:

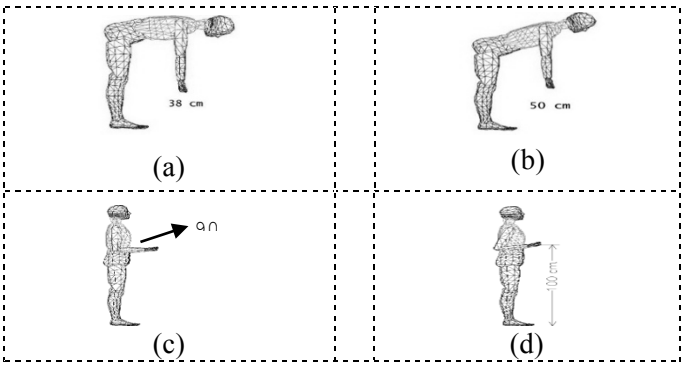


Figure 1. Experiment Position at (a) 38 cm in height (c) 50 cm in height (d) 85 – 115 cm in height for forming 90 degrees of the elbow (d) 100 cm in height

After doing the experiment, participant was instructed to pull an arm-back leg dynamometer again to normalization muscle contraction. It is needs to stabilization of the forearm in recording MVC data. Then, average data of MVC is used to analysis. Figure 2 show the effectiveness of MVC position for normalization muscle contraction.

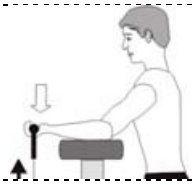


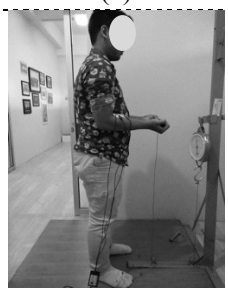
Figure 2. MVC Position of Forearm

2.4. Task

Participant was instructed to pull an arm-back leg dynamometer that it is assumed as handle of objects that has been adapted to four positions. All procedures in the process of pulling should be followed by the respondent, if not appropriate experiment procedures, respondents are asked to do the test again. Figure 3 show the task from this study.

(a)

(b)



(c)

(d)

Figure 3. Experiment Position at (a) 38 cm in height (c) 50 cm in height (d) 85 – 115 cm in height for forming 90 degrees of the elbow (d) 100 cm in height

2.5. Procedure of Experiment

Identify location of the biceps muscle group, *brachioradialis* muscle. Location of *brachioradialis* muscle shown at Figure 4 which the position of electrodes is in parallel of the muscle fibres and in the middle of the muscle mass. Both electrodes are positioned as far as 2 cm [15].

Figure 4. Electrodes Placement at *brachioradialis* muscle

2.6. Data Analysis

Data analysis was conducted based on MVC data. Statistical analysis using SPSS 24 version is to determine the significance of differences in each muscle contraction when during 4 positions of lifting activity. Non-parametric statistical analysis by using Kruskall-Wallis and Mann Whitney at 5% of significance level.

3. Result and Discussion

3.1. Analysis of EMG Signal

In Figure 5 shows RMSE signal on muscle contraction graph of *brachioradialis* muscle and amplitude score for muscle contraction (a) at 38 cm in height is 0.7228 mV for Ethnic A, 0.7134 mV for Ethnic B and 0.7241 for Ethnic C. In addition, for muscle contraction (b) at 50 cm in height is 0.7176 mV for Ethnic A, 0.7168 mV for Ethnic B and 0.7095 mV for Ethnic C. Then for a muscle contraction (c) at 90 degrees of the elbow or 85 - 115 cm in height is 0.8254 mV for Ethnic A, 0.7958 mV for Ethnic B and 0.7729 for Ethnic C. While amplitude scores for muscle contraction (d) at 100 cm in height is 0.7323 mV for Ethnic A, 0.7314 mV for Ethnic B and 0.320 mV for Ethnic C. Those indicate that there is the variation of RMSE score from each ethnic in each position. The highest score in each ethnic is at 90 degrees elbow or height 85-115 cm and Ethnic A has the highest score than the other two ethnics at that position. Then, the lowest score is at 50 cm in height and Ethnic A has the highest score. This condition happens because when pulling an arm-back leg dynamometer at 90 degrees of the elbow or 85 - 115 cm in height requires big contraction of muscle using back lift method. The graph (Figure 5) shows higher fluctuation when forearm becomes more flexes.

Figure 6 (a) shows the result of average percentage MVC (%MVC) for males between Ethnic A, Ethnic B and Ethnic C in each position. Percentage MVC scores for muscle contraction at 38 cm in height is 28.82% for males of Ethnic A, 17.74% for males of Ethnic B, and 22.13% for males of Ethnic C. In addition, percentage MVC score for muscle contraction at 50 cm in height is 34.06% for males of Ethnic A, 19.45% for males of Ethnic B, and 22.63% for males of Ethnic C. Then for muscle contraction at 90 degrees of the elbow or 85-115 cm in height is 79.28% for males of Ethnic A, 55.60% for males of Ethnic B, and 68.67% for males of Ethnic C. While muscle contraction at 100 cm in height is 78.71% for males of Ethnic A, 58.67% for males of Ethnic B, and 68.67% for males of Ethnic C. The highest score for males in each ethnic is at 90 degrees of the elbow or 85-115 cm in height. It is Ethnic A with 79.28% MVC. Then it is followed by 100 cm in height with 67.31% MVC. It means that on those positions may produce high muscle contraction and when the muscle reaches 50% MVC will cause musculoskeletal disorders and even muscle failure [15]. For 90 degrees of the elbow or 85-115 cm in height and 100 cm in height, lifting is done for 1 minute (according to [17]). So, it shows the average value of muscle contraction at 90° of elbow or 85 -115 cm in height and position at 100 cm in height must be considered because it has a value of more than 50% and unsafe for Indonesian's males of Ethnic A, B, and C in more than 1 minute in lifting activity.

Furthermore, Figure 6 (b) shows the result of average percentage MVC (% MVC) for females between Ethnic A, Ethnic B and Ethnic C in each position. Percentage of MVC scores for muscle contraction at 38 cm in height is 28.28 % for females of Ethnic A, 24.47 % for females of Ethnic B, and 24.24% for females of Ethnic C. In addition, percentage MVC scores for muscle contraction at 50 cm

in height is 31.97% for females of Ethnic A, 27% for females of Ethnic B, and 25.90% for females of Ethnic C. Then for muscle contraction at 90 degrees of the elbow or 85-115 cm in height is 80.02% for females of Ethnic A, 70.98% for females of Ethnic B, and 75.67% for females of Ethnic C. While muscle contraction at 100 cm in height is 84.63% for females of Ethnic A, 59.49% for females of Ethnic B, and 66.19% for females of Ethnic C. It shows the average value of muscle contraction at 90° of elbow or 85 -115 cm in height and position at 100 cm in height must be considered because it has a value of more than 50% and unsafe for Indonesian's females of Ethnic A, B, and C in more than 1 minute in lifting activity.

Figure 6 (c) shows the result of average percentage MVC (%MVC) for both males and females between Ethnic A, Ethnic B and Ethnic C in each position. Percentage MVC scores for muscle contraction at 38 cm in height is 28.55% for Ethnic A, 21.10% for Ethnic B, and 23.19% for Ethnic C. And percentage MVC scores for muscle contraction at 50 cm in height is 33.01% for Ethnic A, 23.23% for Ethnic B, and 24.26% for Ethnic C. Then for muscle contraction at 90 degrees of the elbow or 85-115 cm in height is 79.65% for Ethnic A, 63.29% for Ethnic B, and 72.17% for Ethnic C. While muscle contraction at 100 cm in height is 81.67% for Ethnic A, 59.08% for Ethnic B, and 62.42% for Ethnic C.

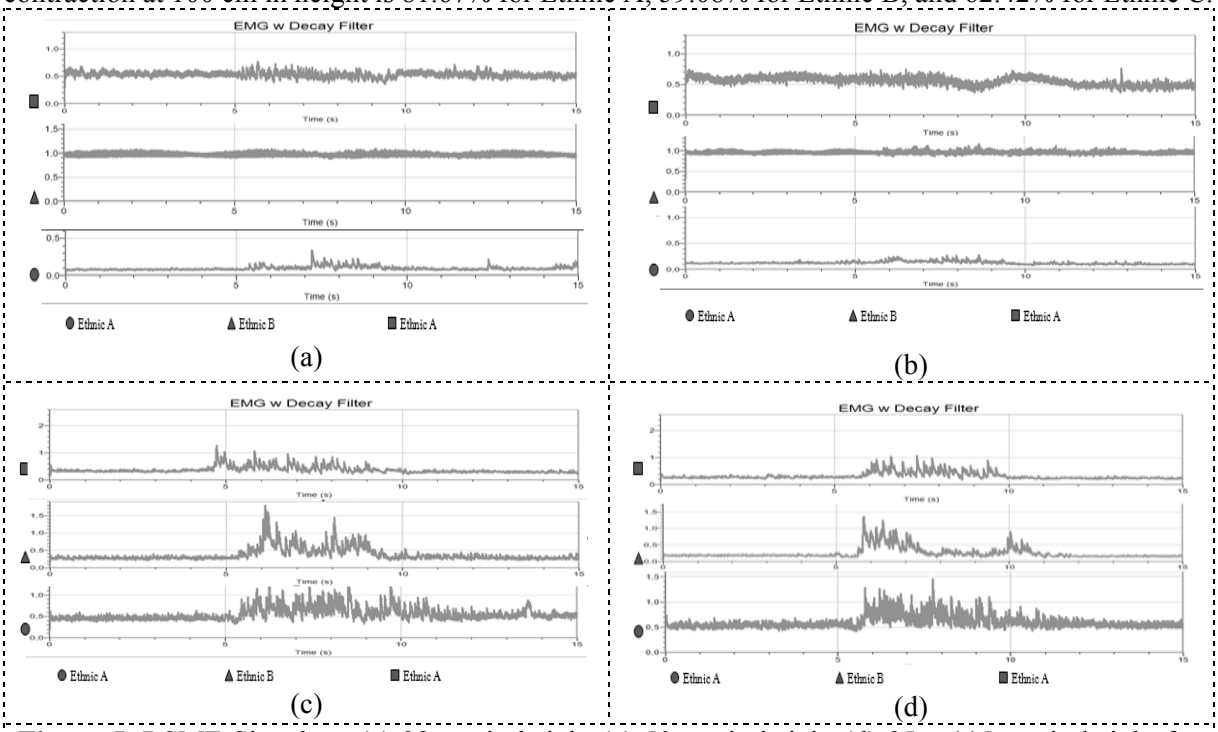
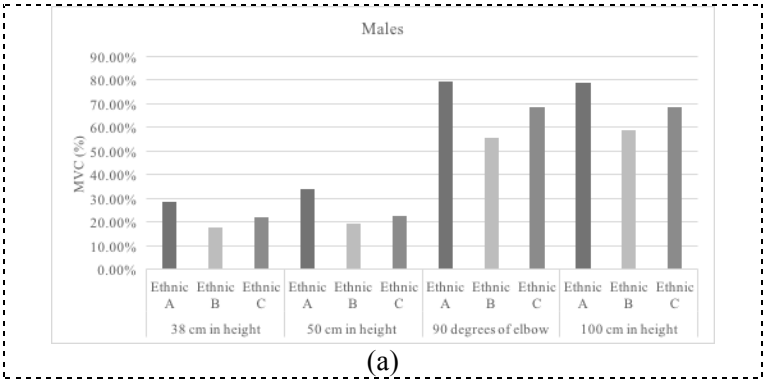


Figure 5. RSME Signals at (a) 38 cm in height (c) 50 cm in height (d) 85 – 115 cm in height for forming 90 degrees of the elbow (d) 100 cm in height



(a)

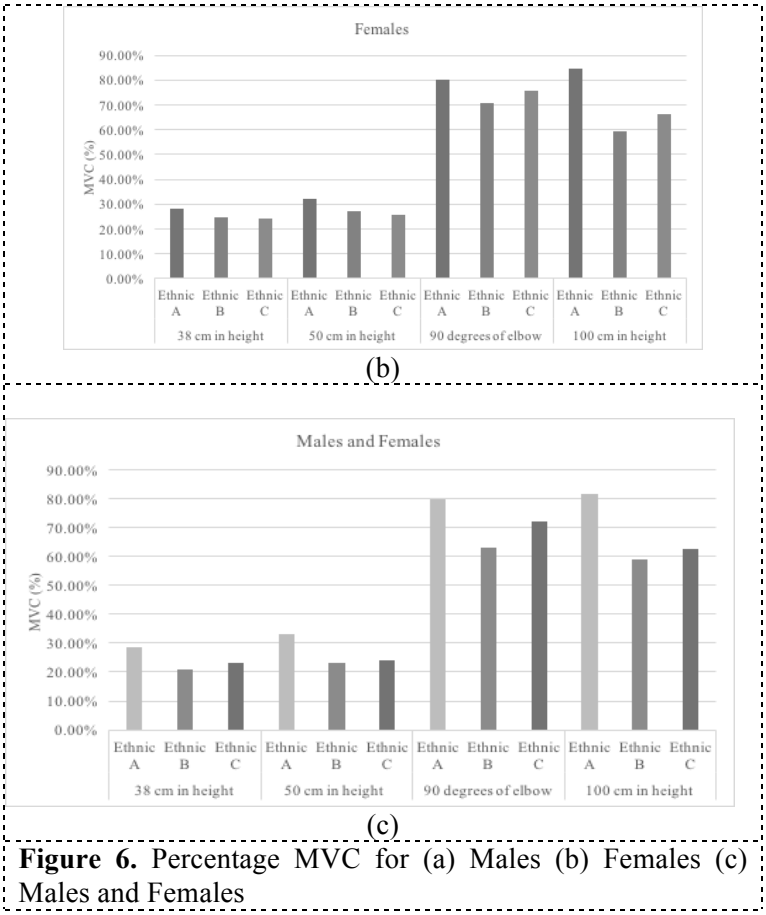


Figure 6. Percentage MVC for (a) Males (b) Females (c) Males and Females

3.2 Statistical Analysis

Non-parametric statistical analysis by using Kruskal-Wallis was performed to describe the difference significant of % MVC score between each position at 5% significant level. The results show that each position has a significant difference.

Table 1. The Result of Mann – Whitney Test for Each Position

	38 cm in height	50 cm in height	90 degrees of elbow	100 cm in height
38 cm in height		0.464	0.000	0.000
50 cm in height	0.464		0.000	0.000
90 degrees of elbow	0.000	0.000		0.190
100 cm in height	0.000	0.000	0.190	

Table 1 shows the result of Mann- Whitney test. It describes the significant difference of % MVC score among each position. There was the significant difference in percentage MVC score between 38 cm in height with 90° of the elbow or 85 -115 cm in height, 38 cm in height with 100 cm in height, 50 cm in height with 90° of elbow or 85 -115 cm in height, 50 cm in height with 100 cm in height. But, there doesn't have a significant difference between 38 cm in height with 50 cm in height and 90° of the elbow or 85 -115 cm in height with 100 cm in height.

Table 2. The Result of Kruskal-Wallis for Males

Positions	Sig.	Decission
38 cm in height	0.003	Difference
50 cm in height	0.011	Difference
90 degrees of elbow	0.041	Difference
100 cm in height	0.005	Difference

Table 2 shows result of Kruskal-Wallis test for each position between males of Ethnic A, Ethnic B and Ethnic C. It is present that there is the significant difference between males of Ethnic A, Ethnic B and Ethnic C in each position at 38 cm in height, 50 cm in height, 90° of elbow or 85 -115 cm in height and 100 cm in height. It caused by differences in height between males of Ethnic a, b and c based on anthropometric data. Males of Ethnic A has a height range of 168.58 cm in percentile 50, Ethnic B has a height range of 171.23 cm in percentile 50 and Ethnic C has a height range of 170.78 cm in percentile 50.

Table 3. The Result of Kruskal-Wallis for Females

Positions	Sig.	Decission
38 cm in height	0.047	Difference
50 cm in height	0.270	No Difference
90 degrees of elbow	0.386	No Difference
100 cm in height	0.011	Difference

Table 3 shows results of Kruskal-Wallis test for each position between females of Ethic A, Ethnic B and Ethnic C. It is present there is significant difference between females of Ethnic A, Ethnic B and Ethnic C in position at 38 cm in height and 50 cm in height. It also caused by differences in height between females of Ethnic a, b and c based on anthropometric data. Females of Ethnic A has a height range of 155.85 cm in percentile 50, Ethnic B has a height range of 156.18 cm in percentile 50 and Ethnic C has a height range of 156.2 cm in percentile 50. But, there is no significant between females of Ethnic A, Ethnic B and Ethnic C in position at 90° of elbow or 85 -115 cm in height and 100 cm in height.

4. Conclusion

Based on the analysis, it can be concluded as follows:

1. The strength level of arm based on Maximum Voluntary Capacity for Indonesian's males are difference among Ethnics considered. Ethnic A has 28.82% of MVC for 38 cm in height, 34.06% of MVC for 50 cm in height, 79.28% of MVC for 90 degrees of the elbow or 85-115 cm in height, 78.71% of MVC for 100 cm in height. Ethnic B has 17.74% of MVC for 38 cm in height, 19.45% of MVC for 50 cm in height, 55.60% of MVC for 90 degrees of the elbow or 85-115 cm in height, 58.67% of MVC for 100 cm in height. Ethnic C has 22.13% of MVC for 38 cm in height, 22.63% of MVC for 50 cm in height, 66.67% of MVC for 90 degrees of the elbow or 85-115 cm in height, 58.65% of MVC for 100 cm in height.
2. The strength level of arm based on Maximum Voluntary Capacity for Indonesian's females are difference among Ethnics considered. Ethnic A has 28.28% of MVC for 38 cm in height, 31.97% of MVC for 50 cm in height, 80.02% of MVC for 90 degrees of the elbow or 85-115 cm in height, 84.63% of MVC for 100 cm in height. Ethnic B has 24.47% of MVC for 38 cm in height, 27% of MVC for 50 cm in height, 70.98% of MVC for 90 degrees of the elbow or 85-115 cm in height, 59.49% of MVC for 100 cm in height. Ethnic C has 24.24% of MVC for 38 cm in height, 25.90% of MVC for 50 cm in height, 75.67% of MVC for 90 degrees of the elbow or 85-115 cm in height, 66.19% of MVC for 100 cm in height.

3. There are significant differences in the muscle contraction of Indonesian's males between Ethnic A, Ethnic B and Ethnic C for 38 cm in height, 50 cm in height, 90 degrees of the elbow or 85-115 cm in height, 100 cm in height. And significant differences occur in the muscle contraction of Indonesian's females between Ethnic A, Ethnic B and Ethnic C for 38 cm in height and 100 cm in height.

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