ORIGINAL ARTICLE

REDUCTION OF MAXIMUM EFFORT LEVEL OF LUMBAR MUSCLE AMONG WORKERS IN AEROSPACE INDUSTRY

Seri Rahayu KAMAT[1], Norhidayah HASHIM[1], Isa HALIM[1], Mohd Shahrizan OTHMAN[1] Mohammad Firdaus ANI[1]

[1]Department of Manufacturing Engineering, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia.

ABSTRACT

In the new era of world industrialization, ergonomics plays an important role to improve occupational safety and health, and productivity in most industries including an aerospace industry. However, the manufacturing industry in Malaysia does not put any priority on ergonomics awareness, for an example, by not selecting a suitable height of workstation with operators' anthropometry. Ergonomics so far has litle impact in Malaysia as majority of the Malaysian managers had believed that the ergonomics is not considered to be associated with performance. In a recent study on ergonomics awareness in Malaysian manufacturing industries by Mustafa et al., (2009), the researchers discovered that the main factors for the lack of ergonomics awareness were the lack of information/education/training and no pressure from the top management to initiate the ergonomics programmes. As a consequence, operators are exposed to various ergonomic risk factors and prone to have ergonomic injuries. The objective of this study was to reduce the maximum effort level of lumbar muscles of operators by changing the height of workstation using suitable anthropometry among operators. This study has conducted two analyses; analysis for quantify maximum effort level of lumbar muscle, and analysis for identify comfort level of working posture The surface Electromyography (sEMG) and Rapid Upper Limb Assessment (RULA) method from Computer-Aided Three-Dimensional Interactive Application (CATIA) software are used to evaluate maximum effort level of lumbar muscle, and comfort level of working posture respectively. Results for maximum effort level of lumbar muscle and comfort level of working posture found that by changing the anthropometry with suitable height of workstation has diminished the physiological stress such as work load in lumbar fascia muscle as well as extreme working posture. The study concluded that anthropometry of operators associated with the height of workstation was influenced the maximum effort level of lumbar muscle and comfort level of working posture when operators performing their jobs. The appropriate selection of workstation's height can contribute significantly to improve physiological performance of the operators.

***Keywords**: Maximum Effort Level of Lumbar Muscle, Anthropometry, Height of Workstation, RULA Method*

INTRODUCTION

In industrial workplaces especially in aerospace industry, choosing an appropriate workstation is really important because it can contribute to feasible occupational safety and health, job satisfaction, and work efficiency (Burgess-Limerick et al., 2009). Physiological factors must be critically studied when selecting a workstation appropriate with operators' anthropometry (Meksawi et al., 2012). In designing workstation, working height is very imperative. The height of workstation should vary based on the operator's height, and the type of work. However, the working height can vary several centimetres, up or down, without any significant effect on performance (Konz & Johnson, 2000). A proper working height will allow a comfortable working posture. In contrast, inadequate posture from an improper designed of workstation can cause ergonomic injuries such as muscle strain, low back pain, and consequently decreased performance and productivity (Vieira & Kumar, 2007).

In general, direct technical measurement method is applied to acquire information on physiological response of operators' muscle. The surface Electromyography (sEMG) is one of the scientific instruments that have been applied to quantify maximum effort level of muscles among operators while they are performing jobs (Öztürk & Esin, 2011; Larivière et al., 2008). Besides that, Rapid Upper Limbs Assessment (RULA) is specifically intended to measure comfort level of working posture corresponding to the jobs and workstations (Hashim et al., 2014; Dockrell et al., 2012). Similar to Rapid Entire Body Assessment (REBA), RULA is useful ergonomic analysis tool when investigating postural stress during performance of jobs (Dockrell et al., 2012).

Realising the needs of ergonomic workstation design, this study was conducted to diminish maximum effort level of lumbar muscle while operators are performing jobs by changing the height of workstation using suitable anthropometry among operators. Additionally, the comfort level of working posture also measured, and was compared to find out which anthropometry are suitable associated with height of workstation. In this study, the anthropometry criterion is only focusing on the height of operators.

METHODS

An aerospace company situated in Malaysia was selected to perform the data collection. The process involved was lay-up process. In the production department of the company, all operators are males and national citizenship as this study focused on Malaysian anthropometry and population. They worked in two shifts based on 12-hour working schedule. A main process line in this company is lay-up process (Kamat et al., 2013).

Six lay-up operators were recruited as subjects in this study. They are selected from lay-up process lines based on three groups of anthropometry which is shorter (height below 170.0cm), medium (height between 170.0cm to 179.9cm), and taller (height above 179.9cm). Based on the anthropometry separation, each group was consist by two operators. Besides that, there are three different height of workstation to be consider which is 50cm, 47cm, and 45cm. Moreover, to make this study reliable, operators with no injuries for the past twelve months were allowed to participate in the experimental work. Demographic of the selected operators are described in Table 1.

Table 1 Demographic information (n=108)

Criteria	Mean (SD)
Age	25.7 (5.0)
Mass (kg)	64.5 (10.9)
Height (cm)	174.2 (7.3)
Experience (year)	4.7 (2.7)

A surface Electromyography (sEMG) TeleMyo 2400 G2 PC Interface (Noraxon, U.S.A.) and Noraxon Software were used to record, store and quantify maximum effort level of lumbar muscle corresponding to contraction of the muscle while operators are performing their jobs in awkward working posture (Kamat et al., 2013). The sEMG quantify the maximum effort level of lumbar muscle in terms of myoelectric level, expressed in micro volt (μV). All sEMG electrodes are attached conscientiously to operator's skin to detect the electromyography signals in a data logger. Two muscles were selected for the evaluation which is left and right thoracolumbar fascia muscle. The selected muscles are chosen based on the statistical data analysis from questionnaire survey that has been answered by 22 workers before the experimental work was started. The operators experienced an intense pain in the lower limb of body about 97.22%. The selected muscles are also suggested by the established guidelines (U.S Department of Health and Humanities Services, 1992) and a recent review article (Graham et al., 2009; Reid et al., 2010).

After all the measurement settings are attached to the operator, the operator can now start to perform his job. The operator was also informed that he has to perform the job at his own pace and should immediately report any feeling of pain or discomfort so that the measurement can be terminated. The location of selected muscles is as shown in Figure 1.

Figure 1 Location of selected muscles: (i) left lumbar muscle, (ii) right lumbar muscle

After first session of sEMG experimental work is done on April 2013, RULA method has been used to measure comfort level of working posture due to three different group of anthropometry associated with three different height of workstation (Larivière et al., 2008). The analysis can be done either using RULA Worksheet (Hashim et al., 2014) or using computer programming to generate the results. Analysis using manual method (worksheet) may be time consuming and may lead to errors especially when large volumes of data have to be assessed. To overcome the shortcomings, a computer interface of design and ergonomics simulation from Computer-Aided Three-Dimensional Interactive Application (CATIA) software was used to design, analyse, and save all data and information regarding working posture analysis (Dockrell et al., 2012). There were 36 analyses evaluated from RULA method for this study. The comfort level of working posture from RULA method is as shown on a score of 1 to 6 and above, as tabulated in Table 2 (Meksawi et al., 2012). When all the analyses from RULA method are accomplished, a suggestion regarding suitable anthropometry of operators associated with height of workstation has been recommended to the organisation. After four months operators worked by using the recommended height of workstation, second session of sEMG experimental work is started on March 2014. Same output parameter was measured from sEMG measurement which is maximum effort level of lumbar muscle in terms of myoelectric level that is expressed in micro volt (μV). Graphical analyses associated with descriptive and comparative analysis were used to interpret the data.

Table 2 Score for comfort level of working posture from RULA method

Score	Comfort Level of Working Posture
1-2	Very comfort, no action required
3-4	Medium comfort, change may be needed
5-6	Low comfort, further investigation and change soon
6+	Negligible comfort, implement change now

RESULTS AND DISCUSSION

This study has conducted two analyses which are; analysis for quantify maximum effort level of lumbar muscle, and analysis for identify comfort level of working posture. There are 36 analyses evaluated from RULA method due to comfort level of working posture. Table 3 shows the results for comfort level of working posture due to left (L) and right (R) body region using RULA method. The results are separated based on three groups of anthropometry, three different heights of workstation, and four processes involved in manufacturing process line.

Table 3 Results for comfort level of working posture using RULA method

	Comfort Level of Working Posture																	
	Small Anthropometry						Medium Anthropometry						Tall Anthropometry					
	50cm		47cm		45cm		50cm		47cm		45cm		50cm		47cm		45cm	
Process	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
Lay-up ply 1-2	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7
Lay-up ply 3-6	7	6	6	5	5	4	6	5	5	4	7	6	5	4	6	5	7	6
Lay-up ply 7-11	6	6	5	5	4	4	5	5	4	4	6	6	4	4	5	5	6	6
Lay-up ply 12	6	6	5	5	4	4	5	5	4	4	6	6	4	4	5	5	6	6

Based on Table 3, all operators experienced discomfort and pain for the process of lay-up ply number one to ply number two. The score of comfort level for this process is 6 and 7, which the working posture must be changed immediately. This process is categorised in tremendous working posture because hand arm is worked above shoulder (Konz & Johnson, 2000). In contrast, the score of comfort level for other lay-up processes are from 4 to 7. Based on Table 2, the range of this score is classified in three different classes of comfort level which is; level 4 is medium comfort, level 5 and 6 is low comfort, and level 7 (above 6) is negligible comfort. As presented in Table 3, the results obtained shows small anthropometry suitable to work with 45cm height of workstation, medium anthropometry suitable to with 47cm height of workstation, and tall anthropometry suitable to work with 50cm height of workstation. Furthermore, all groups of anthropometry can work with all different height of workstation. However, further investigation and changes is needed on the height of workstation in order to reduce the discomfort and pain. The changes can be made regarding the design of workstation. But, the expenditure of changing is high. Moreover, the discomfort and pain usually experienced when the operators performing their jobs continuously with improper selection of workstation (Hashim et al., 2014). Thus, the height of workstation associated with operators' anthropometry is influenced the comfort level of working posture.

In contrast, the maximum effort level for lumbar muscle is measured using sEMG measurement. The sEMG has been measured in terms of myoelectric level that is expressed in microvolt (μV) before and after the recommendation regarding suitable height of workstation is used. The operators have worked using the recommended height of workstation within four months before sEMG measurement is re-setup. Figure 2(i) to Figure 2(iii) illustrates results for maximum effort level of lumbar muscle for three groups of anthropometry which is small, medium and tall.

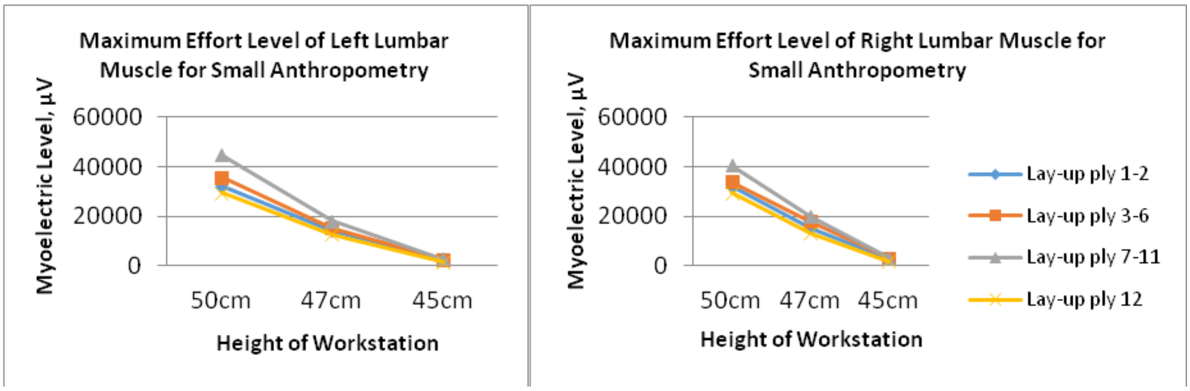

Figure 2(i) Results for maximum effort level of lumbar muscle for small anthropometry

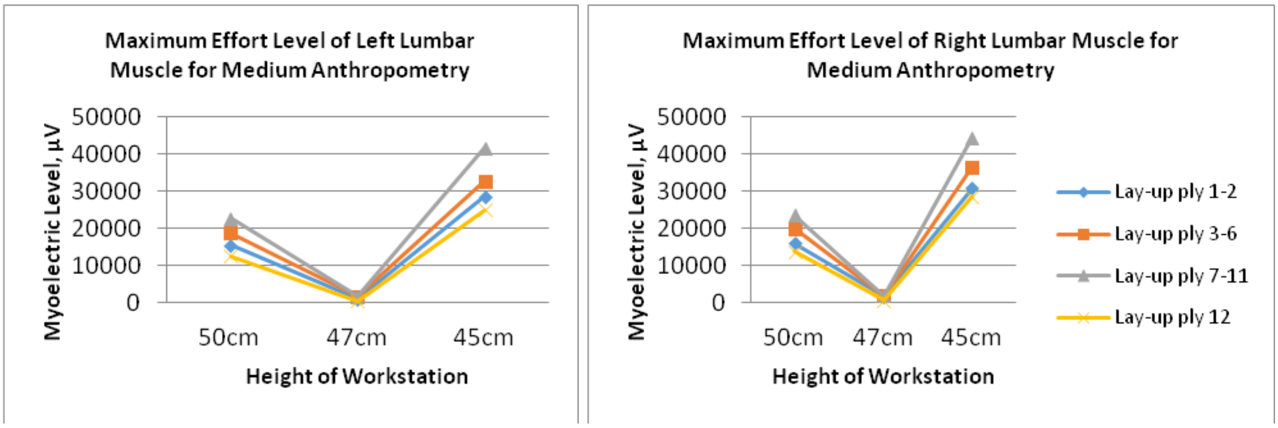

Figure 2(ii) Results for maximum effort level of lumbar muscle for medium anthropometry

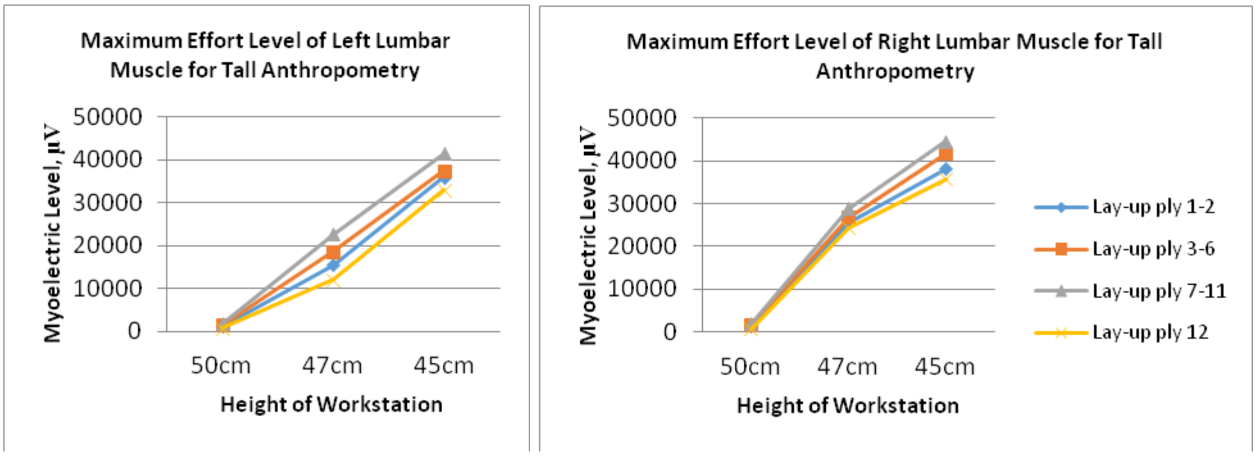

Figure 2(iii) Results for maximum effort level of lumbar muscle for tall anthropometry

Through observation procedure, small operators usually used 45cm and 47cm height of workstation when performing jobs in their workdays before recommendation was suggested. By referring to Figure 2(i), they experienced discomfort and back pain when they are worked using 50cm and 47cm height of workstation. However, they felt comfort when they worked with 45cm height of workstation. Other than that, medium operators usually used 50cm and 47cm height of workstation when performing jobs in their workdays before recommendation is suggested. By referring to Figure 2(ii), they experienced discomfort and pain when they are worked using 45cm and 50cm height of workstation. However, they felt comfort when they are worked with 47cm height of workstation. On other hand, tall operators usually used 47cm and 50cm height of workstation when performing jobs in their workdays before recommendation is suggested. By referring to Figure 2(iii), they experienced discomfort and pain when they are worked using 45cm and 47cm height of workstation. However, they felt comfort when they are worked with 50cm height of workstation. Therefore, the maximum effort level of left and right lumbar muscle was influenced by the height of workstation, working posture, working activity, and anthropometry of operators.

The resutt shows that for maximum effort level of left and right lumbar muscle, a mean for maximum effort level of lumbar muscle for three groups of anthropometry is premeditated. The mean was calculated in order to identify an accurateness results obtained. A graph using mean of maximum effort level for lumbar muscle can be illustrated. The accurateness graph is used to validate the results obtained for maximum effort level of lumbar muscle with the recommended height of workstation among three groups of anthropometry. Figure 3 illustrates the accurateness result of maximum effort level for lumbar muscle among three groups of anthropometry respectively.

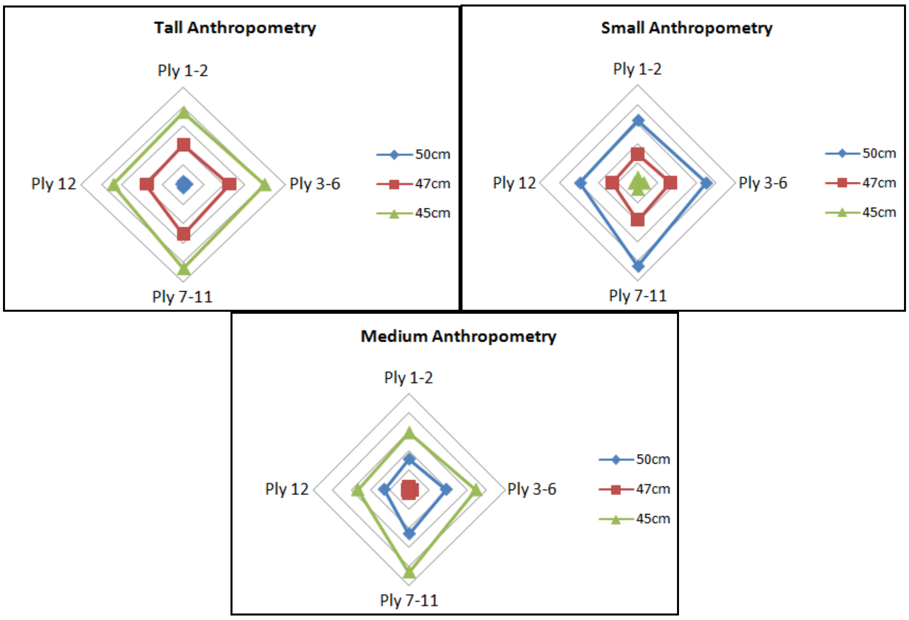

Figure 3 Accurateness graph for maximum effort level of lumbar muscle among three groups of anthropometry

This study pointed that height of workstation and anthropometry of operators had influenced the maximum effort level of lumbar muscle and comfort level of working posture. When the operators are worked in long period of time using improper height of workstation, static contraction of muscles can occur particularly. Due to static contraction, performance of muscles may decrease and this condition can lead to discomfort and pain (Larivière et al., 2008).

CONCLUSION

This study has performed comfort level analysis of working posture and effort level measurement in the lumbar muscle among manufacturing operators in aerospace company for lay-up process. All operators performed their jobs in different height of workstation which is 45cm, 47cm, and 50cm. The comfort level analysis of working posture is done using RULA method in CATIA software. The analysis is done for three groups of anthropometry which is small, medium and tall. According to the comfort level of working posture, the suitable height of workstation is recommended. The small operators comfortable worked with 45cm height of workstation, medium operators comfortable worked with 47cm height of workstation, and tall operators feel comfortable worked with 50cm height of workstation. Based on the accurateness graph, suitable height of workstation associated with operators' anthropometry can reduce the maximum effort level of lumbar muscle while operators performed their jobs. Therefore, this study concluded that maximum effort level of lumbar muscle among lay-up operators in aerospace industry was influenced by the height of workstation, and comfort level of working posture.

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COMPETING INTERESTS

There is no conflict of interest.

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