ORIGINAL ARTICLE

CORRELATIONS BETWEEN HEART RATE, MUSCLE ACTIVITY AND ANGLE OF LUMBAR ASSOCIATED WITH POSTURE DURATIONS OF LAMINATORS IN MANUAL HAND LAYUP PROCESS

Nur Syafiqah RAYME[1] Seri Rahayu KAMAT[1] Syamimi SHAMSUDDIN[1]

[1]Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

ABSTRACT

Laminators are people who worked with layup process in the making of composite products. In hand layup process especially manual handling, the laminators were prone to be in high risk of getting musculoskeletal disorders (MSD). The ergonomic approach in manual handling was already established since 2005 however, no specific studies were done especially in this process. This paper is a continuation of the research done by the authors which focused more on the data analysis of experimental data collection. The study aims to investigate the correlation between heart rate, muscle activity, the angle of lumbar during layup and the duration of the working posture. From observations and survey done in the previous study, the laminators were exposed to awkward posture as they tended enormous size of the mould. Hence, the study collected 4 parameters data simultaneously. The analysis of the correlation was done using MINITAB software using Response Surface Method (RSM) analysis in obtaining the p-value of the model. From the data analysis, only two of the models show insignificant of correlation and 6 out of 8 models show correlations in between parameters. It is concluded that there was a correlation in between muscle activity, heart rate, the angle of lumbar and duration of posture, however, further studies should be done to cater the insignificant of the other 2 models with different muscle type of Lumbar Support Spinae and Multifidus Lumbar.

Keywords: *MSD, HAND LAYUP, ERGONOMICS*

INTRODUCTION

Hand layup is one of the processes of fabricating composite products. Composite fabrication is varying according to the type and function of the products. Some of the composite manufacturing is in manual handling. Composite manufacturing is on high demand in Malaysia as mentioned by the Minister of International Trade and Industry, from the article news title, "Malaysia aerospace industry to grow by 7% this year (The Star Online, 2017). In one of many products of the composite are aircraft panels. Aircraft is an enormous machinery and the workloads in completing the whole aircraft are beyond imagination. Laminator is a profession of the manual hand layup labour that specifies in the production of composite products (Elkington, Bloom, Ward, Chatzimichali, & Potter, 2015). Manual hand layup process is the process of layering the carbon reinforcement sheets layer by layer in the mould before the process of curing. On average, laminators worked around 8 hours daily, 6 days a week with some overtime demands when the demand is high. According to the executives of a composite factory, the hand layup process needs professional handling with extra efforts and heavy workloads. Thus, the high turnover rate of workers is crucial to the companies that produce composite products. It is difficult to recruit laminators with experience on time when the demand is at large, inexperience laminators and lack of practice apprentice will increase the risk of defects in products. The turnover rate is forecasted to be increasing and the main factor of this issue was the high number of absenteeism of workers and the problems associated with a backache (Morken, et al., 2003). This raises questions on how the manual hand layup process is affecting the health of the laminators. Laminators that comprehend with manual handling work were often exposed to the risk of musculoskeletal disorders (MSD). From a preliminary study done by Rayme, et al. (2018) the laminators or the hand layup workers are prone to several ergonomics risk factors. From the study done by Hashim, et al. (2014) and Kamat, et al. (2016) the hand layup process is associated with awkward posture, high repetitive movements, and excessive force and lifting. Several studies were done by Halim, et al. (2004) and Md. Deros, et al. (2010) suggested that ergonomic risk factor leads to the risk of developing MSD. Thus, laminators are in a high frequency of developing occupational diseases such as low back pain. In addition, starting from 2018, Department of Occupational Safety

and Health (DOSH), Malaysia, is implementing the "SOHELP" programme under Hygiene Department which involves 3-factor analysis of safety in the workplace: noise, chemical, and ergonomics. Malaysia in ergonomics especially, the understanding is still lacking in term of ergonomic awareness (Mustafa, Kamaruddin, Othman, & Mokhtar, 2009). From collective literature, in hand layup process the working procedure in ergonomic is still in progress. This paper supports the SOHELP programme as it is to identify the main factor affecting workers' health. The study is the continuation of a study done by Rayme, et al. (in press) and through this paper, the methods used to evaluate the ergonomic risk factors were listed. The literature studies have shown that heart rate, muscle activity can be applied in evaluating risks' presence in the working process. Thus, the paper contributes to finding the correlation in between heart rate, muscle activity, the angle of lumbar and duration of the posture. Mainly in manual hand layup, the ergonomic risk factors that had been identified was high exertion force of hand, awkward postures, high repetitive movement, and heavy lifting. However, the study focused on awkward posture as the number of complaints received by the Health and Safety and Environment (HSE) office and in-house clinics was higher on backache.

From observation done by an ergonomic expert, the workload and working procedure of manual hand layup are indeed contributing to the occupational hazard in ergonomic concept. Heart rate is the most significant because it is the easiest parameter to determine the fitness level of a person. The second parameter was muscle activity, this paper study on how muscle activity correlate with parameters, in this case, how postures with a certain angle of lumbar, duration of posture and heart rate are affecting the muscle activity.

This research was conducted at one composite manufacturing company which had received complaints of a high number of backaches in 2016. Significant with data provided during an interview session with the respective safety officer, it shows that there is a significant number of absenteeism cases associated with a backache. In Eastern Kentucky University online resource, "Without rest to repair the "micro-traumas" that occur in daily repetitive activity, a cumulative trauma disorder may develop", this proves this study claims that the cumulative pain or discomforts that occurred in any body parts will lead to serious occupational diseases as mention in the earlier research.

The research aims to investigate the risk of manual hand layup process to the laminators and the correlation of heart rate, muscle activity, duration of posture and angle of lumbar during work. The research embarks scopes on enormous size mould and sample of respondents were based on Malaysian population. From a preliminary study by Rayme, et al. (2018), suggested that the manual hand layup process research demands on focusing on issues of low back pain. In conjunction with Azizan, et al. (2018), it states that the energy depletion from the laminators occurs during the time of 4.30 p.m. to 5.30 p.m. at the laminators were about to end their shift or preparing for overtime according to demand by customers. The result shows an increase in heart rate after the lunch break time at 2.30 p. m. as the laminators were starting to catch up with the cycle time before the end of their respective shifts. In ergonomics world of studies, there were limited resources done that can be related to ergonomics issues in manual hand layup especially as stated by Elkington, et al. (2015). There was research correlated with layup process which including robotics and automation of the layup process. These prove that manual hand layup was affecting the laminators' health because of the urgency of automating this process. However, the automation of hand layup process done by Elkington, et al. (2015) was based on medium size mould and the research is still ongoing and Malaysia is still far behind from the implementation of automation in hand layup process especially on enormous products to be manufactured. Thus, this research focuses on the correlation in between three parameters: muscle activity, heart rate and angle of lumbar during manual hand layup process.

METHODS

Participants

The study was done among laminators that work in one department producing high scale composite panels. The total number of personnel available were fifty-eight (n=58) in total with different age, gender, and educational level. However, a number of

experimental subjects vary according to the consent of the subjects. From the selected few, twenty-nine (n=27) male subjects consented for heart rate data. As for the simultaneous experiments on muscle activity, heart rate and angle of lumbar the sample taken were two (n=2) subjects and with repetition of manual hand layup more than 40 reps on a similar day per person to ensure fixed control of health state of the subject.

Instrumentations

Calibrated Omron Wrist blood pressure meter was used to obtain the heart rate of the laminators at 4 times a day, with the repetition of 3 days. The time to take the heart rate readings were segregated into four: 8.30 a.m. to 9.30 a.m., 12.00 p.m. to 1.00 p.m., 2.30 p.m. to 3.30 p.m. and 4.30 p.m. to 5.30 p.m. with a maximum number of subjects per day of 5 (due to instrument calibration).

The second stage of the research used a calibrated Garmin 620 Forerunner heart rate watch with chest strap for heart rate readings, calibrated DELSYS surface electromyography (sEMG) using 4 data points of muscle: multifidus lumbar and lumbar support spinae for both left and right and video camera to record the postures of workers to obtain the angle at lumbar during manual hand layup process; 30 to 45 minutes' duration of hand layup. Interview sessions were done beforehand in order to obtain a letter of consent from the participants.

Data Analysis

All data acquired were analysed using Minitab software to obtain the correlation in between parameters using Analysis of Variance (ANOVA) by analysing the number of the p-value. The data reliability of muscle activity is filtered using the DELSYS filtering software using Butterworth, Band Pass, and High Pass. The filtering of muscle activity was done after training with the supplier of DELSYS product by Summit Features Sdn. Bhd. and to increase the confidence several literatures studies were taken into consideration as well and the source were from studies done by Halim et al. (2012), Spyropoulos et al. (2015), Mohamad et al. (2016) and Strazza et al. (2018).

RESULTS

In the study, participants' demographic information includes age and race were obtained by interview session to verify the nationality of the participants as the scope of the study involves a Malaysian case study.

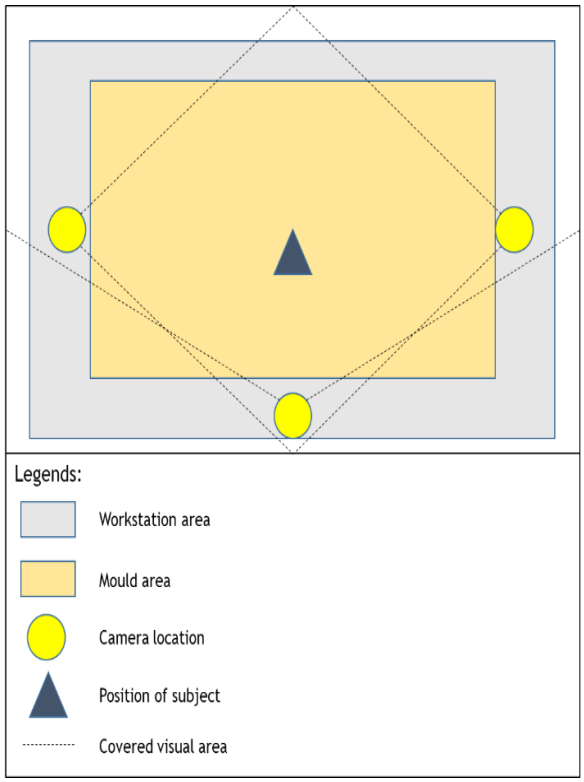


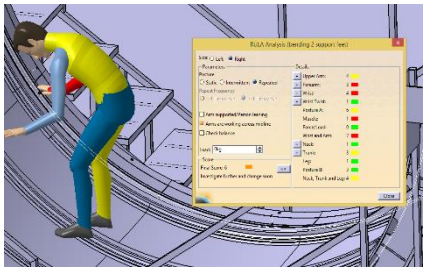
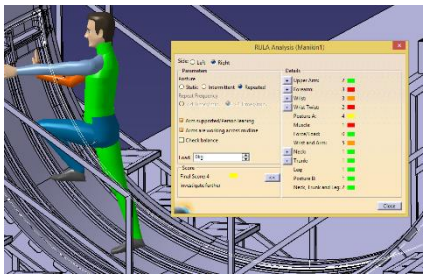
Figure 1 Layout of the camera position for the visual covered area

The video recording of the manual hand layup process was extracted, and the imitation of postures were observed. Verification on the posture is done by ergonomics experts and the video was recorded simultaneously in three visual points to avoid blind spot and producing a 270° viewpoint. Figure 1 shows the layout of the visual of the video recording data.

From figure 1, the posture imitation of laminators during the working process in DELMIA V5 software using ergonomics analysis feature. The postures were obtained through video recording data. In Kamat et al. (2017) study on cafeteria workers were also using similar software of DELMIA V5. Several postures from the manual hand layup process were observed and tabulated into the table to separate the squatting posture and standing posture. Standing postures were analysed using DELMIA V5 software Rapid Upper Limb Analysis (RULA) to verify the risk of MSD towards laminators. Studies done by Hashim et al. (2014), RULA scoring can indicate the risk

of MSD towards the person over time. Hence, the study proves that the laminators were at risk of MSD based on the RULA scoring. Table 1 shows the RULA score and the position of the laminators during manual hand layup process of oversize curvature mould and Figure 2 shows the scoring results indicators for RULA.

Table 1 RULA analysis for posture using DELMIA V5 software

Posture	Results
Posture 1	
	
Angle at Lumbar	14.685°
RULA Score	7
Posture 2	
	
Angle at Lumbar	37.441°
RULA Score	6
Posture 3	
	
Angle at Lumbar	0°
RULA Score	4

Several types of postures were identified by analysing the video recording data. From the data obtained, RULA scores were analysed and from table 1, it shows the correlation in between angle at lumbar and the RULA score. From DOSH Ergonomics Risk Assessment Guidelines (2017), it is stated that the bending angle of more than 30^0 can increase the risk of occupational diseases if exposed in long term.

The study was furthered with correlating the heart rate, muscle activity, duration of posture and the angle at lumbar. Using Response Surface Method analysis in MINITAB 17 software, the number of p-values was compared with α (alpha value) from ANOVA in LINEAR model. Confidence level is 95%, it is in conjunction with alpha (α = 0.05).

From the RSM analysis, the linear model as hypotheses is as follows;

$$Muscle\ activity\ (mVolts) = x\ Heart\ rate\ (bpm) + y\ Duration\ (sec) + z\ Angle\ of\ lumbar\ (^\circ)$$

From the ANOVA Linear and Model, the value of p is compared in between parameters; muscle activity (milliVolts), heart rate (beats per minute), duration of posture (seconds) and angle of lumbar (°). The data of correlations are summarized in Table 2.

Table 2 Summary table of p-value

Percentile	Muscle	p-value (Model)
50^{th}	ML right	0.029
	ML left	0.023
	LSS right	0.032
	LSS left	**0.661**
95th	ML right	0.019
	ML left	**0.186**
	LSS right	0.028
	LSS left	0.020

***ML refers to Multifidus lumbar muscle and LSS refers to Lumbar Support Spinae muscle**

The hypotheses of this study, there are correlations in between the parameters that were used in the experimental session. The experiment data collection was done simultaneously for all parameters that were tested. In the early stage, muscle activity of a person is decreasing meanwhile the heart rate increases, the duration of posture increases, the larger the angle of lumber, the lower the muscle activity. The muscle activity shows significant differences when it reaches fatigue state (Roldán-Jiménez, Bennett, & Cuesta-Vargas, 2015). Muscle activity will drop significantly when the person is considered as fatigue. The difference of this study is the respondents were chosen to be at a normal state of condition. Hence, the theory of muscle activity will be decreasing compared

to other parameters is nullified as fatigue is barely concluded in this study. This study proves that the muscle activity is increasing as well as heart rate, the angle of lumbar and also the duration of posture. The increment of muscle activity shows that the workload is pressuring the muscle and the muscle needs to react more with aerobic and anaerobic respiration activity and this forms the wave of the sEMG reading. From Table 2, it is shown that the p-value(s) of the model is less than 0.05 (α-value), showing that there is a correlation in between muscle activity, heart rate, duration of posture and the angle of the lumbar. However, 2 out of 8 models in the analysis shows different results. Human anatomy and human biological factor are not considered as the scope of this study as the study focuses on the engineering part of the working system. From data tabulated in the table, the body functions were proven to be other factors that should be considered in the future study. This is because some of the muscle activity shows no correlation in between parameters and response. Hence, the deduction that can be done here is muscle multifidus and lumbar reaction process need a thorough investigation and it should be taken into consideration in future.

CONCLUSION

Conclusively, it is proven that manual hand layup is a risky work and there is a need for improving the workstation design or the working procedure by undertaking all aspects of ergonomics. In conclusion, there is a correlation in between muscle activity, heart rate, the angle of lumbar and duration of posture.

For future recommendations, the study should tackle other ergonomic risk factors such as forceful exertion force and any other ERF into consideration.

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COMPETING INTERESTS

There is no conflict of interest.

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