LINEAR REGRESSION ANALYSIS OF LAMINATOR IN HAND LAYUP PROCESS

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ABSTRACT**:** *In the ergonomics world, manual handling that includes human labour is well-known for exposure to health impacts. In the manual hand layup process, the composite products were handcrafted by the laminators, hence, imposing a high risk of getting the musculoskeletal disorder. The laminators in the research subjects were prone to backache and mostly the absenteeism was related to it. The sample subjects taken were from the 50th and 95th percentile of height in anthropometry and the process task was fixed per subjects. The research suggested a simple regression analysis to analyze the data obtained from the conducted experimentation which includes variables such as heart rate, muscle activity, duration of bending and the angle at the lumbar during bending. It was found that from the different percentile types of subjects, the null hypotheses were rejected by 75% in the 50th percentile and 100% in the 95th percentile of the subject sample. Nonetheless, in 25% of the accepted null hypothesis, there is a relationship between the heart rate reading with the angle at the lumbar during bending.*

Index Terms: Anthropometry, Ergonomics, Hand layup, Linear regression**.**

I. INTRODUCTION

Ergonomics in manual hand layup industry is not very common but it has a lot of research in it. It was proven that the need for an ergonomics approach in the manual hand layup industry is crucial when the decision to go fully automated on the process was escalated. However, to go beyond the technology, it was not applicable in many countries and it depends on the types of the product manufactured from manual hand layup itself. It is expected that the automation of the layup process will improve the ergonomics issues as the process reduces the force of a human. On the contrary, the manual hand layup is a delicate and versatile process. The laminators (people who manually layering up the carbon reinforcement sheets) are well-trained and highly skilled as they can produce a product with minimal defects. This is because the products that are produced from the manual hand layup will be acquired in airplanes, ships, and et Cetra. These types of products require high acceptance in quality which leads to consumers' safety. This research was a collaboration project between industries and academicians implying that manufacturers in Malaysia are slowly accepting the ergonomics bigger perspectives and also the need to comply with the Occupational Safety and Health (OSHA, 1994) in Malaysia especially. Department of Safety and Health (DOSH) Malaysia has encouraged industries to participate in the new program called SOHELP, which inputs the ergonomics aspects in safety precautions and audits [1]. The aim of this research is to conduct a simple analysis of the blue-collar workers involved in the making of composite products. From the research done simultaneously in the same project; [2, 3], the workers were prone to having discomfort in the lower back of the body. From the interview session with the Safety Officer of the company, it is said that absenteeism was associated with backaches. The interview was done in December 2016 [4], previously.

II. METHODOLOGY

The research proceeds with the literature reviews and pilot study survey on the level of discomfort in the body. Laminators were the subject of this research. In Malaysia, the availability of laminators is very minimal. They were considered as skilled blue-collar workers. Unless a person is exposed to composite manufacturing, the laminator is rare for job seekers. Indwelling with the subject, the research is bounded by ethical compulsory. Hence, a consent form needs to be obtained beforehand. From the consent form, only participants that were consented will undergo the data collection. The research was divided into three stages. The first stage was the survey on the level of body discomforts where respondents answered the rating of body discomforts from 1 to 5 (not painful to extremely painful). From the problem statement, the survey was conducted to find the body parts that contribute to the level of discomfort. The survey was done by one per one interview sessions and the body parts that were asked in the survey were; calf, feet, hand, knee, lower arm, lower back, neck, shoulder, thigh, upper arm, and upper back.

Next, the research proceeds to the second stage which was the anthropometry data collection. In ergonomics, especially anthropometry, the designs of a product were correlated to the percentile range of the users. In order to obtain the participants for the third stage, anthropometry data must be collected. In this study, the anthropometry data parameter that was used was stature (height in cm). The sample obtained for height measurement was 541 subjects. The mean and percentiles of the human stature for this case study are tabulated in Table I. The anthropometry measurements were taken using the traditional method and the brief methodology was similar to the other research with a similar background done by [3] which followed the standards provided in research done by [1].

The last stage of this study was the participants for the experimentation that used surface electromyography (sEMG), heart rate and video recording. This is to obtain the muscle activity data, heart rate value and angle of the lumbar during bending in manual layup work and the duration of the bending. From the consent form and anthropometry data analysis, only two subjects proceeded and the difference between samples was the duration to complete a similar task. As for sEMG, the muscle chosen for this experimentation was the multifidus lumbar and lumbar erector spinae muscle that was located at the lower back of the human anatomy.

As generally explained, the study was done with the collaboration of industry, however, the experimentation

that involved the human data collection, gathering and keeping needs to be under consent, ethical approval and confidentiality agreement between parties, as a result, the sample obtained for the analysis was two samples special type which one sample can provide many replications of data set different from another analytical test. Hence, it is wise to choose a regression analysis in accordance with the type of data available.

III. RESULTS AND DISCUSSIONS

A. Survey on Level of Discomforts of Body Parts

From the survey, it was shown that the lower back and upper back contributed significant mean compared to other body parts and the rating of the mean was the highest between all body parts which indicates the high level of discomforts. The pilot study was done using survey methods and the data was analyzed using MINITAB 17 software and an interval plot was plotted as in Fig. 1. Fig. 1, toughens the interview claim that the absenteeism was associated with back pain as the level of discomfort of the laminators inquired the highest at lower back as in the analysis with 95% confidence interval. This is because of the analysis of variance, ANOVA uses the 95% confidence interval. The highest mean of the level of discomfort was for the lower back compared to other body parts which had an average or similar mean. Hence, the cruciality of the study will be a focus on the lower back as according to the pilot study.

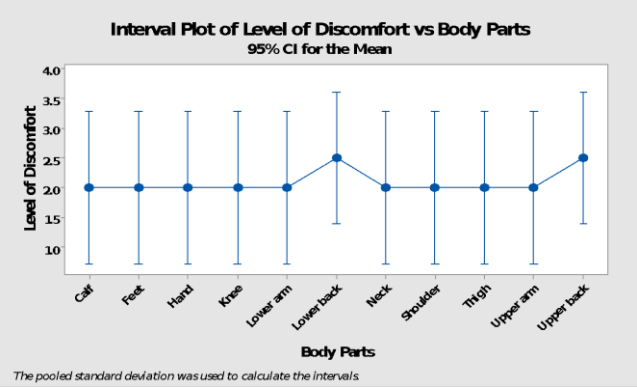

Figure 1: Interval plot of Level of Discomforts of Body Parts

B. Anthropometry measurement and Percentile Selection for sampling

Anthropometry in a very simple manner can be presented as the measurement of the human body. The definition of anthropometry is diversified according to authors around this background. One of them was [5] which stated that "Anthropometry in the definition is the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body". The measurement of the heights of the population sample was taken. In one department of composite hand layup, the laminator's height was as in Table I. All measurements are taken consented to. Fig. 2 indicates the histogram of the laminators in terms of their heights or stature.

Table I. Stature (Height in cm) Data Summary

Mean	167.5
Standard Deviation	6.272
5^{th} Percentile	158.0
50^{th} Percentile	167.5
95^{th} Percentile	177.0

From Table 1, the sample indicates that the 5th percentile sample was 158cm in height or stature, and the 50th and 95th percentiles were 167.5 cm and 177 cm respectively. Further exploring the research, data was collected from these samples, however, the data for the 5th percentile laminator was unavailable as the respondent did not consent to the hair removal procedure before the attachment of the sEMG to the lower back.

Based on the Fig. 1 data collection, the lower back was chosen for the sEMG procedures. The absenteeism related to backache will eventually lead to low back pain. From [6], back pain is defined as any pain that occurs between the twelfth rib and the inferior gluteal folds with or without leg pain where most cases are unspecified. Low back pain is considered as one of the diseases related to musculoskeletal disorder [7] and it is related most to the workers that were involved in manual handling [8].

As the research progressed, the chosen muscle activity reading was the multifidus lumbar and lumbar erector spinae was chosen based on research done by [9]. However, in further analysis, only the muscle activity for the right side multifidus lumbar was analyzed in this research. The author's research, there were aiming to find the significance of heart rate and muscle activity to the workers mainly in the hand layup process similar to this research. In contrast, this research developed a linear regression in order to find a prediction due to the model and the correlation between the variables after the regression analysis.

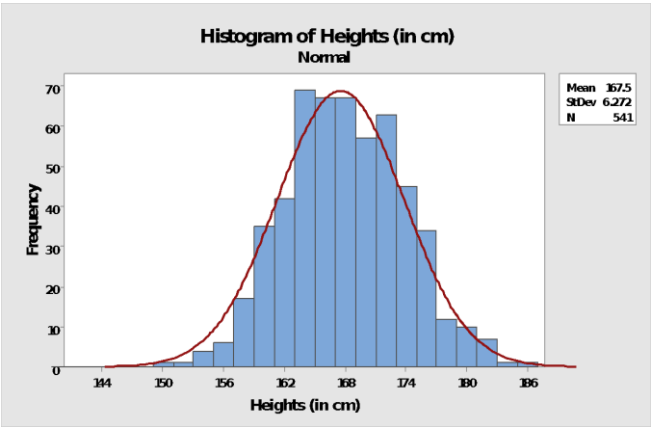

Figure 2: Histogram of Normal Distribution of Height of Laminators

C. Linear Regression for Angle of Lumbar analysis versus predictors (Heart rate, muscle activity, and duration)

The data experimentation using sEMG, heart rate watch and video recording were conducted using the subject that falls into the percentile of the anthropometry analysis which were 158.0 cm, 167.5 cm and 177.0 cm to 5th, 50th, and 95th percentile respectively. However, the experimentation proceeds with the 50th and 95th percentile subjects as consented. Uniquely, Table 2 indicates the result of the regression analysis of the two samples that needed correlation between variables. Henceforth, it is declared that the Angle of the Lumbar (°) is the independent variable that is manipulated for the relationship of two variables. Predictors were the dependent variables of the model in this regression analysis.

Table II. Linear Regression Summary for 50th Percentile

Response	Angle of Lumbar (Mean = 42°)		
Predictors	Heart rate (bpm)	Muscle activity (mVolts)	Duration of bending (sec)
Mean	*128*	*0.0207*	***21***
Model	***Heart rate = 119.9 + 0.1876 Angle of Lumbar***	*Muscle Activity = 0.02302 - 0.000055 Angle of Lumbar*	*Duration = 23.48 - 0.06067 Angle of Lumbar*
p-value	**0.081**	0.522	0.543
Model Acceptance	**Yes**	No	No
Replications	66		

Table III. Linear Regression Summary for 95th Percentile

Response	Angle of Lumbar (Mean = 48°)		
Predictors	Heart rate (bpm)	Muscle activity (mVolts)	Duration of bending (sec)
Mean	127	0.2125	7
Model	*Heart rate = 126.9 + 0.01048 Angle of Lumbar*	*Muscle activity = 0.1825 + 0.000688 Angle of Lumbar*	*Duration = 9.312 - 0.04607 Angle of Lumbar*
p-value	0.358	0.618	0.108
Model Acceptance	No	No	No
Replications	43		

The data in Table II and Table III has excluded the R^2 percentage as analysis because in this research the value of R^2 is not to be concerned as stated in [11]. Moving on to the crucial part of the discussion, the number of replications between the two samples was different, even though the process sequence of hand layup was similar. From the replication perspective, the different heights of the laminators can be the major effects of the lower backache as the higher number of replications of bending will impose great health risks to workers or in this research laminators. In fact, from [1] online ergonomic guidelines, it was suggested that the maximum bending degree of a human body should not exceed 30°. On average, for both percentiles, the angle of the lumbar during bending has a mean of more than 30° which were 42° and 48° respectively. The process sequence chosen in the data collection has a process cycle of 90 minutes, but according to the data collected, a subject that falls on the 50th percentile of height is urged to bend more frequently than the 95th percentile subject. From the time frame of duration and replications, the subject with the 95th percentile of height could complete the job earlier than the 50th percentile subject, as per required the subjects were both experienced laminators with a similar year of service.

As per the analysis results, the value of p indicates whether the null hypothesis can be accepted or not and the reliability of the linear model produced. Linear regression model acts as the predictors where it displays the mathematical equation with variables that can be responsive (dependent) and predictors (independent). In conjunction with the statement above, the null hypothesis of the linear model was that the variables had a correlation or relationship with one another. Table II shows that only the heart rate and the angle of the lumbar had a correlation in the subject with the 50th percentile of height with a 90% confidence level as the p-value less than 0.10 (α = 10%) as the p-value is 0.081. Normally, in statistical analysis, the usage of alpha ranges from 1%, 5%, and 10% as it is less frequently used compared with others. However, since the sample size for this experimental process is small and the experimental related to human consent, the confidence interval used in this paper is 90%. The accepted model was as in (1) and it may be used for future research recommendations in finding the best working heart rate for manual hand layup workers in order to decrease the risk of getting musculoskeletal disorders such as low back pain.

$$Heart\ rate = 119.9 + 0.1876 Angle\ of\ Lumbar \quad (1)$$

IV. CONCLUSION

Conclusively, the research has proven that it is easy to see whether there are correlations in between the variables of the human body. The aim of the research is to provide a simple analysis of the data obtained from the experimental design. However, the sampling should be increased in future work recommendations as the sample size might be too small for the MINITAB software to analyze with a lesser error. Not to be excluded in the research progressiveness in the future, it is recommended that more individuals volunteer to be part of the research as subjects in any other targeted group to become the benchmark of the current or future research that involves quantitative measures in ergonomics. In conclusion, the research found that only subject with 50th percentile height shows a significant relationship between heart rate and the angle of the lumbar. It is also a finding that the difference in height of the workers involved different durations of work process

that can be completed. Lastly, the linear models obtained for the 50th percentile subject is 25% accepting the null hypothesis, and the 95th percentile subject 100% rejecting the null hypothesis.

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