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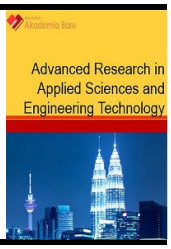

Analysis the Influence of Heart Rate and Muscle Activity towards Muscle Fatique in Layup Workers

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ABSTRACT

Repetitive movement can lead to the pain muscle, nerves, and tendons that cause by repetitive overuse of working task. The muscle will fatigue due to; repetitive movement, force that been applied, posture during working and duration of working. The stress level during working can influent the energy performance usage during working. The aim of this paper is to analyse the influence of heart rate and muscle activity of workers in composite manufacturing towards muscle fatigue. The data was collected for a worker in hand layup department and the Qualitative method was used in a way to investigate the working load and level of pain received by their body. Then, the Qualitative data was sorted and the respondent proceeded for a Quantitative method which involves muscle activity analysis and heart rate analysis. The tools that were used to conduct these experiments were surface electromyography (sEMG), Wristwatch with chest strap and perceived stress scale (PSS). The experimentation used to calculate the average reading of heart rate and muscle activity during working and detect the duration the muscle to start fatigue. Moreover, this paper analysed the relationship between heart rate and muscle activity through the duration of working. As an overall finding of this research, it was shown that the heart rate of the workers influence the muscle activity of workers and has high potential relationship to the fatigue of muscles of the workers in the layup department.

Keywords:
Muscle activity, repetitive movement, Surface electromyography (sEMG), heart rate, fatigue

1. Introduction

In composite manufacturing, most of the working task faced by the worker is manual where it is more one handmade skill, without the aid of any facilities machines. The posture of their bodies during handling this task was the key factor of this research. Nowadays, in the industry field, there is a high demand for production hence, the body will back to its normal state of parameter index after the working hours. This threat is normally known as a stressor because it is a set of conditions where the stress response is occurring in humans. Therefore, the stress can be summarized, as the body's physiological response to a stressor and strain is the body's longer-term reaction to chronic stress.

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Some known occupational stress is workloads and shift schedule. In addition, the more the task that is exposed to the physical danger, the more possibility they will contribute to the stress of a job. Based on previous study [1], occupational stress has the connective effect to various medical related illnesses such as hypertension, depression and musculoskeletal disorder (MSD). As a result, this problem affects the health and performance of the organization because there are challenged by work stress if a large number of workers are stressed.

Based on the survey from European working conditions (EWCS), reported that the issues among industrial workers, where more than 40% were suffered from the muscular pains while they are performing a routine work. Most of working task is repetitive work or called arm movement activities. Besides that, the awkward posture is a common risk that has high probability may face by the worker. About 63% of workers in the industry being exposed to the ergonomics risk [2]. Moreover, the level of ergonomics risks issues is depending on the frequency and duration of the exposure been done such as workload factors with the awkward working posture and repetitive in the movement activities. The tools have been used in this paper include observation methods, subjective method (physiological) and physical methods. According to the study Occupational Repetitive Action tool (OCRA) in 1998, evaluated repetitive handling frequently by upper limb may lead to high ergonomic risk among the workers in industry [8].

Through questionnaires, an assembly worker in a truck axle assembly reported through questionnaires had been facing the trouble with musculoskeletal disorders during the one year working. Low back disorders (LBDs) are normally the common symptom of all musculoskeletal disorders for the workers. The risk of back failure increases for workers whose jobs include lifting with a rotated trunk [11].

In the study by Padula *et al*., [9], the workers involve both genders average age between 18 to 65 years old, with this samples ranging from 11 to 957 workers and within 25 workstations. Other than that, high-hazard job that has been assigned and better recovery time from combined exhaustion were observed when job rotation has been within two hours. To reduce the workload by development, breaks of ten minutes' durations have been proposed between the rotations. Biomechanical in risk factor that been relating to the repetitive motion may lead to higher possibility to get an injury.

This aim of this paper is to investigate the relationship between the psychophysical experience of muscle activity and stress level based on heart rate of workers toward fatigue in hand layup process.

2. Methods

2.1 Participant

The involved respondents participated which from layup department and that had been chosen as experimental workstation. This respondent was chosen through body-mass index (BMI) calculation and male respondents because this workstation occupied by male workers only. The task chosen for the experimental set was a repetitive movement of hand layup process. The third step of data collection was the level of comfort survey, heart rate analysis and muscle activity analysis. The survey involves 31 respondents and other analysis been filtered the respondents based on BMI and worst level of comfort.

2.2 Instrumentations

Figure 1 shows the flowchart of this research in a way to see the relationship between heart rate and muscle activity.

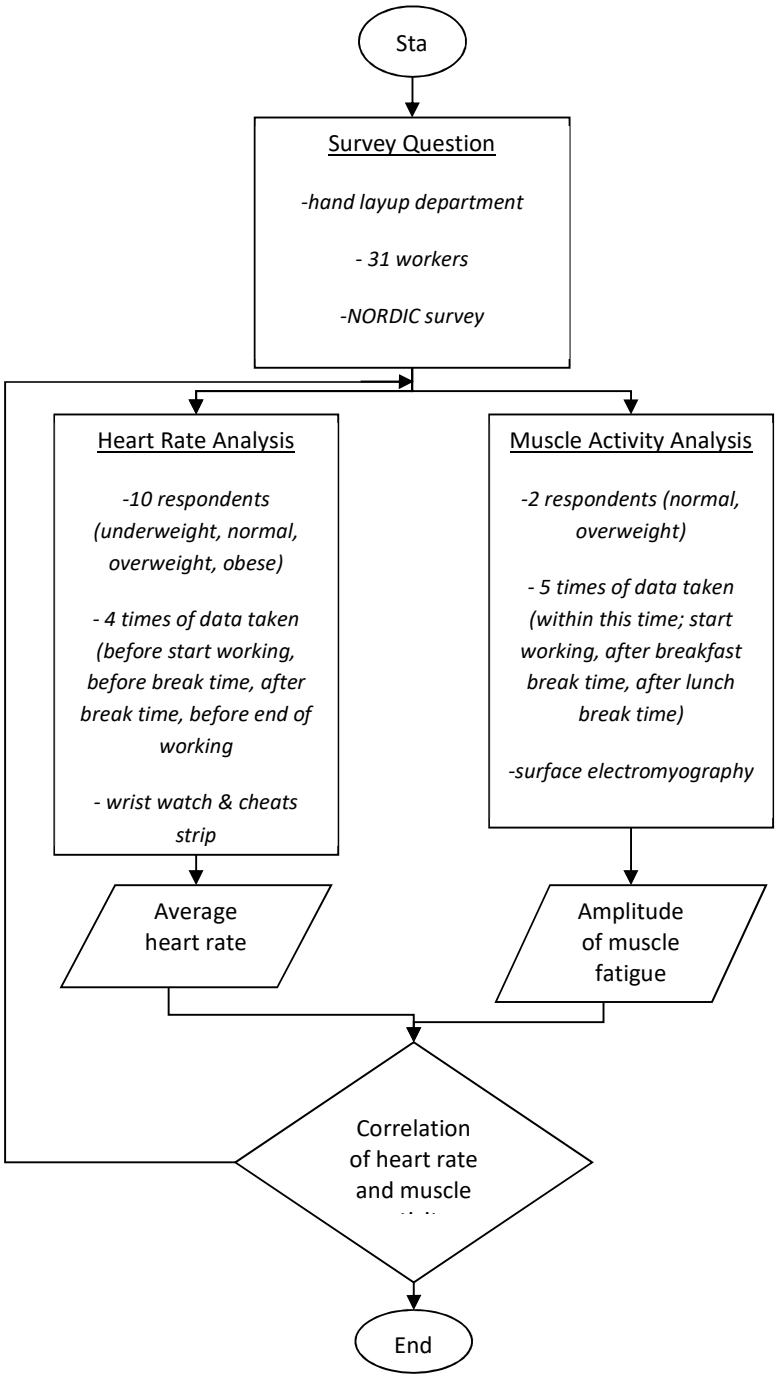

Fig. 1. Flowchart of research

The basic survey was conducted to identify the working activities and discomforts on body parts experienced by respondents after working. The survey form was distributed to workers in layup department involving 31 total respondents. Based on Halim *et al*., [5] framework of survey guideline, the survey is analysed to identify discomfort area in body based on physical workload. From the 31 respondents that involved in this survey, and the data been analysis and sorted out based on discomfort on body parts and body-mass index (BMI) categories which; underweight, normal, overweight and obesity. Ten respondents have been chosen from this sorted data survey and will go through for heart rate analysis and muscle activity analysis. The wristwatch is provided with a chest strap to detect the heart rate. While conducting the PPS survey, the heart rate is also collected to see how stressful the workers when working in this department. The manipulated variable for this experiment is time taken during respondents working which are before start working, before rest time, after rest time and lastly before end of working day.

For muscle activity, there are five muscles that were involved in this experiment; thoracic erector spine, lumbar erector spine, multifidus lumbar, gastrocnemius and soleus [6]. This experiment also analyse trapezius muscle because it related to hand layup process. The experiment was taken during layup process for one hour and repeated by five times using surface electromyography (EMG) for muscle reaction while working. The data taken within this time; start working, after breakfast break time, after lunch break time based on time cycle of the production. The respondents that involved same as heart rate respondents, but for this analysis only take two BMI categories because of time constraints of production.

2.3 Data Analysis

These heart rate and muscle activity data were analysed using Statistical Package for Social Sciences (SPSS) software to get the correlation between heart rate and also muscle activity.

3. Results

The survey form was distributed to workers in layup department involving 31 total respondents. The purpose of this evaluation was to identify the problems related to ergonomic issues experienced by workers at the workstation. Most of the questions were closely related to the problem of discomfort in any part of body. Based on these questions, an experimental test was conducted to determine the fatigue muscle of the spine and legs.

Furthermore, the function of the questionnaire was to be used as evidence for validations after two experimental validations on muscle fatigue and stress-related to heart rate would be conducted on the next stage of the overall research. This repetitive movement will cause muscle pain due to long periods take the same task and posture [3].

Table 1 shows the level of comfort for each body parts. Most of respondents have felt pain in the body part while performing their job task. Based on result, the respondents feel discomfort mostly at spine, calf, leg and lower back. Plus, the shoulder was also affected due to the hand layup process procedures that use high forces for applying ply. The level of discomfort on body parts been classified through this Table 1.

Table 1
Level of comfort for each body regions

Body region	(%)
Arm	2
Wrist	1
Elbow	1
Fingers	1
Shoulders	8
Neck	7
Spine	15
Thighs	7
Knees	3
Calf	14
Legs	12
Heels	2
Footprints	3
Lower back	11
Waist	5
Overall back	8

3.1 Heart Rate Reading

The reading of the heart rate has been taken for respondents that have critical issues discomfort level and BMI calculation. From literate review exaggerated systolic blood pressure (SBP) will respond to exercise and heavy movement is a factor for the future in develop of hypertension and associated a greater cardiovascular disease [7,10]. Therefore, this experimental taken in four different times of working in order to get the average reading data per person. After the experimental done, the watch technology can provide the graph for an overall rate of reading heart rate path of a person working per day through its software. Figure 2 shows the overall average heart rate on the ten respondents has been tested based on BMI category. The highest heart rate average during the initial working task and after break time for all BMI category. This because the workers been exposed to their work plan that was distributed. The working task is considered as high-intensity exercise increases the heart rate of the respondents and this related to their BMI as well. The underweight respondents have a higher pulse because of the metabolism of their body compared to other. In addition, most of respondents were already tired and no motivated to continue their work which are mostly related to the physiological of the workers in performing the job scope given. It showed that the mind behaviour was related to the rate of productivity of a person which detected by heart rate result.

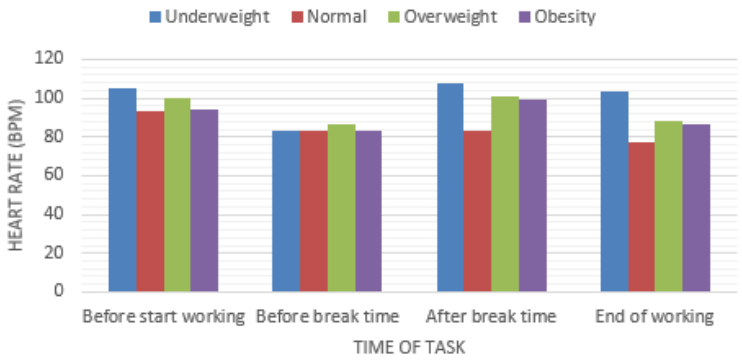

Fig. 2. Average heart rate of respondent

3.2 Muscle Activity While Working

The muscle activity test was done for two BMI categories, which are normal and overweight that being tested based on result of questionnaire because of limitation of production cycle time within this research. The data was taken for one hour and repeated five times consequently during hand layup process. There are 12 muscles (both sides of human body) involved in this testing and had been analysed using Delsys Trigno Wireless EMG System. Figure 3 and Figure 4 below shown two data from BMI categories which are normal and overweight.

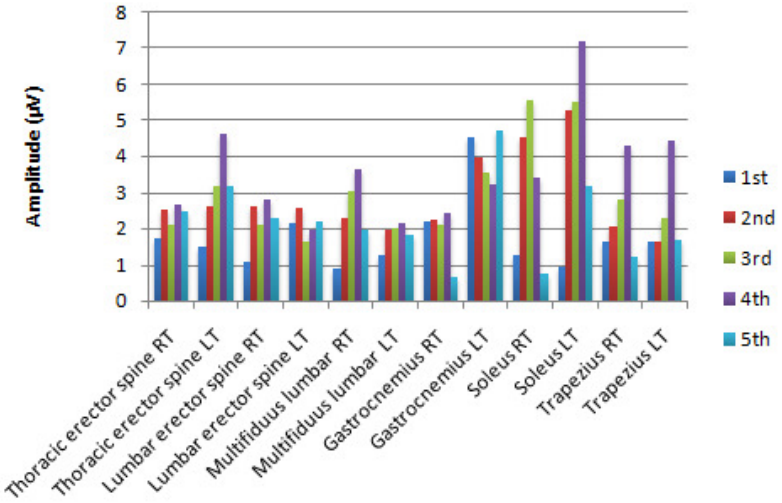

Fig. 3. Muscles activity for normal category

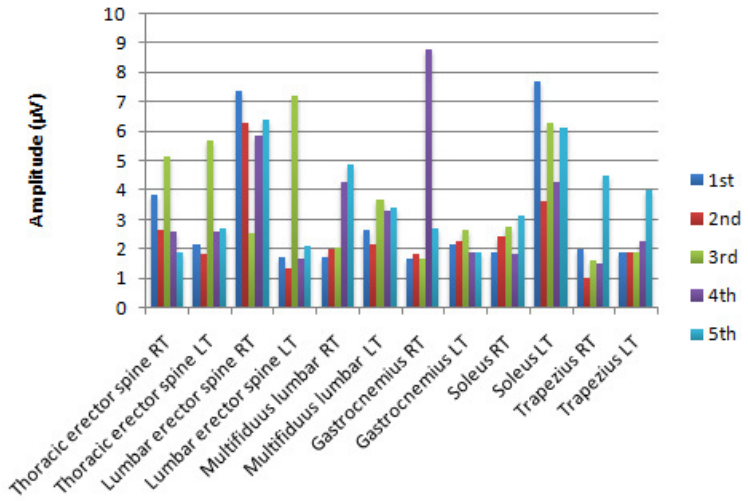

Fig. 4. Muscles activity for overweight category

Based on Figure 3 and Figure 4, it shows that the muscle involves fatigue when the working task was done. The Figure 3 and Figure 4, shows the muscle amplitude started to increase while conducting the works, it detects normally by using amplitude and frequency of the signal [4]. The Freitas [4] stated that the amplitude of EMG signals increases through the time when the fatigue

increases, otherwise the mean power frequency decreases. This showed that the muscle involve fatigue when respondents did their work repetitive time by time. For normal respondent, the spine muscles, lumbar muscles, soleus and trapezius show the muscle become fatigue in peak time until the end of work. While for overweight, the muscle that tends to fatigues are spine muscles, lumbar muscles and gastrocnemius. Table 2 shows the muscle that contract and fatigue during the experimental process.

Table 2
Muscles activity during experiment process

Muscles	Normal respondent	Overweight respondent
Thoracic erector spine RT	Fatigue	Fatigue
Thoracic erector spine LT	Fatigue	Fatigue
Lumbar erector spine RT	Fatigue	Contraction
Lumbar support spine LT	Contraction	Fatigue
Multifiduus lumbar RT	Fatigue	Contraction
Multifiduus lumbar LT	Fatigue	Fatigue
Gastrocnemius RT	Fatigue	Fatigue
Gastrocnemius LT	Contraction	Fatigue
Soleus RT	Fatigue	Contraction
Soleus LT	Fatigue	Contraction
Trapezius RT	Fatigue	Contraction
Trapezius LT	Fatigue	Contraction

3.3 Correlation of Heart Rate and Muscle Activity

The significant values of heart rate value and muscle activity have been analysed through SPSS analytical software. Based on the analysis, the average of heart rate had a relationship with muscle activity. Table 3 shows the significance of heart rate and muscle activity. Heart Rate (HR) describes as the heart rate of respondent while Electromyography (EMG) describes as the muscle activity of respondent. HR have four times of data taken which includes; before start working (HR1), before break time (HR2), after break time (HR3) and end of working (HR4). EMG have five set of hand layup process in one day of working which have; start working (EMG1), after breakfast break time (EMG2 & EMG3), after lunch break time (EMG4 & EMG5).

Table 3
The significance of heart rate and muscle activity

	HR 1	HR 2	HR 3	HR 4	EMG 1	EMG 2	EMG 3	EMG 4	EMG 5
HR 1		0.511	0.606	0.123	0.158	0.190	0.235	0.090	0.769
HR 2	0.511		0.735	0.235	0.117	0.688	0.257	0.715	0.426
HR 3	0.606	0.735		0.017*	0.534	0.660	0.538	0.713	0.029*
HR 4	0.123	0.235	0.017*		0.632	0.995	0.638	0.513	0.035*
EMG 1	0.158	0.117	0.534	0.632		0.794	0.728	0.441	0.108
EMG 2	0.190	0.688	0.660	0.995	0.794		0.000**	0.021*	0.404
EMG 3	0.235	0.257	0.538	0.638	0.728	0.000**		0.012*	0.775
EMG 4	0.090	0.715	0.713	0.513	0.441	0.021*	0.012*		0.291
EMG 5	0.769	0.426	0.029*	0.035*	0.108	0.404	0.775	0.291	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The heart rate of respondents decreases in the evening because of the pressure and work task that was done through the day. The heart rate of respondents influenced by the working task and stress during working. Moreover, the muscle activity of the respondents getting slow in the amplitude through EMG, it shows the significant effect on heart rate at the end of working at duration of 3pm to 5pm. This because the energy of workers been use during working and muscle start to fatigue towards the end of working day. The relationship of heart rate and muscle activity connected at the end of working day because the workers start to feel tired and suggested there is a need for a break to refresh back their energy to start back the work for the workers that have overtime for working. In this stage most of workers faced a critical phase with the workload, stress level and working posture that made them feeling discomfort. This duration also can be a framework for industry, as a guideline for them in order to improve the production quality.

4. Conclusion

In a nutshell, the discomfort had been identified through survey questions whether the upper and lower back (spine area) of body was in discomfort felt by respondents. The working postures of the workers are bending in this hand layup process and it been done repetitively along with working days. Therefore, the unrealized works in daily work beyond the limits of the human ability to bend the body that will affect the psychophysical experienced and stress level workers toward the fatigue. The muscle activity of workers been analysed and show that 83% of muscle tended to fatigue while finishing their work task while for heart rate data 11% slightly decrease before break time and another at the end of work while it decrease 7% average of heart rate. This shows the workers are fatigue and needs rest to counter back the energy and prevent injuries in a way to make a better performance and healthy working environment. The relationship between heart rate and muscle activity show it has significant, this due to the biomechanics of human body. This analysis can be one of a way to improve the health of working by eliminating the risk of getting MSD. Due to the repetitive movement, it can be suggested to the company to redesign a comfort tools like lumbar support that can reduce the discomfort of body thus, limit motion is required and less energy required forcing the body that can help in reducing fatigues.

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