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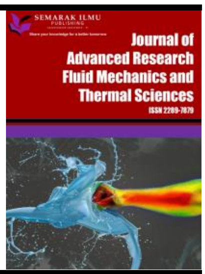

The Effects of Constant Illuminance at Multiple Temperatures Towards Muscle Activities for Rubber Scrap Industries

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ABSTRACT

The objective of this study is to determine the effect of ergonomic factors, such as temperature and illuminance level towards muscle activities through repetitive loading and unloading tasks. The study settings are in Ergonomic Laboratory Chamber and a rubber factory. Six male respondents that participated in this study wear Electromyography (EMG) device on both sides of their bodies to measure muscle fatigue. EMG output signal data were analysed to determine the correlation between muscle activities with illuminance level and temperature. At constant 500 lux illuminance level and 24˚C temperature, respondent's body shows optimum correlation between left sides and right sides. On the contrary, findings show unbalanced correlation at 19˚C and 32˚C which indicate one side of the body is using too much energy for the task.

1. Introduction

Ergonomic is a serious concern for employers nowadays due to its impact on workers performance and health. Hence, employers aim to establish workplace with good ergonomic environment that promotes efficiency, safety and overall job satisfaction. Two major ergonomic aspects that need to be considered are temperature and illuminance level [1]. Illuminance is significant in rubber industry as it is the major light source for workers to perform their job, hence it is important to determine the comfort level of workers in the workplace [2]. Moreover, lack of illuminance can affect workers' health such as resultant migraine and headache, and it can also contribute to Sick Building Syndrome [3]. Furthermore, poor lighting can also indirectly reduce the revenue of a company in the case of accidents or injuries, and increased absenteeism and reduced productivity [4].

Besides that, temperature is another crucial ergonomic factor that needs to be monitored in the rubber industry workplace; especially in Malaysia which has a warm and humid climate throughout

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the year [5]. Sukadarin *et al.,* [1] mentioned that varying temperature levels can affect task performance and thermal comfort of a person. A study by Ismail *et al.,* [6] found that temperature and relative humidity can indirectly affect the perception of comfortable level of workers at the workplace and influence productivity. Temperature range below 19˚C or above 32˚C can cause heat stress discomfort to the workers [7]. Results from Lan *et al.,* [8] computerized neurobehavioral tests show that thermal discomfort caused by air temperature had negative influence on office workers' productivity.

The combination of poor illuminance and extreme temperature can influence worker's muscular activities [9]. When the muscles exerted beyond its capacity for a period of time without adequate rest and break, lactic acid accumulation in the muscle tends to cause fatigue [10]. Muscle fatigue easily gets people exhausted and then reduce their working performance. Other than that, muscle fatigue can cause work-related musculoskeletal disorders such as back pain or muscular strain [11]. Muscle activities can be detected by electromyography (EMG), a technique that is used to detect and record electrical activity produced by skeletal muscles [12].

This study aims to examine the effect of constant illuminance at multiple pre-determined temperatures towards muscle activities of rubber scrap industries workers. Data for the study were collected through an experimental study using a simulation chamber.

2. Methodology

An experimental study had been conducted to analyse the impact of illuminance level and temperature on rubber industry's workers performances. The experiments were conducted in two environments: fieldwork (rubber factory) and simulation chamber. Six males were chosen as respondents for this study.

For experimental task in fieldwork, respondents were asked to perform their work activities which are to load and unload 25kg weight repetitively in 4 hours with 10 minutes intervals. Afterwards, respondents repeat the task in a simulation chamber. A weight was carried by the subject with their dominant hand from designated point A and unload at certain point B at relative working height level. This task was repeated for 30 seconds as per actual cycle time and estimated ten times repetitive task for one respondent with 10 minutes rest and break before continuing for 4 hours.

The EMG measurements from four muscles in the subjects' right upper limb using disposable skin surface electrodes were obtained with a computer-based data acquisition system (Shimmer150, Synchronised Biomechanics Sensor Detection). The four selected muscles in the hand-arm-shoulder complex were the right trapezius, right biceps brachii, left trapezius and left biceps brachii as shown in Figure 1 [13].

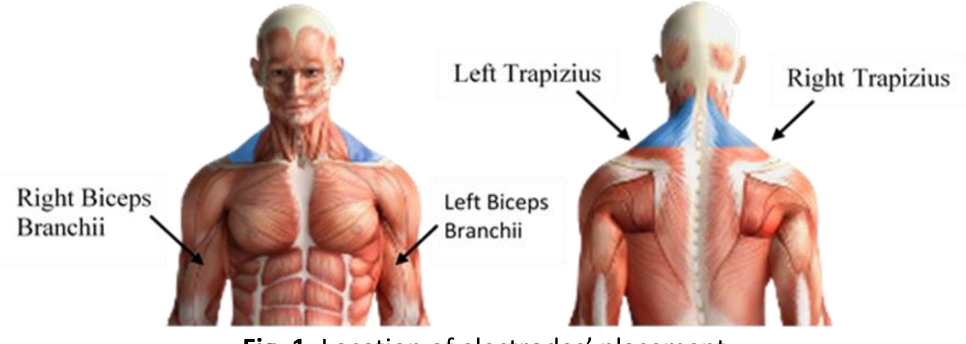


Fig. 1. Location of electrodes' placement

For the fieldwork procedure, temperature and illuminance readings were measured and recorded using WBGT and Lux Meter. Measurement was taken at each location of the muscles involved when the sampling workers perform their lifting and lowering of the rubber scraps. On the other hand, illuminance level in the ergonomics simulation chamber was manually adjusted and being set to desired parameter by adjustable light bulb and a lux meter. The temperature in the ergonomics simulation chamber is controlled and set to the designed level by adjusting the setting its control panel unit.

3. Results

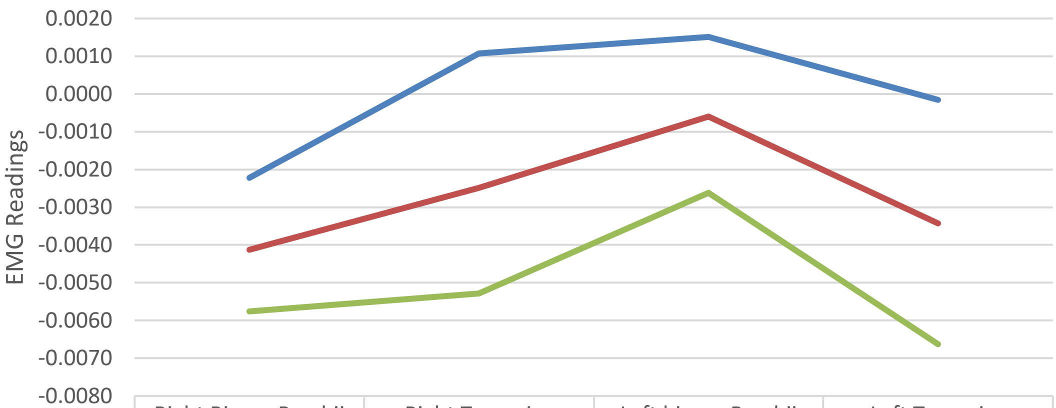
3.1 EMG Output At 500 Lux For 19˚C, 24˚C and 32˚C

Results from Figure 2 show that left biceps brachii area produced the highest EMG output for all respondents, followed by right trapezius, left trapezius and right biceps brachii. Based on temperature, the highest reading recorded were for 19˚C, followed by 24˚C and 32˚C. The left biceps area exerts more energy for the task since all of the respondents are right-handed. The non-dominant hand will exert more energy compared to dominant hand when doing task [14].

Figure 3 shows 5 respondents recording highest EMG output readings for left biceps brachii and 1 respondent for left trapezius area at 32˚C. On the other hand, lower readings are shown for right biceps, right trapezius and left trapezius. Significantly lower reading for left trapezius is shown by respondent 6, who also recorded highest left biceps reading. Respondent 4 recorded high right trapezius and left biceps brachii readings at the same time.

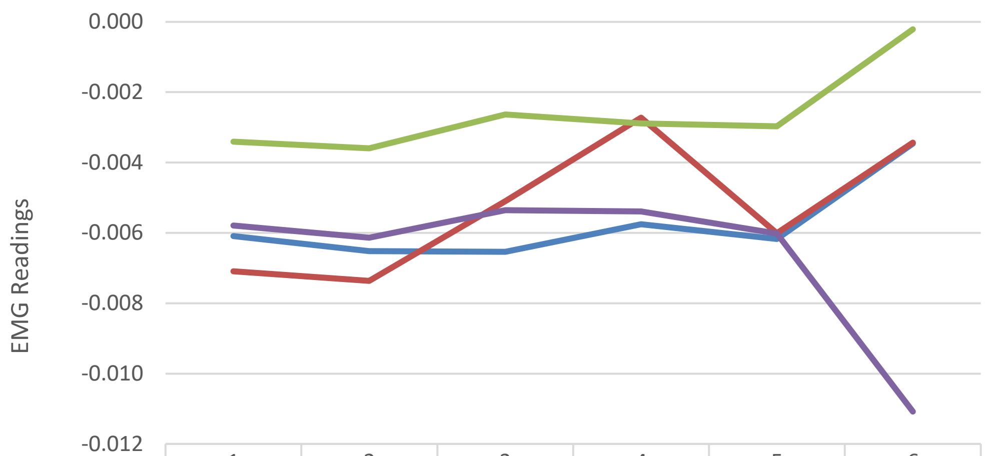
Figure 4 shows EMG output at 24˚C, where 5 respondents recorded high readings for left biceps and 1 respondent for right biceps. Besides that, output for right trapezius, left trapezius and right biceps were lower than left biceps. There were no significantly low or high EMG output recorded at this temperature. Respondent 5 exerts more energy on right bicep brachii followed by left bicep brachii.

Figure 5 shows the EMG output at 19˚C shows 4 respondents recorded high left biceps reading, while the other 2 recorded high right trapezius reading. Outputs for right biceps brachii are very low for all 6 respondents, while right trapezius and left trapezius readings were lower than left biceps, except for respondent 5.



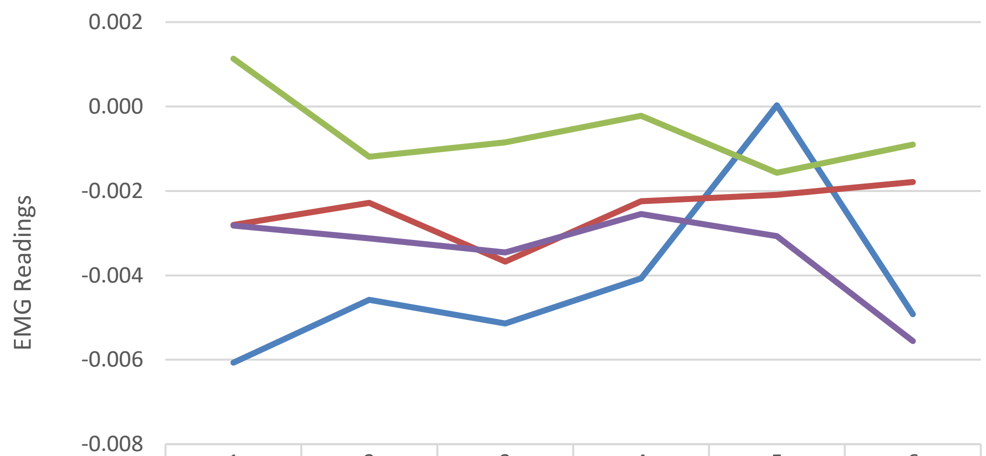
	Right Biceps Brachii	Right Trapezius	Left biceps Brachii	Left Trapezius
19°C	-0.0022	0.0011	0.0015	-0.0002
24°C	-0.0041	-0.0025	-0.0006	-0.0034
32°C	-0.0058	-0.0053	-0.0026	-0.0066

Fig. 2. EMG results for muscles activities at 500 lux illuminance and temperatures of 19˚C, 24˚C and 32˚C



	1	2	3	4	5	6
Right Biceps Brachii	-0.006	-0.007	-0.007	-0.006	-0.006	-0.003
Right Trapezius	-0.007	-0.007	-0.005	-0.003	-0.006	-0.003
Left biceps Brachii	-0.003	-0.004	-0.003	-0.003	-0.003	0.000
Left Trapezius	-0.006	-0.006	-0.005	-0.005	-0.006	-0.011

Fig. 3. EMG results for muscles activities at 500 lux and 32˚C



	1	2	3	4	5	6
Right Biceps Brachii	-0.006	-0.005	-0.005	-0.004	0.000	-0.005
Right Trapezius	-0.003	-0.002	-0.004	-0.002	-0.002	-0.002
Left biceps Brachii	0.001	-0.001	-0.001	0.000	-0.002	-0.001
Left Trapezius	-0.003	-0.003	-0.003	-0.003	-0.003	-0.006

Fig. 4. EMG results for muscles activities at 500 lux and 24˚C

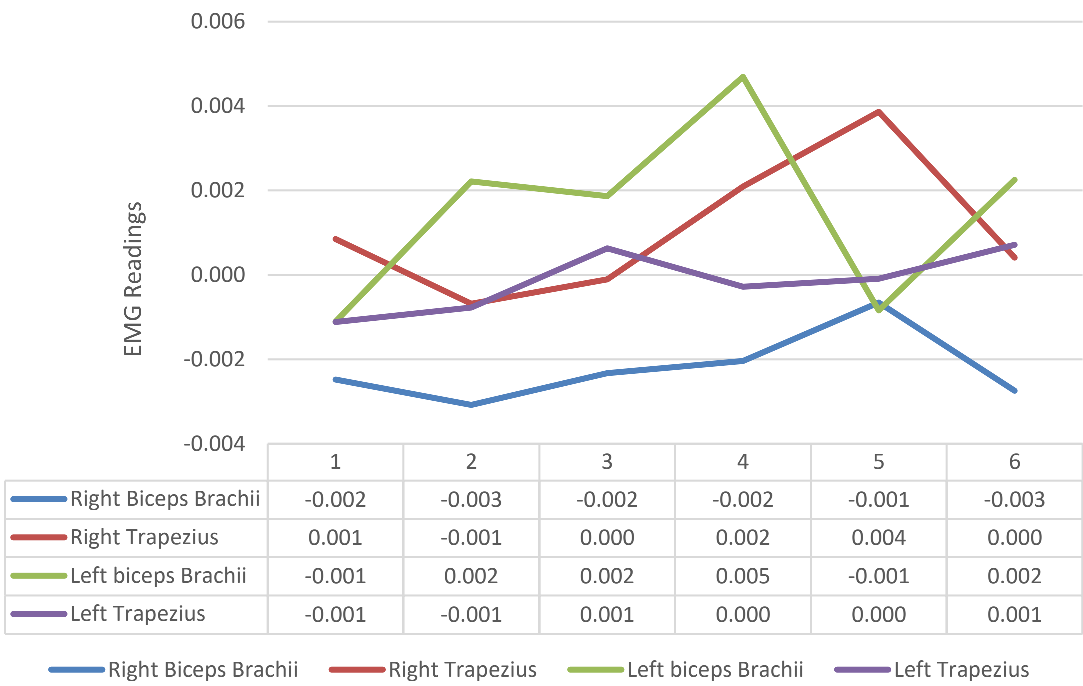


Fig. 5. EMG results for muscles activities at 500 lux and 19˚C

3.2 Correlation Results Between Right and Left Body Sides At 500 Lux

Table 1 shows the summary of correlation between the right side and left side body at constant 500 lux illuminance. At 32˚C temperature and 500 lux illuminance, correlation between right biceps brachii and right trapezius is 0.5977 while the correlation between left biceps brachii and left trapezius is -0.9169. These results indicate that the respondents utilised their muscles on the left side more than their right side while performing the loading and unloading tasks. This is because right hand dominant respondents tend use their left biceps brachii during loading and unloading. On top of that, respondents were heavily sweating during the experiments at 32˚C since it was very warm. The excessive sweating adds more strain on respondent's muscle activity and this further increased EMG output reading compared to 19˚C and 24˚C.

Table 1
Correlation results for 500 lux at 19˚C, 24˚C and 32˚C

Illuminance Level	Temperature	Right body side (relation between right biceps brachii to right trapezius)	Left body side (relation between left biceps brachii to left trapezius)
500lux	32˚C	0.5977 (medium)	-0.9169 (very strong)
	24˚C	0.3932 (weak)	0.2907 (very weak)
	19˚C	0.9394 (very strong)	0.3064 (weak)

Apart from that, for temperature 24˚C, the correlation between right biceps brachii and right trapezius is 0.3932 while the correlation between left biceps brachii and left trapezius is 0.2907. These correlations indicate that left body side is much weaker than right body side right body side. At 24˚C, respondent's right side exerts more energy, however, not significantly different than their left side.

The correlation results for 19˚C show significant changes between both right and left body sides. The right biceps brachii and right trapezius is 0.9394 while the correlation between left biceps brachii and left trapezius is 0.3064. These results show that respondents exert their muscles on the right sides far more than left sides, which is the opposite to results for 32˚C. The overall EMG reading range for 19˚C (-0.003 to 0.004) is much lower compared to 24˚C (-0.006 to 0.001) and 32˚C (-0.011 to 0). The range indicates there are not much muscle activities involved during the experiment due to low temperature.

4. Conclusions

EMG output readings from the simulation chamber experiment exhibit the impact of illuminance at 500 lux towards respondents on three different temperature settings, 19°C, 24°C and 32 °C. At very high temperature (32°C) the range of EMG output reading is the highest compared to the other two temperature settings. Moreover, respondents started to sweat heavily while performing the task due to warmer temperature. This sweating adds strain to respondent muscle and in the long run can cause muscle fatigue. On the contrary, EMG output reading is the lowest for 19°C setting. At this temperature, respondents were feeling too cold since that is not Malaysia's normal temperature range (23°C-30°C) [15]. Therefore, respondents' bodies started to adapt with the cold environment by not moving too much in conserving energy. As a result, work performance was slowed down compared to at 24°C and 32°C.

EMG reading for 24°C is at the middle among all temperature levels. In addition, the correlation between left sides and right sides of the body is not that high, and this means respondents did not excessively use one part of body compared to the other. Observation also shows no excessive sign of sweating due to the temperature. From the perspective of illuminance, there is not much impact observed or reported by the respondents. The illuminance level (500 lux) is sufficient for the respondent to do the assigned tasks, it is not too bright that it became a hindrance.

In conclusion, the ideal temperature based on experiment findings is 24°C, where respondent can perform the task without additional strain due to temperature.

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