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Determining Improvement of Working Conditions Through Evaluation of Cardiovascular Load, Extra Cardiac Pulse Due to Metabolism (ECPM) And Extra Cardiac Pulse Due to Heat Transfer to Periphery (ECPT) Workloads Traditional Industrial Bronze Metal in Bali

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ABSTRAC: *Evaluation of physical workload is very necessary, especially in traditional industries, considering that ergonomic risks, which are caused by heavy physical demands in complex work environments, often occur in various industries so that accurate and timely measurement of physical workload is the first step towards ergonomic holistic control psychosocial and physical factors improving performance. Workers in the bronze metal craft work process are accompanied by exposure to heat radiation originating from the furnace hearth burning bronze metal. The workload evaluation is based on cardiovascular workload load, extra cardiac pulse due to metabolism (ECPM) and extra cardiac pulse due to heat transfer to periphery (ECPT) to find out whether the physical workload is influenced by the demands of the task or influenced by the physical environment of the workplace. The average ECPT value is greater than the ECPM value, this shows that the physical workload is smaller than the workload due to environmental temperature, so the ergonomic intervention in this research is directed at efforts to improve environmental temperature conditions, namely by using a system for removing hot air and dust outside the work station. WBGT value in this study was 30.02 ± 0.28 o C and. The mean % CVL in this study was 57.84 ± 5.05. The results of plotting work - rest time based on the WBGT index value and % CVL, it is recommended that 50% work and 50% rest.***

KEYWORDS: *physical workload, ECPM, ECPT, CVL, WBGT.*

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I. INTRODUCTION

The currently developing concept of 4.0 ergonomics requires an understanding and agreement on the application of ergonomics in various fields to include ergonomic values and considerations in the broader conceptual framework of Industry 4.0 [1]. The application of ergonomics in traditional industry is very necessary for evaluating physical workload on human physiological and cognitive performance through objective assessments of pulse rate and body temperature [2]. Evaluation of physical workload is very necessary, especially in traditional industries, considering that ergonomic risks, which are caused by heavy physical demands in complex work environments, often occur in various industries so that accurate and timely measurement of physical workload is the first step towards ergonomic holistic control [3], because it was found that psychosocial and physical factors had more influence on improving performance than other factors [4].

Many researchers have carried out workload evaluations in various industries as an effort to increase work productivity and work safety. The application of ergonomic work combined with work safety factors can reduce operator fatigue [5], and improvements in collaborative manufacturing system is designed by balancing workload with task and equipment demands can reduce fatigue [6]. Quantitative evaluation methods of physical workload during work behaviour can be applied to design work environments taking physical workload into account [7]. Physical workload can have negative impacts, including musculoskeletal disorders that can be observed through perceived exertion (RPE), electromyography (EMG), heart rate reserve percentage, and changes in facial features [8]. Research in the construction sector shows that physical workload is a variable causing work accidents in Spain [9], so to improve work ability, designing the work environment by considering physical workload can be effective [7]. Researchers have carried out several physical workload evaluation studies, such as computer vision-based [3], biomechanical analysis methods, measuring work pulse (heart rate) for improving health conditions and working conditions [10], measuring the pulse of physical workload due to the use of personal protective equipment [11], evaluating fatigue and workload among workers performing complex assembly tasks for planning work schedules (shift duration, start time, and end time) [12].

Workload evaluation research on traditional bronze metal craft workers in Bali to fill the gap in previous research evaluating workload focused on increasing work productivity, balancing physical workload with task demands and work equipment, for biomechanical analysis, improving working conditions, use of personal protective equipment and planning work schedules. The novelty of this research is that the workload evaluation is based on cardiovascular workload load, extra cardiac pulse due to metabolism (ECPM) and extra cardiac pulse due to heat transfer to periphery (ECPT) to find out whether the physical workload is influenced by the demands of the task or influenced by the physical environment of the workplace. Workers in the bronze metal craft work process are accompanied by exposure to heat radiation originating from the furnace hearth burning bronze metal. The integrative cardiovascular response to heat stress during work depends on various variables, such as thermal stress and work intensity which causes hot skin temperatures (more than 38 O C) [13], even exposure to heat temperatures of agricultural sector workers in Taiwan increases the risk of impaired kidney function [14].

Cardiovascular workload, extra cardiac pulse due to metabolism (ECPM) and extra cardiac pulse due to heat transfer to periphery (ECPT) for Traditional Bronze Metal Craft Workers are to determine the factors that form workload based on extra cardiac pulse due to metabolism (ECPM) and extra cardiac pulse due to heat transfer to periphery (ECPT) so that improvements in working conditions can be recommended. The hypothesis proposed in this research includes extra physical workload cardiac pulse due to heat transfer to periphery (ECPT) is greater than extra cardiac pulse due to metabolism (ECPM) of bronze metal craft workers in Tihingan Village. In accordance with the hypothesis, the research question is how big is extra cardiac pulse due to heat transfer to peripheral (ECPT) and extra cardiac pulse due to metabolism (ECPM) in bronze metal craft workers.

This research is expected to contribute to recommendations for improving working conditions which include work methods, work tools, work organization and work environment to design new approaches and improve human factors and ergonomics approaches [15], which harmonize humans in the management of work systems and the environment to suit needs, human abilities [16] and limitations [17]. Thus, workers can work safely, comfortably, healthily [18] and productively [16].

II. SOLAR PLANTS MONITORING SYSTEM

2.1 Research design

This type of research is Pre-Experimental Design in one-shot form pre-test case study and post-test group design with quantitative research methods to produce generalizable results [19]. Quantitative research methods can be interpreted as research methods used to research certain populations or samples, data collection using research instruments, quantitative or statistical data analysis, with the aim of testing predetermined hypotheses. Participants in the study were only observed once and measurements were made on the status of the variables measured during the examination.

2.2 Research Location and Time

The research was carried out in the bronze craft industry, Tihingan Village, Banjarangkan District, Bali Province. The research was undertaken for the period of 3 months from January-March 2024.

2.3 Participants

Research participants were selected based on inclusion criteria, namely: (a). aged 20-56 years who are recorded based on the identity of the Resident Identity Card, (b). BMI 18-22, (c). Minimum one year work experience working in traditional metal crafts, (d). there are no physical abnormalities that could interfere with work activities which are recorded based on observations of the physical condition and the Participant's confession, and (e). declare their willingness to be a research participant. The inclusion population that meets this is then selected to become research participants. The number of samples was calculated based on the Slovin formula [20]:

$$\text{Number of samples (n)} = \frac{N}{1 + (N.e\ 2)}$$

The total population is 45 people, the confidence level is 95%, the z score value is 1.96, the margin of error (e) is 0.05 [21].

$$\text{Number of samples (n)} = \frac{45}{1 + 45\,(0.05)\,2} = 41 \text{ people}$$

2.4 Data collection techniques

Participants who stated they were willing after signing the informed form Consent data includes characteristics including: name, age according to population data, length of work experience, body weight, height, body mass index, haemoglobin (Hb) level, and systolic and diastolic blood pressure. All data Participants' health was recorded by local Health Officers. Before starting work, participants had their pulse rate, body temperature and weight recorded before work by a local Health Officers. During work, participants had their work pulse and body temperature measured every hour for 4 working hours starting at 08.00 to 12.00 Central Indonesian time. After finishing work, participants were again measured for recovery pulse rate, body temperature and body weight after work. The worker's pulse is measured by holding and pressing the wrist to feel the pulse on the radial artery, after reaching the 10th pulse, the time (seconds) is calculated, then the pulse with the formula:

$$\text{Pulse (beats/minute)} = \frac{\text{10 beats}}{\text{time (seconds)}} \times 60$$

Cardiovascular Strain (%CVL), calculated based on pulse rest, pulse work, and pulse maximum with formula:

$$\%CVL = \frac{100\ (\text{beats pulse work} - \text{Pulse Rest})}{(\text{Pulse maximum} - \text{Pulse Rest})}$$

Temperature body be measured with a digital thermometer, and body weight was measured with digital body scales. The physical conditions of the work environment include: Wet air temperature, dry air temperature, spherical air temperature, relative humidity, WBGT index, light intensity, noise and wind speed measured every hour by the Bali Province Corporate Hygiene and Occupational Health Officer. Participants in work activities during the research were given daily wages for 3 days of data collection. Each participant involved was given a pseudonym to maintain ethical data confidentiality and this was communicated to the participant before data collection began [22].

2.5 Data analysis

The data obtained was then processed and analysed with the help of a computer, the SPSS (Statistical) program Packages for The Social Sciences) version 23.0 for windows to test the relationship between predetermined variables. In this research, the data that will be processed are: participant characteristics, workload (pulse rate and body temperature) which are analysed in the following way: (1) Descriptive analysis, to provide an overview of the characteristics of the data obtained from the research results; (2). Normality test on all data from research results using Shapiro-Wilk Test. ($n<50$); (3). The data comparability test is comparing the average value before work (O 1) and after work (O 2); (4). For data between groups with normal distribution, Paired - Samples t- Test is used; (5). For data that is not normally distributed, transformation is carried out, if the transformation results are not normal then Wilcoxon is used Sign Ranks Test; (6). The difference test before and after work is to test the difference between the average data before work (O 1) and the average data after work (O 2); (7). All tests have a significance level of 5% (α=0.05).

III. WIND TURBINES MONITORING SYSTEM

3.1 Participant Characteristics

There were 45 research participants, all of whom were male. Participant characteristics include age, height, weight, body mass index (BMI), blood haemoglobin level (Hb), systolic blood pressure, diastolic blood pressure, and work experience. Complete characteristics of research participants are presented in Table 1.

Table 1
Participant Characteristics According to Age, Weight and Height, Work Experience, Systolic, Diastolic and BMI of Industrial Workers Traditional Bronze Metal in Tihingan Klungkung Village, Bali (n=41)

No.	Description	Minimum	Maximum	Average	Standard Deviation
1.	Age (years)	24.00	55.00	42.15	8.31
2.	Height (cm)	161.80	175.00	165.87	4.03
3.	Body Weight (kg)	52.70	72.60	62.43	6.77
4.	BMI (kg/m ^{2})	18.85	21.09	20.89	1.53
5.	Hb (gr /dl)	12.03	14.42	13.32	0.83
6.	*Systole* (mmHg)	110.00	120.00	116.14	4.64
7.	*Diastole* (mmHg)	70.00	80.00	75.21	3.98
8.	Work Experience (years)	5.00	14.00	7.90	3.15

n: number of measurements

Table 1 shows that the mean age of the participants was 42.15 ± 8.31 years and the age range was 24 – 55 years. This age range is still included in the working age group and includes the workforce according to the Central Statistics Agency (BPS). The applicable age limit for the workforce in Indonesia is 15 to 64 years. Law of the Republic of Indonesia Number 13 of 2003 concerning Employment, in Chapter I General Provisions, article 1 paragraph (2) states that labour is every person who is able to do work to produce goods and/or services either to meet their own needs or for the community. The average age of the participants in this study when viewed from muscle strength, specifically after the age of 30 years, there is a continuous loss of muscle mass and strength, which has an impact on bone quality (osteoporosis or osteopenia), balance (falls) [23]. Physical strength will begin to decline and Muscle contractions and body strength at the age of 40 years begin to decrease in isometric, concentric and muscle contractions, eccentric, and muscle decline occurs more rapidly with age 65 - 70 year [24]. Meanwhile, productivity increases with age up to the age of 40 years and then remains stable after that age [25]at the age of 20-60 years. There has been no decline in the productivity of workers in service sector companies [26].

The minimum participant BMI calculation results were 18.85 kg/m 2 and the maximum was 21.09 kg/m 2 with the mean being 20.89 ± 1.53 kg/m 2. The meaning of this BMI value is that the worker is in a condition of normal nutritional status. According to World Health Organization Asian- Population Normal BMI criteria for Asians range from 18.5-23 kg/m2, while the risk cut-off points vary from 22 kg/m2 to 25 kg/m2 in Asian populations and for diabetes and cardiovascular risk. disease height varies from 26 kg/m2 to 31 kg/m2 [27].

The participant's minimum haemoglobin level in the blood (Hb) was 12.03 gr /dl and a maximum of 14.42 gr /dl with a mean of 13.32 ± 0.83 gr /dl. Systolic blood pressure was obtained as a minimum of 110 mmHg and a maximum of 120 mmHg with a mean of 116.14 ± 4.64 mmHg. Diastolic blood pressure was a minimum of 70 mmHg and a maximum of 80 mmHg with a mean of 75.21 ± 3.98 mmHg. Haemoglobin is a component that functions as a means of transporting oxygen (O2) and carbon dioxide (CO2). The amount of haemoglobin in whole blood is expressed in grams per deciliter (g/dl). Normal haemoglobin levels in men are 14 to 18 g/dl, while for women it is 12 to 16 g/dl and low haemoglobin levels if the haemoglobin amount is less than 12 g /dl indicates anaemia [28].

Participants' minimum work experience is 5.00 years and the maximum is 14.00 years with a mean of 7.90 ± 3.15 years. During the implementation of the research, no participants dropped out. Work experience in formal sector jobs is generally considered to increase a person's work ability, the relationship between work experience and income reaches a point of change from a positive correlation to a negative correlation at a minimum age of 36 years, with an average age of 56 years [29]. Studies show that as work experience increases, workers tend to perform relatively better [30].

3.2 Physical Work Environment Conditions

The physical environmental conditions of the workplace measured in the research include wet air temperature, dry air temperature, spherical air temperature, relative humidity, Wet Bulb Globe Temperature (WBGT) index, light intensity, noise and wind speed as presented in Table 2.

Table 2
Industrial Physical Environmental Condition Data
Traditional Bronze Metal in Tihingan Village, Klungkung, Bali (n=16)

	Description	Minimum	Maximum	Average	Standard Deviation
1.	Wet air temperature (^{0}C)	27.98	29.59	28.71	0.41
2.	Dry air temperature (^{0}C)	32.20	33.63	32.99	0.38
3.	Ball air temperature (^{0}C)	31.90	33.80	32.92	0.54
4.	Relative humidity (%)	59.96	63.91	61.53	1.04
5.	*WBGT Index* (^{0}C)	29.65	30.78	30.02	0.29
6.	Light intensity (Lux)	320.47	330.50	325.57	3.20
7.	Noise (dB)	82.60	87.80	85.81	1.50
8.	Wind speed (m/ sec)	0.50	1.10	0.82	0.17

n: number of measurements

Table 2 shows that the wet air temperature is in the minimum range of 27.98 0 C and the maximum is 29.59 0 C with an average of 28.71 ± 0.41 0 C. The dry air temperature is in the minimum range of 32.20 0 C and the maximum is 33 .63 0 C with an average of 32.99 ± 0.38 0 C. The ball air temperature is in the minimum range of 31.90 0 C and a maximum of 33.80 0 C with an average of 32.92 ± 0.54 0 C. Relative humidity is in the minimum range of 59.96% and maximum 63.91% with a mean of 61.53 ± 1.04%. The results of the WBGT index calculation obtained a minimum of 29.65 0 C and a maximum of 30.78 0 C with a mean of 30.02 ± 0.29 0 C. The light intensity is in the range of a minimum of 320.47 lux and a maximum of 330.50 lux with a mean of 325, 57 ± 3.20 lux. Noise is in the minimum range of 82.60 dB and maximum 87.80 dB with a mean of 85.81 ± 1.50 dB. Wind speed is in the minimum range of 0.50 m/sec and maximum 1.10 m/sec with an average of 0.82 ± 0.17 m/sec. Data normality test results with Shapiro-Wilk test as presented in Table 3.

Table 3
Normality Test Results with Shapiro-Wilk Test Data on Industrial Physical Environmental Conditions
Traditional Bronze Metal in Tihingan Village, Klungkung, Bali (n=16)

No.	Physical Environmental	z	p	Test results
1.	Wet air temperature (^{0}C)	0.394	0.286	Normal
2.	Dry air temperature (^{0}C)	0.975	0.911	Normal
3.	Ball air temperature (^{0}C)	0.960	0.654	Normal
4.	Relative humidity (%)	0.962	0.703	Normal
5.	*WBGT Index* (^{0}C)	0.907	0.106	Normal
6.	Light intensity (Lux)	0.946	0.436	Normal
7.	Noise (dB)	0.928	0.229	Normal
8.	Wind speed (m/ sec)	0.949	0.478	Normal

n: number of measurements

Based on the Minister of Health's decision nomor. 405 of 2002 concerning requirements and procedures for implementing healthy industrial work environments and Minister of Manpower and Transmigration regulations no. 13 of 2011, concerning NAB Physical and Chemical Factors in the Workplace, noise intensity must not exceed 85 dB at a daily exposure time of 8 hours that workplace noise is still within normal limits if it is below 85 dB [31]. Noise above the threshold value can trigger cardiovascular changes such as heart rate per minute [32]. The wind speed value in this study is in comfortable working conditions so it is recommended that air movement in the room be no more than 0.2 m/second so that air movement does not have a negative impact on workers, while for work environments that are exposed to heat a higher wind speed is needed. tall [31].

3.3 Workload, CVL percentage, ECPT, ECPM, skin surface temperature, and weight loss

The results of measurements of participants during work in Period I and Period II research showed that the participant's pulse rate continued to increase, which had an impact on % CVL, ECPT, ECPM, and there was an increase in skin surface temperature and a decrease in body weight during the 4 hours of work. The measurement results data are presented in Table 4.

Table 4
Data on Pulse Rate, % CVL, ECPT, ECPM, Skin Surface Temperature, and Weight Loss Traditional Bronze Metal Industry Workers in Tihingan Village, Klungkung, Bali (n=41)

No.	Description	Minimum	Maximum	Average	Standard Deviation
1.	Resting heart rate (beats/minute)	66.67	80.00	74.33	4.00
2.	Working pulse (beats/minute)	132.27	136.41	134.01	1.14
3.	Working pulse (beats/minute)	53.39	65.47	58.94	3.71
4.	% *CVL*	47.09	66.77	57.84	5.05
5.	*ECPT*	15.11	23.78	19.26	2.52
6.	*ECPM*	12.89	22.89	17.46	2.96
7.	Skin surface temperature before work (^{o} C)	36.20	36.87	36.56	0.18
8.	Skin surface temperature after work (^{o} C)	39.06	40.28	39.74	0.36
9.	Weight before work (kg)	51.30	73.43	61.05	6.41
10.	Body weight after work (kg)	51.30	72.23	59.72	6.47
11	Weight loss (kg)	1.20	1.50	1.34	0.09

n: number of measurements

Table 4 shows that in this study the average resting pulse rate of workers was in the range of a minimum of 66.67 beats/minute and a maximum of 80.00 beats/minute with a mean of 74.33 ± 4.00 beats/minute. The average working pulse rate of workers is in the range of a minimum of 132.37 beats/minute and a maximum of 136.41 beats/minute with a mean of 134.01 ± 1.14 beats/minute. Participants' working pulse was in the minimum range of 53.39 beats/minute and maximum 65.47 beats/minute with a mean of 58.94 ± 3.71 beats/minute. Cardiovascular load (% CVL) was in the minimum range of 47.09 and maximum 66.77 with a mean of 57.84 ± 5.06. The ECPT value is in the minimum range of 15.11 and maximum 23.78 with a mean of 19.26 ± 2.52. The ECPM value is in the minimum range of 12.89 and maximum 22.89 with a mean of 17.46 ± 2.96. The average skin surface temperature before work was in the minimum range of 36.20 o C and a maximum of 36.87 o C with a mean of 36.56 ± 0.18 o C. The average skin surface temperature after work is in the range of a minimum of 39.06 o C and a maximum of 40.28 o C with a mean of 39.74 ± 0.36 o C. The average body weight of workers before work is in the range of a minimum of 51.30 kg and a maximum of 73.43 kg with a mean of 61.05 ± 6.41 kg. The average body weight of workers after work is in the range of a minimum of 49.87 kg and a maximum of 72.23 kg with a mean of 59.72 ± 6.47 kg. The average weight loss of participants was in the range of a minimum of 1.20 kg and a maximum of 1.50 kg with a mean of 1.34 ± 0.09 kg.

Table 4 shows that the average ECP T value is greater than the average ECPM value, meaning that the workload of participants in this study is more influenced by environmental temperature conditions, namely exposure to radiant heat from the process of burning bronze metal before it is forged into craft products. The workload classification as measured by the worker's pulse rate is included in the "heavy" workload category because it is in the range of 125-150 beats/minute [31].

Judging from the results of ECPT and EPM calculations as shown in Table 4, the average ECPT value obtained is greater than the ECPM value. This shows that the physical workload is smaller than the workload due to environmental temperature, so the ergonomic intervention in this research is directed at efforts to improve conditions. environmental temperature, namely by using a hot air and dust exhaust system outside the work station.

3.4 Plotting work time – rest

To monitor external load originating from environmental temperature, calculated using the WBGT index (Wet Bulb Globe Temperature) and cardiovascular load (% CVL). The mean WBGT value in this study was 30.02 ± 0.28 o C and. The mean % CVL in this study was 57.84 ± 5.05. The results of plotting work - rest time based on the WBGT index value and % CVL are presented shows that work activities in this study are recommended at 50% work and 50% rest in Figure 1.

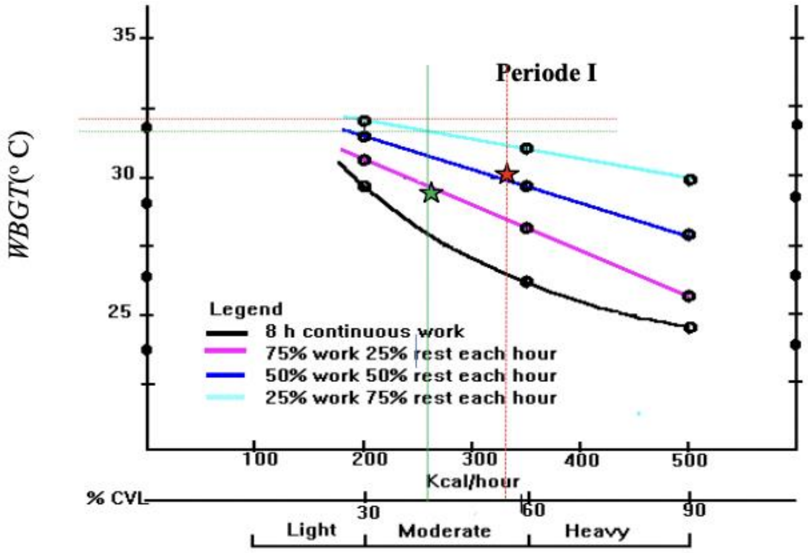

Figure1 Plotting of Work and Rest Time Based on the WBGT Index and % CVL of Participants in the Traditional Bronze Metal Industry Workers in Tihingan Village, Klungkung, Bali

3.5 Proposals to Improve Working Conditions

According to the research results, it was found that the increase in the physical workload of workers in the bronze metal craft industry was due to exposure to hot temperatures originating from the process of burning bronze metal materials in forging bronze metal into craft objects in the desired shape. Exposure to hot temperatures occurs because the combustion furnace is still open and the remaining combustion ash becomes a source of heat which spreads into the environment and the heat of the flame also spreads and exposes workers who must be near the furnace. Several researchers proposed efforts to apply ergonomics to hot work environments , including: practical application of protective clothing standards for moderate thermal radiation environments [33], to reduce the occurrence of heat stress is recommended by providing adequate drinking water [34], implementing regular breaks with the provision of adequately ventilated rest rooms [35], and improving existing control strategies, including engineering controls, management controls, and personal protective equipment [36]. Efforts to improve the workplace for burning furnaces from open flames recommend using a closed furnace system equipped with a canopy to exhaust dust and residual combustion heat to the outside, thereby reducing workers' exposure to heat radiation

IV. CONCLUSION

Cardiovascular workload load, extra cardiac pulse due to metabolism (ECPM) and extra cardiac pulse due to heat transfer to periphery (ECPT) in traditional bronze metal craft workers obtained that:

a. Participants' working pulse was in the minimum range of 53.39 beats/minute and maximum 65.47 beats/minute with a mean of 58.94 ± 3.71 beats/minute.
b. Cardiovascular load (% CVL) was in the minimum range of 47.09 and maximum 66.77 with a mean of 57.84 ± 5.06.
c. ECPT value is in the minimum range of 15.11 and maximum 23.78 with a mean of 19.26 ± 2.52.
d. ECPM value is in the minimum range of 12.89 and maximum 22.89 with a mean of 17.46 ± 2.96.
e. The average skin surface temperature before work was in the minimum range of 36.20 o C and a maximum of 36.87 o C with a mean of 36.56 ± 0.18 o C.
f. The average skin surface temperature after work is in the range of a minimum of 39.06 o C and a maximum of 40.28 o C with a mean of 39.74 ± 0.36 o C.
g. The average body weight of workers before work is in the range of a minimum of 51.30 kg and a maximum of 73.43 kg with a mean of 61.05 ± 6.41 kg. The average body weight of workers after work is in the range of a minimum of 49.87 kg and a maximum of 72.23 kg with a mean of 59.72 ± 6.47 kg. The average weight loss of participants was in the range of a minimum of 1.20 kg and a maximum of 1.50 kg with a mean of 1.34 ± 0.09 kg.
h. The average ECPT value is greater than the ECPM value, this shows that the physical workload is smaller than the workload due to environmental temperature, so the ergonomic intervention in this research is directed at efforts to improve environmental temperature conditions, namely by using a system for removing hot air and dust outside the work station.

i. WBGT value in this study was 30.02 ± 0.28 o C and. The mean % CVL in this study was 57.84 ± 5.05. The results of plotting work - rest time based on the WBGT index value and % CVL, it is recommended that 50% work and 50% rest.

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