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Research Article

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Workload Evaluation on Workers at Steam Power Plant Based on Physiology Condition

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Abstract The physical and mental health conditions of the workers in night shift strongly affect the safety program and the quality or productivity of work in the office. The objective of this research is to know the level of health and work load of workers especially in Steam Power Plant. The first step is to study literature about work shifts and their metabolism, and also body rhythms of the human being. Every worker will measure his physiological condition by measuring the average change in heart rate and blood pressure at rest and while working on steam power plant. The workers in the operation department who work three shifts have the highest blood pressure average value 138 mmHg/86 mmHg. Heart rate change before and during work is equal to 2.6 bpm (2.45 kcal/min), can be categorized in light work load. Thus, it can be concluded that workers have poor health condition due to night shift work.

Keywords work shift, metabolism, cardiovascular, energy expenditure, steam power plant

1. Introduction

Twenty-four hour services are a growing part of modern society. Essential services are provided without interruption, and several industries and business establishments operate on a 24 h basis so as to meet the constantly changing demands of the modern world [1, 2]. Not only the company, but also the workers who were forced to work for 24 hours. Thus, shift work becomes absolutely necessary to divide the work load. Therefore, the workers can be sure there will be work at night. In many studies it is said that many night shifts adversely affect health. A Japanese study compared the annual checkups of day workers with those of adults with alternating day/night shifts between 1991 to 2005. Alternating shift workers were found to have increased arterial pressure, even after adjusting for confounding factors. These findings suggested that alternating shift work may constitute an independent risk factor for increased blood pressure levels regardless of the known risk factors such as age and BMI [2, 3]. A study of worker health performed in seven French hospitals evaluated participants on two occasions and found that the systolic arterial pressure of night workers was 2.5 mmHg ($p < 0.001$) higher than that of day workers [2, 4].

Heart rate and blood pressure are human physical indicators that can be used to determine the health and Physio-psychological load of workers. Sugiono [5] in his article reported that the difference of rest heart rate and activity heart rate were used to measure and to classify workload for static bicycle test. Sanchita Ghosha and friends in their research noted that heart rate can successfully be used as a proxy for the measurement of rate of oxygen consumption or metabolic [6]. Environment condition e.g. temperature and relative humidity are also influences on the human comfort as well as workers' in Steam Power Plant. Difference environment parameters will impact on human physiological such as increasing heart rate, blood pressure and breathing rate [7,8]. According to the reference, physiological factors (heart rate and blood pressure) are important factors to evaluate and classified workload in industry. The paper used the human physical approaching (heart rate behavior correlated with activity, age and weight) to figure out the best solution for workers in Steam Power Plant at PJB, Paiton, Indonesia.

2. Methods

Heart rate and blood pressure data collection (further referred as physiological data) were performed at all departments in PJB Paiton factory as shown in table 1 below. Measurements were made twice on each worker, i.e. measurement of heart rate at rest (before work) and measurement of heart rate at work, each replication performed three times. The need of replication is to find out how big the data variants are due to the equipment used and the readiness of the workers. The measurement method used in this research is sampling method. The experimental subject are workers who are ready and fit the research needs. The basic principle is to be used as a worker as possible sampling research to be able to describe the working conditions of the company as a whole and true.

Table 1: The number of sampling workers taken as a source of data in each department

Department	Room	Population (People)	Sample (People)
Administration	Procurement	10	5
	Finance	10	3
	Human Resource (HR)	8	3
Engineering	CBM	10	3
	SO	12	5
	RendalHar	12	8
Maintenance	MI	15	5
	I&C	11	4
	Electrical	12	7
	M2	11	5
Operation	CCB Room	15	5
	CHCB Room	8	5
	Rendal Ops	7	3

The process of physiological data collection is taken carefully and in accordance with the procedure on the worksheet. First, socialize the purpose of measurement data, so that all prospective respondents feel comfortable at the time of measurement. In resting conditions (before work) respondents are given time to take a supine position either in a chair or in lying down for approximately 10 minutes. Each replication is given pause in 4 minutes, to allow workers calm down or in normal rest condition.

A

B

Figure 1: a. Heart rate data collection while rest condition, b. Heart rate data collection while working condition

Figure 1 is an example of the physiological data retrieval process based on the reference worksheet assessment. In the worksheet assessment the heart rate measurement was performed twice on each sample, i.e. at rest (before work) in relaxed condition (Figure 1A), and while working (Figure 1B), each of which was performed three times. There are 4 teams that make measurements with each carrying a pulse meter and an assessment worksheet. In addition to the measurement of physiological data, interviews were also conducted after the measurement process was completed. Interviews are about daily life patterns such as smoking habits, exercise habits, diet, and also complaints at work or afterwards in each department.

In table 2 below is an example of the physiological data of one of the workers in the CCB Operations department, measured at rest and at work. Table 2 shows that the heart rate increases from 102 bpm to 107 bmp or up 5 bpm (5%), while for average systole increases from 135 mmHg to 142 mmHg or up 7 mmHg (5.2%), average diastole also increases significantly from 91 mmHg to 99 mmHg or up 8 mmHg (8.8%).

Table 2: Example of worker physiological data at rest and at work

Replication	Heart rate (bpm)	Blood Pressure		Condition
		Systolic (mmHg)	Diastolic (mmHg)	
1	106	134	89	At Rest
2	98	135	91	
3	101	136	94	
Average	**102**	**135**	**91**	
	108	150	95	At Work
	108	135	103	
	106	141	99	
Average	**107**	**142**	**99**	

Table 3 shows average workers' old and average workers' body weight for all departments in steam power plant. From the table it can be seen that the range different of average age and weight for all department is not wider. The average age range is 26.2 to 34.8 and the average weight range is 60.4 to 75.9. The workers in operation CCB, operation CHCB and engineering RendalHar have weight > 70 Kg or more than average weight. In addition to physiological data, it also provides questions about the conditions of the workers when measurements are made, such as:

- At the time of measurement, have the workers eaten?
- Do workers regularly consume cigarettes and coffee?
- Does the workers have a condition of body stiff or aches, and eyes feel blurry when seeing something?

Table 3: Age and Body Weight Data of workers from each department

Department	Average Age (years)	Average Body Weight (Kg)
Operation CCB	32.4	75.2
Operation CHCB	29.6	72.0
RendalEngineering (CBM)	26.3	65.4
Engineering (SO)	30.4	65.9
Engineering (RendalHar)	28.9	73.2
Maintenance (MI)	33.0	68.4
Maintenance (I&C)	29.5	63.5
Maintenance (electrical)	29.6	67.3
Maintenance (M2)	34.8	60.4
Administration (Procurement)	26.2	61.7
Administration (Finance)	31.7	69.5
Administration (HR)	29.7	65.0

This measurement standard also applies to workers in other departments either from the administration department, the maintenance department and also the engineering department. The average data of average heart rate and blood pressure in rest condition and in working condition for all departments (13 department with different specific job) of Steam Power Plant, PJB Paiton are shown in table 4.

Table 4: Measurement results of physiological data in each department

Department	Average Heart Rate		Average Blood Pressure (Systolic)		Average Blood Pressure (Diastolic)	
	Rest (bpm)	Work (bpm)	Rest (mmHg)	Work (mmHg)	Rest (mmHg)	Work (mmHg)
CCB	84.8	87.4	124	131	80	86
CHCB	79.4	81.4	122	138	76	85
Rendal	68.7	70.9	98	103	66	69
Engineering (CBM)	80.1	79.8	114	107	74	65
Engineering (SO)	77.5	77.3	113	112	78	74
Engineering (RendalHar)	83.1	80.4	124	123	81	76
Maintenance (MI)	81	74.6	128	119	82	59
Maintenance (I&C)	77.8	76.9	116	115	80	77
Maintenance (electricity)	88	84.6	117	98	77	65
Maintenance (M2)	75	75	116	104	69	62
Administration (Procurement)	70.1	72	127	127	78	78
Administration (Finance)	67.6	74.6	101	105	64	73
Administration (HR)	82.4	81.8	116	119	81	80

The heart rate investigation such as measurement of oxygen consumption (VO_2 max) needs special technical knowledge, skill and sophisticated instrumental setup. It becomes difficult to determine the oxygen consumption of a human with limited resources. As consequence, many researches exploit the relationship among heart rate, blood pressure and VO_2 max consumption. According to the journal noted that the VO_2 max can be calculated as formula 1bellow [8]:

$$VO2max = 15 \frac{mliter}{Kg.minute} x \frac{HRmax}{HRrest}$$

Where:

VO_2max = Maximum oxygen consumption (mliter)
HRmax = maximum heart rate (bpm)
HRrest = Heart rate in rest condition (bpm)

3. Results and Discussion

Data processing that has been collected both, the physiological data and the information from the interview (lifestyle, job complaints) used to analyze the workload and the health evaluation of the workers. This is done as an effort to continuously improve productivity. For example, such as: job scheduling, physical work environment, medical record, daily living patterns, stress levels, work motivation, and company management.

This research will generally be divided into two main parts, namely workload analysis and work physiological analysis obtained from physiological data as well as interviews. The first step in determining the workload is with calculating oxygen (O2) consumption by the body in conducting its activity through aerobic reactions. O2 here will be used by the body in three functions, ie to survive (breathing and blood circulation), to digest food, and to work. oxygen consumption as follows:

VO_2 = (15 x W x HR) / (1000 x RHR) L/minute
= (15 x 105 x 107) / (1000 x 102) L/minute
= 1.66 L/minute

The three kinds of energy needs to be released by the human body is called the energy expenditure. Energy expenditure is the total metabolism rate in the human body (basal metabolism rate = BMR, digestive metabolism rate = DMR and activity metabolism rate = AMR). The operator 1 at operation CHCB will has the total of energy expenditure as follow:

$E_{expenditure}$ = VO2 x 4.8 Kcal/Minute
= 1.66 x 4.8 Kcal/minute
= 7.98 Kcal/minute

Basal Metabolic Rate (BMR) or energy for survival (breathing and circadian) is highly dependent on the sex and age of the workers. The older workers, the decrease of metabolism ability. From the sample workers 1 above it can be measured the amount of its BMR as follows:

Age correction factor (fku) = ((A – 20)/10)*0.02
= (34 - 20)*0.02
= 0.028

BMR = K Kcal/Kg hour x (1- fku) x W Kg x (1/60 menute)
= 1x (1- 0.028) x 105 x (1/60) Kcal/minute
= 1.70 Kcal /minute

Digestive Metabolic Rate (DMR) or energy for digestion is highly dependent on BMR and AMR. The more hard work the faster the digestion process. From the sample workers above it can be measured the amount of its DMR as follows:

DMR ≅ 0.1 $E_{expenditure}$
≅ 0.8 Kcal/minute

Total of energy activity (doing job) for operator 1 at operation CHCB Steam Power Plant can be calculated as follow:

AMR = $E_{expenditure}$ – DMR – BMR
= 7.98 - 0.80–1.70
= 5.48 Kcal/minute

From the measurement data and calculations it can be summarized that one worker in the CCB Operations department has oxygen consumption = 1.66 L / min, heart rate at work with an average of 107 bpm and Energy expenditure = 7.98 kcal. With additional information that the worker is 34 years old, weight = 105 kg, height 165 cm, working length = 8 years, have body aches, smoking and coffee consumption. From table 5 it can be concluded that these workers are categorized as workers who have heavy workload based on oxygen consumption and also energy expenditure, but in moderate category if based on heart rate at work. This difference must of course be compared to other workers in the same type of work that is generally based on light work, so it can be concluded that this worker has a very bad health, as evidenced by heart rate before work is very high that is 102 bpm and only rose by 107 bpm.

Table 5: Work load classification based on 3 considerations [9]

Work Load	Consumption (liter/minute)	Energy Expenditure (Cal/min)	Heart Beats during Work (Beats/min)
Light	0.5-1.0	2.5-5.0	60-100
Moderate	1.0-1.5	5.0-7.5	100-125
Heavy	1.5-2.0	7.5-10.0	125-150
Very Heavy	2.0-2.5	10.0-12.5	150-175

Overall changes in the worker's heart rate in PJB Paiton can be shown in the graph in Figure 2below. Graphs of heart rate changes in workers at rest and work only contain some departments only, while other departments are not included in the graph because of having a non-significant heart rate change or tend to be the same as the heart rate before work (resting conditions). From the graph it can be concluded that workers in all departments have a fairly low working heart rate (safe area) and a fairly high heart rate rest especially on the CCB and CHCB Operations department. Based on further explanation this is due to the workers having night shift at the time before the day of measurement.

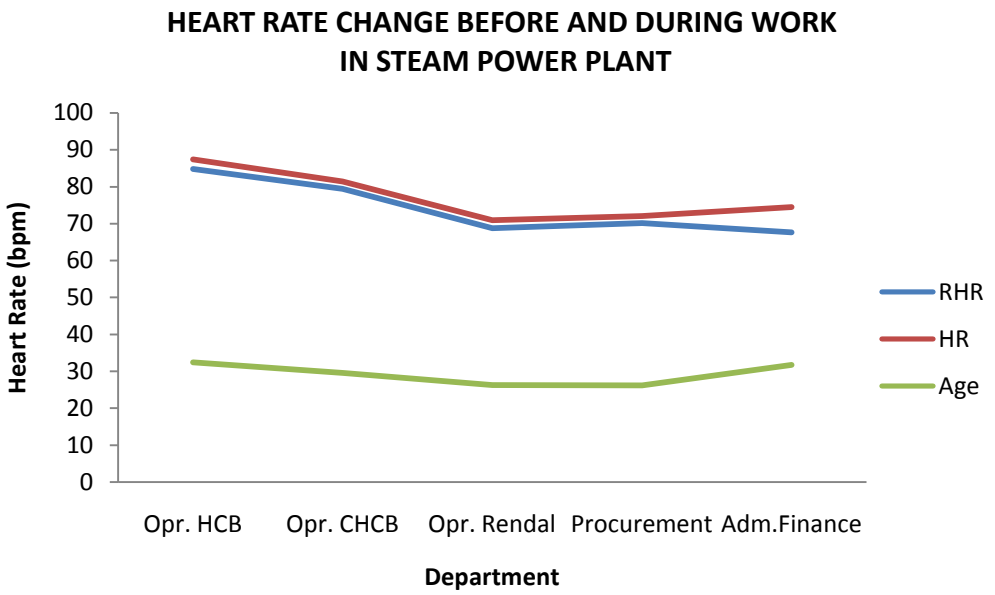

Figure 2: Graph of heart rate change before and during work in PJB Paiton, unit 9

4. Conclusion

Based on the theory of ergonomics, measurement process, observation process, interview, and results analysis, it can be concluded that:

1. Overall workload of employees can be classified as a light workload, but will be dangerous due to poor worker health. This is evidenced by high blood pressure in some workers, especially operating workers.
2. The solution offered for this problem is improving the health conditions of the workers by exercising regularly, dietary patterns that fit the needs of the body, not smoking, and so forth. In addition to workers who perform shifts work must be made a good schedule that follows the rules of the clock rhythm of the human body. The management must ensure that the standard of work of the worker in carrying out his duties and ensuring the work ethic is carried out regularly and responsibly.

Improved work culture to reduce the risk of safety and health even better

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