DINAMIKA REKAYASA
http://dinarek.unsoed.ac.id

Volume 20 Nomor 2 (2024) Hal. 127-134
e-ISSN 2527-6131
http://jurnal.dinarek.unsoed.ac.id

Analysis of Mental and Physical Workload on Kerupuk Sehati Factory Employees

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Abstract

The Kerupuk Sehati Factory produces and sells cooked and raw crackers. The production capacity of raw crackers is 1000 kg per day for 8-9 working hours with 17 employees. The problem is that workers feel an excessive physical workload, so worker performance decreases and workers cause errors, namely, products become defective. This research aims to measure workers' mental and physical workload and make improvements so that workers' workload is reduced. Workers' mental workload was measured using the NASA-TLX method, and workers' physical workload was measured using the CVL method. Measurement results based on NASA-TLX revealed that the average mental workload is in the high category of eleven workers and the very high category of six workers. The calculated CVL values showed that the two greatest physical workloads were felt by Respondent A, with a CVL value of 31.36%, and Respondent L, with a CVL value of 38.93%. Reducing physical and mental workload is recommended by adding exhaust fans, checking machines and equipment before production, using conveyance, organizing training, and providing rest areas.

Keywords: *Workload, NASA-TLX, CVL, Production Control*

I. INTRODUCTION

The factory of Kerupuk Sehati was established in 1996 at Jatibening, Pondok Gede subdistrict, Bekasi. It produces fried and raw crackers and is widely known as the producer of rose crackers. It supplies consumers with daily demand for raw rose crackers that reach a production capacity of 1000kg daily and 24 tons monthly. Rose cracker production is carried out using machines such as rolling, mixers, ovens, and cracker molding machines. Rose cracker production activities are carried out by 17 employees from 07.00 to 16.00 GMT+7. Factors such as low lighting levels (77 lux), room temperature between 32°C - 35°C, and inadequate air circulation can affect the worker's workload. The working position, workload, and mental state of the worker during work must be known to the company. Workers experience fatigue and suffer injuries if the workload is excessive [1].

According to Putri and Sukarna (2017), in Sitorus et al. [2], workload analysis can be used as a tool for assessing and evaluating the needs of the workers within the perspective of ergonomics and industrial occupational health and safety. Human work activities can be grouped into two main components, which are physical and mental work activities. Both work activities are inseparable since they are interrelated. Mental work activities take less energy than physical work, but someone with mental work activities must have a bigger responsibility and morals; thus, mental work activities are tougher than physical ones. Mental work activities are related to mental health, thinking abilities, and quick but careful actions [3].

In the factory of Kerupuk Sehati, suboptimal work postures such as standing, drooping, and sitting hunched over for 8-9 hours can also increase work pressures. If employees are forced to perform excessive workloads, stress, and anxiety while on work duty may have been caused, resulting in bad performance and disadvantaging companies [4]. In the factory of Kerupuk Sehati, excessive physical and mental workloads can reduce work performance, increase the number of defective products (around 5% of daily production capacity), and affect work activities. Therefore, the NASA-TLX method was used for workload assessment, and CVL was used to analyze and understand the workload of employers in the factory of Kerupuk Sehati. NASA-TLX method can evaluate perceived mental work, such as task effectiveness, system, team, or other performance aspects, or assessments with high sensitivity on mental workload assessments [5].

Based on the psychologies of workers in UD Lancar Abadi, physical work assessments were conducted by measuring energy consumption to determine the weight of a workload [6]. Maulana et al. [7] conducted research on the manufacture of *tempe* crackers within the home industry of Wijaya Kusuma, and discovered that the work posture of sitting with a drooping head and hunched back causes complaints or post-work systems, so it is necessary to classify workloads with %CVL method by the pulse rate of the workers.

Yulistyari et al. [8] researched the relationship between physical and mental workload using %CVL and NASA-TLX to improve the performance of forklift operators. Manurung et al. [9] utilized %CVL and NASA-TLX in workers' workload physically or mentally. Fikri and Casban [10] performed a study using the NASA-TLX method for mental workloads and the CVL method for physical workloads. Siregar and Yurisditira [11] utilized NASA-TLX and %CVL methods to calculate the workload of each mechanic in the remanufacturing department and measure the workers' pulse before and after work. Ervil and Fadli [12] utilized the CVL method to evaluate the physical workload perceived by mechanics.

Problems that occur in the factory of Kerupuk Sehati are: excessive physical and mental workloads perceived by the workers cause reduced performance of the workers and human errors while performing tasks. Thus, the study aims to utilize the NASA-TLX method to evaluate mental workload and the CVL method to evaluate physical workload.

II. LITERATURE REVIEW

Mental workload evaluation based on NASA-TLX had several steps [13]:

The first step was weighing. Respondents determined one of the influential indicators that caused mental work pressures related to the task. The second step was to rate based on the NASA-TLX method. The mental workload of the person was then rated. Table 1 presents the score tables of mental workloads divided into several categories [14].

The third step in the NASA-TLX method was to calculate the product value in which each rank was multiplied by the weight of the corresponding factor on each descriptor. The step provides the level of individual workload in performing a particular task.

$$\text{Product value} = \text{rating} \times \text{weight factor} \quad (1)$$

The fourth step was to count the weighted workload (WWL). The six product values previously counted were then summed. The step measures the level of mental workload and analyzes it within a certain situation.

$$\text{WWL} = \Sigma\ \text{product values} \quad (2)$$

The fifth step was calculating the average weighted workload (WWL). The average weighted workload was obtained from the total WWL values divided by the overall sum of weights. The step presents a more accurate description of the average mental workload perceived by workers within a particular situation.

$$\text{Averaged WWL} = \frac{WWL}{15} \quad (3)$$

Physical workload can be classified based on cardiovascular load (%CVL) [15]. Cardiovascular Load (CVL) calculation utilized a pulse oximeter to measure pulse. The 10-beat method using a stopwatch can be used if pulse oximeter is unavailable [16].

$$\%CVL = 100 \times \left(\frac{DNK - DNI}{DNM - DNI}\right) \quad (4)$$

where: %CVL = percentage of *Cardiovascular Load*
DNK = pulse rate during working
DNI = rest pulse rate
DNM = maximum pulse rate
The following is the classification used to compare the calculated %CVL [17]:
1. <30% = no fatigue
2. 30 - <60% = improvement needed
3. 60 - <80% = work in short period
4. 80 - <100% = immediate action needed
5. >100% = no activity allowed

III. METHODS

The object of the study was 17 employees in the production department in the factory of Kerupuk Sehati, consisting of 1 employee in the raw material mixing division, 1 employee in the dough rolling division, 5 employees in the printing division, 4 employees in the steaming division, 5 employees in the sun-drying division, and 1 employee in the drying division. Data collection was conducted by distributing NASA-TLX questionnaires and pulse rate instrumentations by pulse oximeter. Data was taken in 1 day: before work, while on work duty, during rest time, and when back to work after resting. In NASA-TLX questionnaires, the product value of the mental workload data was calculated. Mental workload is a type of workload that is measured based on the operator's assessment of the job demands with the maximum workload capacity that can be handled by the individual while working [18].

Table 1. Rating Classification of Workload Scores

Number	Rating Score	Load Category
1	0 - 9	Low
2	10 - 29	Moderate
3	30 - 49	Quite High
4	50 - 79	High
5	80 - 100	Very High

IV. RESULTS AND DISCUSSIONS

For the 17 employees in the production department, the mental workload was evaluated using the NASA-TLX questionnaires, and the physical workload was evaluated using an oximeter. Measured data can be seen in Table 2, which presents data on production department employees as respondents.

After distributing the questionnaires, the next step was to perform weighting that displays 15 pairs of indicators to determine which was more dominant. There were six indicators in total on the NASA-TLX questionnaires: Physical Demand (PD), Mental Demand (MD), Temporal Demand (TD), Own Performance (OP), Frustration Level (FR), and Effort (EF). Table 3 displays the weighting results of the six indicators.

Then, each indicator of mental workload was given a rating score. Based on the level of mental workload perceived by employees, a rating score of 0-100 was given to each indicator. Table 4 presents the rating scores by all production department employees.

Product values were obtained from weighting scores multiplied by the rating score of each indicator. The step of calculating product values allows a more measurable assessment of each indicator. Table 5 presents the results of product values from the 17 production department employees.

After calculating the product values, the next step was to calculate the weighted workload values. The weighted workload was calculated from the sum of the product values of each indicator. Table 6 presents the results of the weighted workload values of production department employees.

Table 2. Data of production department employees in the factory of Kerupuk Sehati

Number	Respondent	Age (Years)	Task Division	Work length period (Years)
1	A Darus	31	Raw material mixing	4
2	B Sandi	26	Dough rolling	3
3	C Dian	21	Cracker printing 1	3
4	D Azis	23	Cracker printing 2	5
5	E Guntur	24	Cracker printing 3	2
6	F Soni	22	Cracker printing 4	3
7	G Fikri	25	Cracker printing 5	2
8	H Rizky	22	Steaming 1	3
9	I Agung	31	Steaming 2	8
10	J Fadli	26	Steaming 3	3
11	K Gilang	21	Steaming 4	4
12	L Gigin	23	Sun-drying 1	1
13	M Fahmi	24	Sun-drying 2	4
14	N Fatur	22	Sun-drying 3	2
15	O Imam	25	Sun-drying 4	4
16	P Rudi	22	Sun-drying 5	1
17	Q Dikri	31	Drying	1

Table 3. Weighting results of NASA-TLX questionnaires

n	Respondent	Age (Year)	Indicators						Total
			PD	MD	TD	OP	EF	FR	
1	A	31	4	1	2	2	4	2	15
2	B	26	4	1	3	3	3	1	15
3	C	21	3	1	4	3	2	2	15
4	D	23	4	1	4	3	3	0	15
5	E	24	3	2	4	4	2	0	15
6	F	22	4	1	3	3	3	1	15
7	G	25	3	2	4	3	2	1	15
8	H	22	3	2	3	3	4	0	15
9	J	24	3	1	3	4	4	0	15
10	I	30	3	2	2	3	3	2	15
11	K	31	3	3	2	2	3	2	15
12	L	22	4	1	2	3	4	1	15
13	M	23	3	2	3	2	3	2	15
14	N	21	3	1	4	2	3	2	15
15	O	22	3	1	4	3	3	1	15
16	P	23	3	1	4	3	2	2	15
17	Q	24	3	1	4	4	3	0	15

The NASA-TLX scores were obtained from the weighted workload values divided by the sum of the weights, which was 15. The score was then classified based on the corresponding class of the workload classification. Table 7 presents the NASA-TLX scores and the production department employees' workload classification.

Table 4. Rating scores based on NASA-TLX questionnaires

n	Respondent	Age (Year)	Indicators					
			PD	MD	TD	OP	EF	FR
1	A	31	100	50	60	80	90	50
2	B	26	80	40	60	80	70	40
3	C	21	90	60	80	90	80	70
4	D	23	100	50	90	90	80	80
5	E	24	80	60	90	90	80	70
6	F	22	100	60	80	80	80	80
7	G	25	80	60	90	90	80	70
8	H	22	80	50	80	80	80	50
9	I	24	80	60	70	70	80	60
10	J	30	90	80	80	70	80	50
11	K	31	80	70	70	80	70	60
12	L	22	100	60	50	90	90	80
13	M	23	90	40	80	70	80	80
14	N	21	80	60	80	70	70	50
15	O	22	90	30	60	80	70	50
16	P	23	70	80	70	80	70	80
17	Q	24	40	20	60	80	50	50

According to the measurement of mental workload on 17 employees in the production department, 65% of the employees had mental workload classified as high category and 35% as very high category. The average weighted workload (WWL) of the 65% of employees that belonged to the high mental workload category had rating scores ranging between 50 to 79, while the remaining 35% had rating scores ranging from 80 to 100. These situations occurred due to various factors, such as work activities that run continuously during working hours, a dense work pattern by an individual, work demand to achieve the appointed production target, and the work length period of the six employees, which was less than five years, in which they had not adjusted to the work environment yet and could not handle the work pressures. After the data was processed, it was revealed that the average mental workload of the employees was reasonably high in average, especially in the physical demand aspect (PD). Then, the CVL method was utilized to process the data for the physical workload. The company must improve the workload pressure by reducing the mental workload of its employees.

Table 5. Product value assessment from NASA-TLX questionnaires

n	Respondent	Age (Year)	Indicator					
			PD	MD	TD	OP	EF	FR
1	A	31	400	50	120	160	360	100
2	B	26	320	40	180	240	210	40
3	C	21	270	60	320	270	160	140
4	D	23	400	50	360	270	240	0
5	E	24	240	120	360	360	160	0
6	F	22	400	60	240	240	240	80
7	G	25	240	120	360	270	160	70
8	H	22	240	100	240	240	320	0
9	I	24	240	60	210	280	320	0
10	J	30	270	160	160	210	240	100
11	K	31	240	210	140	160	210	120
12	L	22	400	60	100	270	360	80
13	M	23	270	80	240	140	240	160
14	N	21	240	60	320	140	210	100
15	O	22	270	30	240	240	210	50
16	P	23	210	80	280	240	140	160
17	Q	24	120	20	240	320	150	0

Data sampling of the pulse rate was done four times in 1 working day. The pulse rate was taken at 06.30 a.m. before the employee started to work, at 11.00 a.m. when the employee was working, at 12.30 p.m. when the employee was resting during break time, and at 15.00 when the employee began to go back to work after resting. Table 8 presents the pulse rate data in pulse/minute of the employees in the production department.

After obtaining the pulse rate (pulse per minute), the next step was calculating the CVL percentage presented in Table 9. Age, gender, and pulse/minute data are required to calculate CVL. The CVL percentage value will be analyzed and classified based on the physical load catego.

Table 6. Weighted Workload

n	Respondent	Age (Year)	Indicator						Weighted Workload
			PD	MD	TD	OP	EF	FR	
1	A	31	400	50	120	160	360	100	1190
2	B	26	320	40	180	240	210	40	1030
3	C	21	270	60	320	270	160	140	1220
4	D	23	400	50	360	270	240	0	1320
5	E	24	240	120	360	360	160	0	1240
6	F	22	400	60	240	240	240	80	1260
7	G	25	240	120	360	270	160	70	1220
8	H	22	240	100	240	240	320	0	1140
9	I	24	240	60	210	280	320	0	1110
10	J	30	270	160	160	210	240	100	1140
11	K	31	240	210	140	160	210	120	1080
12	L	22	400	60	100	270	360	80	1270
13	M	23	270	80	240	140	240	160	1130
14	N	21	240	60	320	140	210	100	1070
15	O	22	270	30	240	240	210	50	1040
16	P	23	210	80	280	240	140	160	1110
17	Q	24	120	20	240	320	150	0	850

Table 7. Classification based on mental workload category

n	Respondent	Task Division	Average Weighted Workload	Workload Category
1	A	Raw material mixing	79.33	High
2	B	Dough rolling	68.67	High
3	C	Cracker printing 1	81.33	Very High
4	D	Cracker printing 2	88.00	Very High
5	E	Cracker printing 3	82.67	Very High
6	F	Cracker printing 4	84.00	Very High
7	G	Cracker printing 5	81.33	Very High
8	H	Steaming 1	76.00	High
9	I	Steaming 2	74.00	High
10	J	Steaming 3	76.00	High
11	K	Steaming 4	72.00	High
12	L	Sun-drying 1	84.67	Very High
13	M	Sun-drying 2	75.33	High
14	N	Sun-drying 3	71.33	High
15	O	Sun-drying 4	69.33	High
16	P	Sun-drying 5	74.00	High
17	Q	Drying	56.67	High

Table 8. Pulse per minute data of the production department employees

n	Respondent	Gender	Age (Years)	Pulse Rate (Pulse/min)			
				Morning (Rest)	Noon I (work)	Noon II (Rest)	Afternoon (Work)
1	A	Male	31	70	107	72	109
2	B	Male	26	81	110	83	108
3	C	Male	21	76	104	74	106
4	D	Male	23	88	103	88	101
5	E	Male	24	83	96	80	99
6	F	Male	22	77	108	79	108
7	G	Male	25	86	97	88	99
8	H	Male	22	80	101	82	109
9	I	Male	24	87	96	88	99
10	J	Male	30	69	95	67	97
11	K	Male	31	71	96	73	98
12	L	Male	22	69	108	65	128
13	M	Male	23	68	100	71	98
14	N	Male	21	76	97	74	97
15	O	Male	22	79	98	77	100
16	P	Male	23	68	98	68	99
17	Q	Male	24	78	101	78	105

Table 9. Percentage of Cardiovascular Load (CVL)

n	Respondent	Gender	Age (Year)	Average pulse rate (working)	Average rest pulse rate	Max pulse rate	CVL (%)
1	A	Male	31	108.00	71.00	189	31.36
2	B	Male	26	109.00	82.00	194	24.11
3	C	Male	21	105.00	75.00	199	24.19
4	D	Male	23	102.00	88.00	197	12.84
5	E	Male	24	97.50	81.50	196	13.97
6	F	Male	22	108.00	78.00	198	25.00
7	G	Male	25	98.00	87.00	195	10.19
8	H	Male	22	105.00	81.00	198	20.51
9	I	Male	24	97.50	87.50	196	9.22
10	J	Male	30	96.00	68.00	190	22.95
11	K	Male	31	97.00	72.00	189	21.37
12	L	Male	22	118.00	67.00	198	38.93
13	M	Male	23	99.00	69.50	197	23.14
14	N	Male	21	97.00	75.00	199	17.74
15	O	Male	22	99.00	78.00	198	17.50
16	P	Male	23	98.50	68.00	197	23.64
17	Q	Male	24	103.00	78.00	196	21.19

The next step after obtaining CVL values was to interpret them, which was done by classifying the physical load based on the %CVL values obtained. Table 10 presents the list of interpreted CVL percentage values.

Table 10. Interpretation of Cardiovascular Load (CVL)

n	Respondent	CVL (%)	Classification of CVL values
1	A	31.36	Improvement Needed
2	B	24.11	No Fatigue
3	C	24.19	No Fatigue
4	D	12.84	No Fatigue
5	E	13.97	No Fatigue
6	F	25.00	No Fatigue
7	G	10.19	No Fatigue
8	H	20.51	No Fatigue
9	I	9.22	No Fatigue
10	J	22.95	No Fatigue
11	K	21.37	No Fatigue
12	L	38.93	Improvement Needed
13	M	23.14	No Fatigue
14	N	17.74	No Fatigue
15	O	17.50	No Fatigue
16	P	23.64	No Fatigue
17	Q	21.19	No Fatigue

The physical workload was measured, calculated, and classified using the CVL method. As a result, 12% of the employees belong to the category of "improvement needed" due to their %CVL being in a range of 30% - 60%. Meanwhile, the rest of the 88% of employees experienced no fatigue due to their %CVL being less than 30%. Two employees required improvement: Respondent A, with a reasonably high CVL value (31.36%), and Respondent L, with the highest CVL value (38.93%). The high CVL value on Respondent A was due to his job duties requiring heavy load and repeated lifting activities, causing physical fatigue indicated by the increased pulse rate. The high CVL value on Respondent L occurred due to his work pattern, which was quite dense, causing pressures on his muscles and joints that may cause hand or back injuries and increased pulse rate while working. The work length period can influence the workload since their work length period was less than five years, during which time they had not been adjusted to their work environments and could not handle the work pressures. Therefore, the company must improve the conditions so that the physical workload of the employees can be reduced.

Based on field observations and interviews with respondents from the production department, recommendations for improvements to help the company are presented in Table 11.

Table 11. Recommendations for improvements

n	Indicator	Recommendation
1	Physical workload	1. Add an exhaust fan into the steaming process room to vent out hot air. 2. Perform machine and tool checking before production started to reduce the employees' work demands of heavy duties. 3. Considering assisting tools such as trolleys or lifting machines to reduce extensive physical pressures on the employees. 4. Training employees regarding the cracker's printing machine to assist and substitute the employees in the printing division when one of the printing employees experiences fatigue, as well as to improve the employees' skills in managing the production process.
2	Mental Workload	1. Give additional break time as much as 10-15 minutes. 2. Perform work evaluation along with the employees at the end of the month to help reduce mental complex and pressures. 3. Rewarding the best-performed employee monthly (employee of the month) 4. Provide salary increases so workers feel appreciated and motivated to work harder, perform better, and achieve higher targets.

V. CONCLUSIONS

The mental workload of the 17 employees in the production department of the Kerupuk Sehati factory was measured using the NASA-TLX method. The average mental workload belonged to the high category, as many as 65%, and to the very high category, as many as 35%. The study findings describe a significant mental workload among the production department employees of the Kerupuk Sehati factory.

The physical workload of the 17 production department employees was measured using the CVL method. 12% of the employees were categorized as those with improvement needed. In contrast, 88% of the employees had CVL values classified as no fatigue category. The study results indicate that most production department employees in the factory of Kerupuk Sehati were classified as having no fatigue category based on their CVL values.

Suggested further research, that is necessary, is to consider other factors in analyzing mental and physical workload, not only based on the factors contained in the NASA-TLX and CVL methods, but also considering other factors such as the calorie factors required by employees and oxygen levels, as well as considering other methods.

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