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Effects of the Occupational Physical Environmental Conditions and the Individual Characteristics of the Workers on Occupational Stress and Fatigue

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ABSTRACT

This research was conducted to study the effects of environmental factors i.e. heat stress, thermal comfort, and occupational noise and individual factors of the workers i.e. age, work duration (expressed in months), and nutrition status on occupational fatigue and stress. Occupational fatigue was measured using Reaction Timer L-77 Lakassidaya. Occupational stress was measured using questionnaire adapted from Wambrauw (2010). Heat stress and thermal comfort were measured using Questemp 34 Thermal Environment Meter and Lutron AM-4200 Anemometer. Occupational noise level was measured using Lutron SL-4022 Sound Level Meter. Nutrition status was measured using microtoise and body weight scale. Age and work duration was obtained using a personal profile form filled in by each worker. This research employed Structural Equation Modelling (SEM) consisted of direct and indirect effects of exogenous and endogenous variables on endogenous variables. Data analysis was conducted using AMOS 19 software. Data analysis showed that (1) different level of fatigue was indicated on workers working in different work shifts, (2) there was no direct effects of heat stress and thermal comfort on occupational fatigue, (3) there was a positive direct effect of occupational noise on workers stress but there was no indication that the stress itself has a direct effect on occupational fatigue, thus preventing the indirect effect of occupational noise on occupational fatigue, (4) there was no direct effect of the age of the workers on occupational fatigue, (5) there was a positive direct effect of the workers age on work duration, but the work duration itself did not exhibit any effect on occupational fatigue so therefore no indirect effect of workers age on occupational fatigue was found in this research, (6) and finally, there was a positive direct effect of nutrition status on occupational fatigue.

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1. INTRODUCTION

In the environment, there is a relationship between human being and the environment. In smaller scope of the environment, in industrial environment, there is also a relationship between human being and environment i.e. the workers and the occupational environment.. Occupational environment is affected by the activities of the workers and vice versa.

This research was conducted in PT Apac Inti Corpora, a textile manufacturing company in Bawen, Semarang Regency, Indonesia. Nugraheni (2008) showed that most of the workers of PT Apac Inti Corpora experience occupational fatigue. On the contrary, workers are required to achieve optimum productivity to meet the production target set by the company. Occupational fatigue decreases work productivity of the workers thus adversely impacts not only the workers' work performance and health, but also the company performance and revenue.

Occupational fatigue as a body condition is affected by environmental factors and individual (intrinsic) factors of the workers. Previous researchers were able to identify environmental factors affecting occupational fatigue. Suharni (1997) and Ramdan (2007) both found that the heat experienced by the workers increases fatigue. Heat experienced by the workers in the work environment is defined as heat stress which is expressed by Wet Bulb Globe Temperature index (WBGTi). (Suma'mur, 2009). Heat in the environment also affects the thermal comfort experienced by the workers inside a factory building. Thermal comfort is expressed by effective temperature (Koenigsberger et al., 1973). Occupational fatigue is indirectly affected by noise level. Workers exposed to high level of noise experience higher level of work stress and according to Ruliati (2006), work stress triggers increase in occupational fatigue.

Occupational fatigue was also found to be affected by individual characteristics of the workers i.e. circadian rhythm, age, work duration, and nutrition status. Human beings are basically diurnal living organism. Day is the normal time for human being to work and night is the normal time to rest and sleep. Life pattern that is not conformed to this "normal" rhythm e.g. work at night and sleep at day increases the level of fatigue. Moreover, the absence of melatonin hormone at day prevents human beings from achieving optimum level of rest and recuperates, thus further increasing the level of fatigue. (Shen et al., 2006; Wijaya et al., 2006). Workers' age directly and indirectly affects occupational fatigue. Phoon (1988) stated that the muscle strength is directly affected by age. The higher the muscle strength means the better performance and the better endurance of the muscles to work. Indirectly, workers age is positively correlated with work duration. The longer the work duration means the better experience a worker has. Better experience leads to better skill to do a particular work, thus minimizing fatigue from having to sort out problems arisen from fulfilling particular tasks. Better experience also provides a bigger chance for the workers to be promoted to higher position in hierarchical organization at work which is characterized as more managerial and coordinative type of works thus requiring less physical work that leads to lower level of fatigue. (Phoon, 1988; Winwood et al., 2006). Finally, nutrition status, expressed by Body Mass Index (BMI), also affects the level of fatigue. Energy used to work is obtained by food intake. Balanced diet of carbohydrate, protein, fat, mineral, and vitamin provides enough energy to work. The imbalance of nutrition status leads to the lower level of work performance and endurance (Trisnawati, 2010).

2. RESEARCH METHOD

This research was conducted in 9 sampling days in every sections and every work shifts in Department of Weaving I, PT Apac Inti Corpora. The respondents were all the production workers (administrative workers were excluded) in every team (there were 3 teams: A, B, and C covering total 24 hours of work) in every section of Department of Weaving 1 who were present at the time of the sampling and had stated his/her consent to participate and provide all personal data required in the research. There were 156 workers participating. 38 workers were from Preparation section that consisted of 18 workers from Warping subsection and 20 workers from Sizing subsection). 84 workers were from Loom section. 34 workers were from Inspection section.

Environmental data were collected every hour in total 8 hours of a sampling day on every sampling point that had been purposively determined based on workers location at work in every section. There were 16 sampling points in Preparation (7 points in Wraping and 9 points in Sizing), 15 sampling points in Loom, and 10 sampling points in Inspection. Occupational fatigue, work stress, age, work duration, and nutrition status data were collected once in every sampling day. A sampling day was 8 days long in which the research targeted workers from a particular work shift in a particular section only. Data collection scheduling was carefully planned so that workers from team A, B, and C were all targeted and no repetition of sampling on the workers from the same team in two different sampling days.

Environmental data were collected using some measuring apparatus i.e. Questemp 34 Thermal Environment Meter, Anemometer Lutron AM-4200, and Sound Level Meter Lutron SL-4022. Occupational fatigue was measured using Reaction Timer L-77 Lakassidaya. Work stress was measured using work stress questionnaire modified from Wambrauw (2010). Work hours and age were filled in by the workers on a personal questionnaire form. Nutrition status data were collected using body weight scale and microtoise.

Statistical analysis was employed to measure the contribution of environmental and personal variables towards work stress and occupational fatigue experienced by the respondents. Analysis of Variance (ANOVA) was employed to identify whether there is a difference of occupational fatigue level experienced by workers working in different work shift (morning shift, afternoon shift, night shift). A path analysis using Structural Equation Modeling (SEM) was employed to measure the effects of exogenous variables i.e. heat stress, thermal comfort, noise level, age, and nutrition status towards endogenous variables i.e. work duration, work stress, and occupational fatigue.

3. RESULTS OF DATA ANALYSIS

Occupational fatigue was indicated by the time needed by the respondents to respond to the stimulus given by the researcher. The longer the response time indicates the higher occupational fatigue experienced by the workers, and vice versa (Ratu, 2009). Result of ANOVA and mean response time of the workers working in different work shift in different sections was shown in Table 1 and Figure 1.

Table 1. ANOVA Result and Mean Response Time of the Workers

ANOVA	Section (subsection)	Work Shifts	Mean response time (milliseconds)
F = 4.621	Preparation	Morning	245.0
Sig. = 0.000	(Warping)	Afternoon	320.6
		Night	272.7
	Preparation	Morning	274.4
	(Sizing)	Afternoon	349.8
		Night	328.8
	Loom	Morning	252.2
		Afternoon	351.2
		Night	363.3
	Inspection	Morning	288.4
		Afternoon	340.7
		Night	434.9

Source: Data Analysis

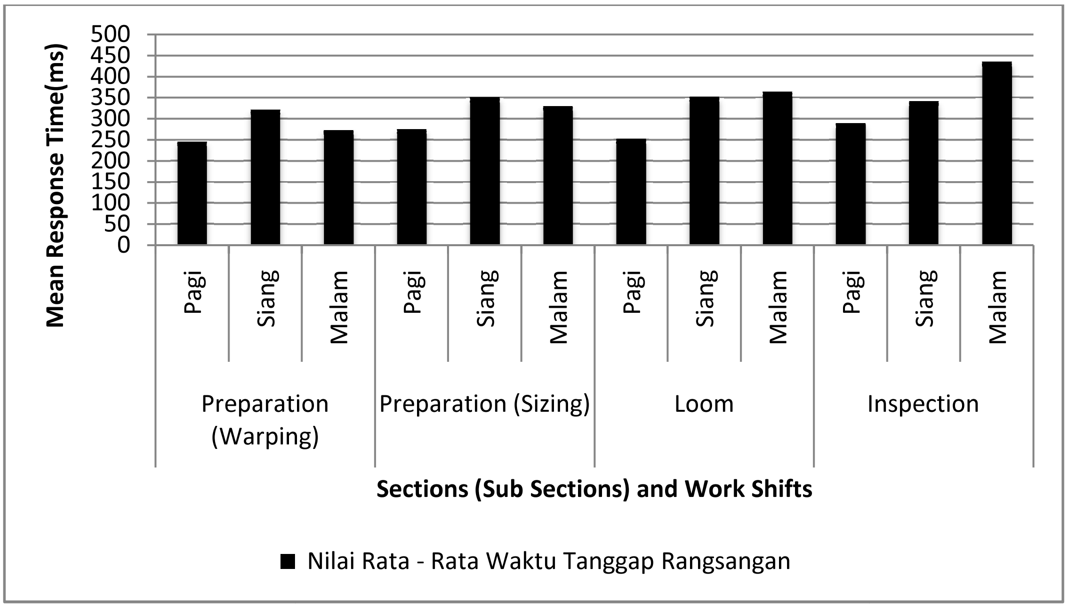

Figure 1. Mean Response Time
(Source: Data Analysis)

Figure 2 shows the result of path analysis using Structural Equation Modeling including the regression weights of each path. Regression weights, total effects, direct effects, and indirect effects acquired from path analysis are shown in Table 2, Table 3, Table 4, and Table 5.

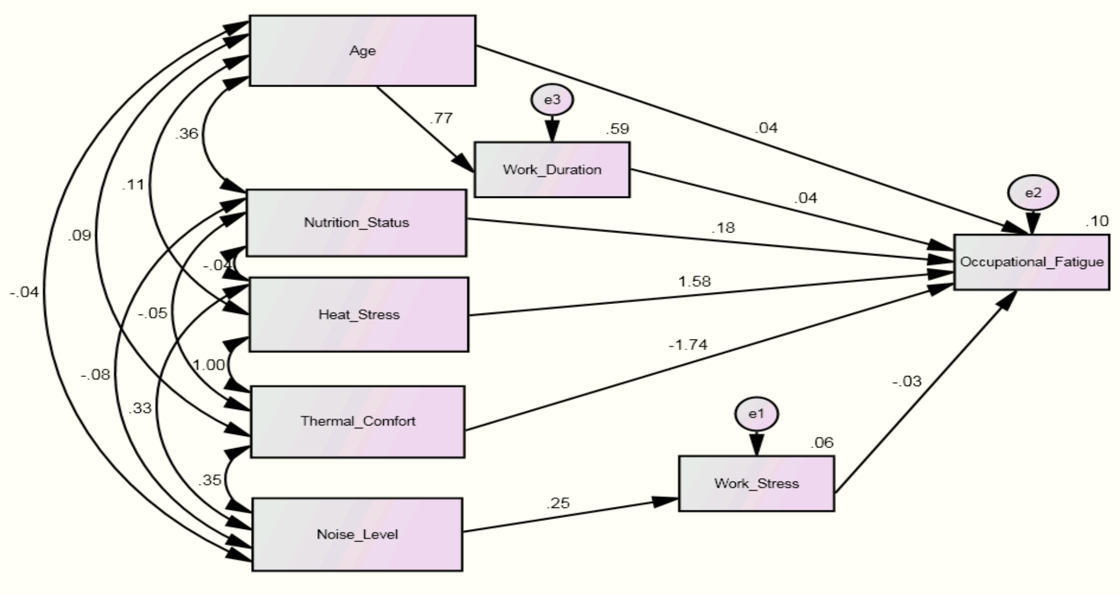

Figure 2. Result of Path Analysis. (Source: Data Analysis)

Table 2. Regression Weights

Paths	Regression Weights	P
Noise level towards work stress	0.247	0.001
Age towards work duration	0.770	0.000
Work duration towards occupational fatigue	0.042	0.724
Nutrition status towards occupational fatigue	0.175	0.034
Heat stress towards occupational fatigue	1.576	0.216
Thermal comfort towards occupational fatigue	-1.745	0.170
Work stress towards occupational fatigue	-0.035	0.649
Age towards occupational fatigue	0.041	0.745

Source: Data Analysis

Table 3. Total Effects

Paths	Effects
Noise level towards work stress	0.247
Noise level towards occupational fatigue	-0.009
Thermal comfort towards occupational fatigue	-1.745
Heat stress towards occupational fatigue	1.576
Nutrition status towards occupational fatigue	0.175
Age towards work duration	0.770
Age towards occupational fatigue	0.073
Work stress towards occupational fatigue	-0.035
Work duration towards occupational fatigue	0.042

Source: Data Analysis

Tabel 4. Direct Effects

Paths	Effects
Noise level towards work stress	0.247
Thermal comfort towards occupational fatigue	-1.745
Heat stress towards occupational fatigue	1.576
Nutrition status towards occupational fatigue	0.175
Age towards work duration	0.770
Age towards occupational fatigue	0.041
Work stress towards occupational fatigue	-0.035
Work duration towards occupational fatigue	0.042

Source: Data Analysis

Table 5. Indirect Effects

Paths	Effects
Noise level towards occupational fatigue	-0.009
Age towards occupational fatigue	0.033

Source: Data Analysis

4. CONCLUSION

A. Occupational Fatigue Difference

ANOVA Sig. = 0,000 indicated that there was a significant difference of mean response time exhibited by the workers working in different sections and different work shifts. In Loom and Inspection, the longest mean response time was recorded on the night shift workers, the shortest mean response time was recorded on the morning shift workers, while the afternoon shift workers showed the mean response time in between morning and night workers' mean response times. In Preparation, the longest mean response time was recorded on afternoon shift workers, the shortest mean response time was recorded on morning shift workers, while night workers' time came in between morning workers' mean response time and afternoon workers' mean response time.

Circadian rhythm works like a biological clock in human body. Melatonin hormone, secreted in the night, helps human being to sleep and rest well. Normally, night is the time to rest and recuperate after humans work at day. In 24 hours work system, some workers are scheduled to work at night and sleep at day. This work schedule violates the circadian rhythm where workers are scheduled to work at the time of rest and are supposed to sleep at the time of activities. Therefore, workers working at night shift experienced fatigue in a higher level than their colleagues working in morning shift. Moreover, according to Wijaya et al. (2006), night shift workers do not get the same quality of sleep and rest as their morning shift colleagues do because the absence of melatonin at day prevents them from getting a good quality of relaxation and sleep thus accumulating the fatigue.

An anomaly was found in Preparation, where the highest level of occupational fatigue was recorded on afternoon shift workers. This phenomenon remains an open question. Other factors may contribute to this anomaly e.g. the difference of work load of the workers working in different work shifts as showed by Rantung (2009)

B. Effect of Heat Stress towards Occupational Fatigue

Table 2 and Table 4 shows that the direct effect of heat stress towards occupational fatigue was 1.576 and the P value was 0.216. The significance value (P) > 0.05 indicated that the heats stress in Department of Weaving I did not have significant effect towards occupational fatigue experienced by the workers.

Heat stress recorded in Department of Weaving I generally did not exceed the heat stress standard (28^{o}C) in the Republic of Indonesia based on the Decree of Indonesian Ministry of Labor Force Number. Kep-51/MEN/1999. Therefore it is assumed that the heat stress effect on occupational fatigue in Department of Weaving I is absent due to the "acceptable" level of heat stress experienced by the workers. It is interesting to note that Ruliati (2006) found a 28^{o}C – 29,9^{o}C heat stress level and Ratu (2009) recorded a 30.5^{o}C – 34.38^{o}C heat stress level, yet both researchers did not find any positive effect of heat stress towards occupational fatigue. On the contrary, Chen et al. (2003) reported a positive effect of heat stress towards occupational fatigue in a Chinese workers exposed to 30.0^{o}C – 33.2^{o}C heat stress level in a steel smelter. It is therefore assumed that Indonesian workers are generally more tolerant to higher level of heat stress because Indonesian workers are accustomed to live and work in warm tropical environment.

The production building design helped prevent the heat from being accumulated inside. The production rooms were spacious and were equipped with several openings and exhaust fans. They helped dispersing the heat and keeping the heat stress level below the national standard. Mauliku (2007) found a positive effect of heat stress towards occupational fatigue in a weaving department of a different garment industry. Lack of good ventilation aggravated by small and cramped production rooms made heat produced from sun radiation, machine operation, and workers metabolisms weren't easily dispersed and tended to be accumulated inside the room, leading to higher occupational fatigue.

C. Effect of Thermal Comfort towards Occupational Fatigue

Direct effect of thermal comfort towards occupational fatigue was – 1.745 but statistically not significant (P = 0.170 > 0.05).

Thermal comfort is a scale used in architectural design to express the thermal sensation or the experience of the building occupants. It is actually not a scale used in occupational and environmental health science. However, the rationale is thermal comfort is almost similar with heat stress (both has wet temperature as a variable). This research put thermal comfort as an exogenous variable in explorative point of view, to study whether there is an effect of heat, subjectively sensed by the workers, towards their fatigue level.

Statistical analysis shows that there was no significant effect of thermal comfort towards occupational fatigue. This leads to conclusion that thermal comfort, despite its near similarity with heat stress, is not a valid variable to predict the occupational fatigue. On the contrary, Figure 1 shows that there was a perfect correlation between heat stress and thermal comfort (correlation coefficient = 1). In that case, the question was yet to be resolved. It was possible that the absence of thermal comfort effect towards occupational fatigue, analogous with heat stress, was caused by the level of the effective temperature was still in “acceptable” level. Effective temperature data generally did not exceed 28.1^{o}C, which is the upper limit of national standard of thermal comfort stated in SNI 03-6572-2001.

D. Effect of Noise Level towards Occupational Fatigue

Effect of noise level towards occupational fatigue was an indirect one with work stress served as intervening endogenous variable. Indirect effect of noise level towards occupational fatigue was -0.009 which means the effect was negative and almost negligible. Direct effect of noise level towards work stress was 0.247 and statistically significant. However, the effect of work stress towards occupational fatigue was negative and insignificant, thus nullifying the effect of noise level towards occupational fatigue.

Work stress was generated from workers relation with their social and physical environment at work. Noise in the work environment was found to increase the level of work stress. Noise level was varied between 65.4 dB and 95.5 dB while the national standard for occupational noise is 85 dB as stated in the Decree of Indonesian Ministry of Labor Force Number KEP-51/MEN/1999.

The highest level of noise was recorded in Loom where all noise data was found to be higher than 85 dB. Unfortunately, not all the workers in Loom wore hearing protective equipment while at work. Both lead to higher risk of noise exposure including elevated work stress.

In Preparation and Inspection, the noise level data were lower than 85 dB but this did not directly mean that the risk of noise exposure was absent. The effect of work stress was still present in noise level below 85 dB as shown by Khairat (2008) who found positive effect of noise level towards work stress in noise level that ranged between 67 dB – 81.3 dB, well below the national standard of occupational noise.

On the other hand, work stress was not indicated to affect occupational fatigue. In stressful situation, workers employ two strategies of coping mechanism, known as 2Fs i.e. Fight or Flight. In stressful situation, human being will exert more effort to achieve work targets and to alleviate stress. Therefore, in certain level, stress helps increasing work performance and productivity. However, if Fight mechanism fails to alleviate stress, human being tended to escape from the stress source (Flight) e.g. going on a vacation, taking a temporary break, resign from work, etc. If the both coping mechanisms fails to alleviate stress, the level of stress gets higher and adverse effects, including fatigue occurs as shown by Sujoso (2008).

To sum up, the indirect effect of noise level towards occupational fatigue was statistically insignificant. The noise level was found to affect the work stress but the coping mechanism employed by the workers was still able to keep the stress in an acceptable level thus preventing adverse effects of stress, including fatigue.

E. Effect of Age Towards Occupational Fatigue

Age affects occupational fatigue either directly or indirectly through work duration as an endogenous intervening variable.

The direct effect of age towards occupational fatigue was 0.041 but statistically not significant. Phoon (1988) stated that physically the best level of muscle strength and endurance is achieved in the middle of the twenties will start to decline when 30 years of age is reached. High level of muscle strength and endurance is needed in doing tasks that is physically demanding such as in doing a sport as a professional athlete. The insignificant effect of age towards occupational fatigue indicated that the type of work in Department of Weaving I was not the type of work that demanded high level of muscle strength and endurance.

The indirect effect of age towards occupational fatigue was based on the premise that age also effects work duration which in turns affects occupational fatigue. Longer work duration in a company means better experience that enables workers to finish the job in the simplest possible way with no problem and with efficient use of effort thus minimizing fatigue. (Phoon, 1988). Longer work duration also gives workers a chance to be promoted to higher position in the company hierarchy (Winwood et al., 2006).. High position jobs are characterized as managerial and coordinative type of work which is less physically demanding thus minimizing fatigue.

Indirect effect of age towards occupational fatigue was 0.033. The direct effect of age towards work was 0.770 and statistically significant. The direct effect of work duration was 0.042 but statistically insignificant. The insignificance effect of work duration towards occupational fatigue means that the indirect effect of workers age towards occupational fatigue was also insignificant, despite the significant effect of age towards work duration.

The direct effect of age towards work duration was significant because the workers started working at the company at rather same age. The maximum age of new workers hired is 23 for unskilled workers and 27 for skilled workers. As the year progresses, workers will be more senior either in age or in work duration.

Work duration had no effect towards occupational fatigue. This contradicts the result of the work of Winwood et al. (2006). The effect of work duration towards occupational fatigue was found on workers with heterogeneous background of job position and job assignment. The workers experienced less level of fatigue in the higher position in the job hierarchy. On the contrary the respondents of Department of Weaving I were homogeneous in job position and job assignments. They were production workers (administrative and managerial workers were excluded due to the difference in work shift schedule), working at the same building, and doing rather same assignments every day. It can be concluded that even though the workers age were varied, the similarity of job position and job assignments produced no different level of occupational fatigue based on workers age.

F. Effect of Nutritional Status towards Occupational Fatigue

The direct effect of nutrition status towards occupational fatigue was 0.175 and statistically significant.

Nutritional status was expressed with Body Mass Index (BMI) scale using nutrition status criteria Department of Health of The Republic of Indonesia as stated by Ratu (2009). The best nutrition status is the normal status which indicates balanced diet of carbohydrates, proteins, fats, minerals, and vitamins. Trisnawati (2010) found that lack of nutrition intake lead to the decrease of the workers ability and endurance to do job assignments. It is interesting that in Department of Weaving I, the effect of nutrition status, contradicting previous research, was significant and positive. The higher level of the BMI meant a higher level of occupational fatigue experienced by the workers.

The dominant nutrition status of the workers was normal, some were high and a few were low. Based on relative proportion, the highest percentage of workers having a high BMI level was found in the Inspection

High level of BMI leads to the decrease of work ability and endurance although the nutrition intake is more than enough to do work. Energy from metabolism is needed to do work assignments. The energy needed to finish a particular work is different based on body weight. A worker having high BMI needs more calories to finish the same job than his colleague with normal BMI does. (Suma'mur, 2009). On the contrary, high level of BMI means more effort needed from the heart and the lung to supply oxygen needed in metabolism. The lack of oxygen hampers the metabolism that produces energy to do work, thus decreasing the work ability and endurance.

5. CONCLUSIONS

Some points can be concluded in this research: (1) Circadian rhythm affected workers physical condition to do work. Work schedule that does not conform to circadian rhythm increases fatigue. The highest level of fatigue was experienced by workers working in night shift. The lack of sleep quality further increased night shift workers fatigue. (2) Heat in work environment had no effect towards occupational fatigue. Good ventilation coupled with workers acclimatization in tropical condition reduced the risk of fatigue (3) Noise level, coupled with workers tendency not to wear hearing protective devices while working increased the work stress. The greatest risk was expected in Loom where the all noise data have exceeded the national standard of noise. However the work stress did not trigger the increase in occupational fatigue. Workers were still able to prevent the adverse effect of work stress by employing coping mechanism of stress. (4) Age had no direct effect towards occupational fatigue indicating that the type of work in Department of Weaving I did not require a high level of muscle strength and endurance. The indirect effect of age towards occupational fatigue was also absent because the of the homogeneous background of job position and job assignments of the workers participating in the research, despite the variation in workers age. (5) Nutrition status had a positive and significant effect towards occupational fatigue. Higher level of calories was needed by workers having a level of BMI to do a particular work. The production of energy was further hampered by the lack of oxygen provided by the heart and the lung thus decreasing work ability and endurance.

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