



Occupational fatigue in bakery workers: A retrospective analysis of physical workplace factors in 2019

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ABSTRACT

Occupational fatigue is an important occupational health concern that may reduce workers' performance and increase the risk of workplace accidents. This study aimed to analyze the associations between physical workplace factors and occupational fatigue among bakery workers in Indonesia. This quantitative analytical observational study used a cross-sectional design and was conducted at a bakery factory CV "X" in Kampar Regency, Riau Province, Indonesia, in 2019. A total of 55 workers were recruited using total sampling. Workplace illumination, noise, temperature, and vibration were measured using environmental monitoring instruments, whereas occupational fatigue was assessed using the Work Fatigue Feeling Measurement Questionnaire (KAUPK2). Data were analyzed using chi-square tests and multiple logistic regression. Of the 55 workers, 38 (69.09%) experienced occupational fatigue. Bivariate analysis showed significant associations between fatigue and illumination ($p = 0.004$), noise ($p = 0.001$), and vibration ($p = 0.006$), whereas temperature was not significantly associated with fatigue ($p = 0.170$). In the multivariable analysis, illumination (POR = 0.124, 95% CI: 0.021–0.726; $p = 0.021$) and noise (POR = 8.381, 95% CI: 1.093–64.256; $p = 0.041$) remained significantly associated with occupational fatigue. Occupational fatigue was prevalent among bakery workers and was associated with workplace illumination and noise. Improving workplace lighting and controlling noise exposure should be considered in occupational health and safety programs.

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1. INTRODUCTION

It is undeniable that everyone has experienced fatigue. One of the issues in Occupational Safety and Health that can trigger workplace accidents is fatigue. Fatigue is subjective for each individual because it is related to feelings; in addition to being influenced by physical and biological factors, fatigue is also affected by psychological factors (psychological) (Lock et al., 2018). Fatigue is one of the factors that can reduce a worker's work capacity and physical endurance. There are two types of fatigue: muscle fatigue and general fatigue. Muscle fatigue is characterized by tremors in the muscles. General fatigue is marked by a decreased willingness to work, caused by psychological

requirements. The causes of general fatigue are monotony, the intensity and duration of mental and physical work, and environmental conditions (Rosado et al., 2022).

According to (Tarwaka, Bakri, 2004), fatigue is a condition accompanied by a decrease in efficiency and endurance at work. The term fatigue refers to a variety of conditions, but all result in a reduction of work capacity and bodily endurance. Fatigue can clearly affect the health of workers. The World Health Organization (WHO) (WHO, 2020), in its health model projected up to 2020, predicts that psychological disorders in the form of severe fatigue that leads to depression will become the second leading cause of death after heart disease. Research conducted by the Ministry of Labor of Japan involving 12,000 companies and about 16,000 randomly selected workers in the country showed that 65% of workers reported physical fatigue from routine work, 28% reported mental fatigue, and about 7% complained of severe stress and feeling marginalized. According to recent estimates issued by the International Labour Organization (ILO), 2.78 million workers die each year as a result of occupational accidents and work-related diseases. Approximately 2.4 million (86.3 percent) of these deaths are due to work-related diseases, while more than 380,000 (13.7 percent) are due to occupational accidents (ILO, 2018).

Based on data from BPJS Ketenagakerjaan, occupational accident cases in 2017 reached more than 123,000 incidents, with over 3,000 workers killed, whereas in 2018 there were 175,000 cases of occupational accidents (Ketenagakerjaan., 2019). This number is 40 percent higher compared to the cases in 2017. According to data from the Ministry of Manpower and Transmigration of the Republic of Indonesia, occupational accident data in the first quarter of 2018 show 5,318 cases of occupational accidents with 87 workers killed, while 52 workers suffered disabilities and 1,361 other workers recovered after receiving medical treatment due to the occupational accidents they experienced.

Work productivity essentially encompasses a mental attitude that always holds a perspective on life regarding the implementation of production within a company, where it is expected that today's production will be better than yesterday's, as should the work system itself. Individuals are always seeking improvement by thinking dynamically, creatively, innovatively, and openly (Duncan & Swart, n.d.). An increase in productivity means that the number of resources used is matched by a growing and improving quantity of goods and services produced. Productivity consists of work, nutritional status, and gender. Work factors include workload and monotony (Van & Pham, 2022). Environmental factors include lighting, room temperature, and noise. Psychological factors include relationships with other workers. Physical factors are components found in the work environment such as noise, lighting, temperature, vibration, and radiation (Pimpong, 2023).

The condition of the work environment affects workers' capabilities and limitations. In a high-temperature work environment, workers bear an additional burden in the form of heat. This environmental heat is absorbed by the body to maintain normal temperature; therefore, the absorbed heat is then released by increasing sweat secretion to the surface of the skin to provide cooling. If the body is exposed to excessive temperatures, the body heat load will increase and this can happen both inside and outside of industry (Budiono, 2023; N & Xu, 2024). A hot work environment can cause various effects/impacts on workers, including influencing blood pressure and pulse rate, fatigue, a decline in work performance, reduced agility, prolonged reaction time, delayed decision-making, disruption of sensory and motor nerve coordination, reduced responsiveness, and heat-related disorders such as heat cramps, heat exhaustion, heat stroke, and miliaria (De Sario et al., 2023; Venugopal et al., 2021). CV "X" is a home industry that produces sweet bread, plain bread, jam, and others. Various types of bread are produced daily and marketed on the same day. There are approximately 15 types of bread produced. CV "X" has a production target of 7,000–8,000 units per day, requiring 15–20 sacks of flour each day. The number of workers is 55, with operational hours from 06:00–17:00 WIB each day, interspersed with breaks for prayer and meals. However, if the work cannot be completed by 17:00 WIB, it will be continued until 21:00 WIB. The management system in the industry is flexible, meaning that if a worker wishes to take leave or is ill, they are allowed to rest as long as another worker replaces their position. With the high targets to be achieved, the workload

borne by the workers is also increasingly heavy. Based on interviews with the factory operations manager, it was found that there are workers who experience fatigue after working all day in the factory. The symptoms they feel include overall body fatigue, sluggishness, lack of concentration, and a tendency to forget things.

The production area covered an area of approximately 130 m², with lighting provided by six 45-watt light bulbs distributed throughout the room and limited reflected daylight entering through ventilation gaps. Noise was generated by the dough mixer, bread grinder, and filling machine, which were used to prepare dough for 15 types of bread daily. All production activities, from dough preparation to baking, were performed in the same room, while packaging took place in an adjacent room. Four fans were installed along the side walls, and two large bread ovens were located at the back of the production area. Heat exposure was primarily associated with the repeated use of these ovens, which could reach temperatures of 200°C. Vibration originated from the operation of production machinery and equipment. These working conditions highlight the potential for simultaneous exposure to multiple physical environmental stressors. However, the extent to which lighting, noise, ambient temperature, and vibration are individually and collectively associated with worker fatigue in small-scale bread production remains insufficiently characterized. Therefore, this study examined the relationships between these four environmental factors and worker fatigue to provide context-specific evidence that may inform occupational health risk assessment and workplace improvement strategies

2. RESEARCH METHOD

Study Design

This study employed a quantitative analytical observational design with a cross-sectional approach to investigate the association between physical environmental factors and occupational fatigue among workers at a bread factory designated as CV “X” in 2019. In a cross-sectional study, exposure variables and outcome variables are assessed at a single point in time or during the same study period, without follow-up of the participants. The independent variables were workplace illumination, noise, working temperature, and vibration, while the dependent variable was occupational fatigue.

Study Setting and Period

The study was conducted at the CV “X” bread factory, located in the Pandau Raya Housing Complex, Siak Hulu District, Kampar Regency, Riau Province, Indonesia. Data collection was conducted over approximately three weeks in June–July 2019.

Study Population and Sample

The study population comprised all 55 workers employed at the CV “X” bread factory in 2019, including 45 male workers and 10 female workers. A total sampling technique was employed, whereby all eligible members of the population were included in the study. Accordingly, the sample consisted of 55 workers. The inclusion criteria were: (1) Workers employed at the CV “X” bread factory, (2) Workers who were willing to participate in the study.

Study Variables and Measurement Instruments

The categorization of workplace illumination, noise, working temperature, and vibration was based on the applicable occupational health and safety standards and regulations. The threshold values and measurement units for each environmental factor were determined according to the relevant standards applicable to the workplace and measurement conditions. The measured values were classified into exposure categories based on these predefined thresholds. The instruments used for each variable are presented in Table 1. The instruments used for each variable are presented in Table 1.

Table 1. Study variables, data collection methods, and measurement instruments

Variable	Data collection method	Measurement instrument
Workplace illumination	Direct measurement	Lux meter

Workplace noise	Direct measurement	Sound level meter
Working temperature	Direct measurement	Multifunction environmental meter
Workplace vibration	Direct measurement	Vibration meter
Occupational fatigue	Questionnaire administration	Work Fatigue Feeling Measurement Questionnaire (KAUPK ₂)

Source: (Primary Data, 2019)

Workplace illumination, noise, working temperature, and vibration were assessed using their respective measuring instruments. Occupational fatigue was assessed using the *Kuesioner Alat Ukur Perasaan Kelelahan Kerja* (KAUPK₂), an Indonesian questionnaire designed to assess perceived occupational fatigue.

Data Collection Procedures

Data were collected using direct workplace measurements and a self-administered questionnaire. The independent variables were assessed through environmental measurements, whereas occupational fatigue was assessed by asking participants to complete the KAUPK₂ questionnaire. Environmental measurements and data collection activities were conducted over approximately three weeks. Measurements were taken at three scheduled times: 07:00, 13:30, and 16:00 Western Indonesia Time (WIB). The instruments used during data collection included a lux meter, sound level meter, multifunction environmental meter, vibration meter, and the KAUPK₂ questionnaire.

Statistical Analysis

Data analysis comprised univariate, bivariate, and multivariable analyses. Univariate analysis was conducted to describe the distribution of study variables, with categorical variables summarized using frequencies and percentages to characterize the study population and the distribution of occupational fatigue and its associated factors. Bivariate analysis was performed to examine the associations between occupational fatigue and workplace environmental factors, including workplace illumination, occupational noise, working temperature, and vibration. The chi-square test was used to assess associations between categorical variables, while prevalence odds ratios (PORs) with 95% confidence intervals (CIs) were calculated to estimate the magnitude and direction of the associations. Statistical significance was determined at $p < 0.05$; for PORs, a 95% CI excluding 1 indicated a statistically significant association. Multivariable analysis was conducted using multiple logistic regression to identify factors independently associated with occupational fatigue while controlling for potential confounding variables, variables with bivariate p -values < 0.25 were considered for inclusion in the multivariable model, alongside variables deemed substantively important. Potential confounding was assessed by comparing the adjusted PORs before and after removing each variable from the model. A change of 10% or more in the POR for the main exposure was considered indicative of potential confounding. Variables were retained based on statistical significance, their confounding effects, and substantive relevance, rather than statistical significance alone.

3. RESULTS AND DISCUSSIONS

3.1 Results

3.1.1 Univariate Analysis

Dependent Variable Measurements were carried out on Tuesday, July 16, 2019, with one measurement taken. In this study, two stages of examination were conducted. As shown in Figure 4.1, among 55 respondents who completed the KAUPK₂ assessment, 38 respondents (69.09%) experienced fatigue, while 17 respondents (30.91%) reported minimal fatigue.

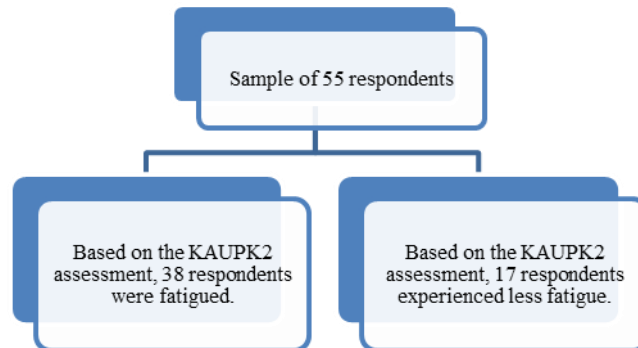


Figure 1. Research flowchart on the influence of physical factors on work fatigue among bread factory workers at CV “X” in 2019

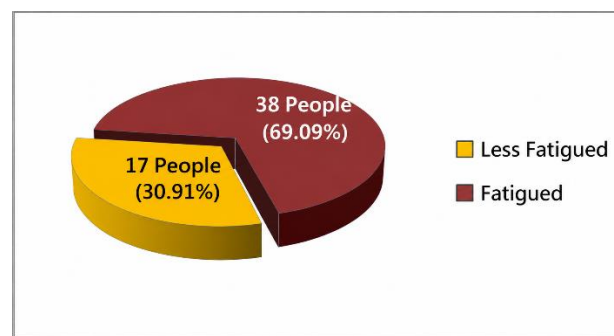


Figure 2. Proportion of work fatigue among bakery workers at CV “X” in 2019

Table 2 presents the distribution of workers exposed to potentially hazardous workplace physical environmental conditions associated with occupational fatigue. A total of 33 workers (60.00%) were exposed to illumination levels below the applicable threshold limit value (TLV). Regarding noise exposure, 31 workers (56.36%) were exposed to levels exceeding the applicable TLV. Similarly, 30 workers (54.55%) were exposed to working temperatures exceeding the applicable TLV, and 25 workers (45.45%) were exposed to vibration levels above the applicable TLV.

Table 3. Distribution of independent variables by work fatigue among bakery workers at CV “X” in 2019

3. Distribution of independent variables of work fatigue among bakery workers at CV 1				
No.	Independent Variables	Category	Number (n)	Percentage (%)
1	Illumination	Not at risk (> 300 lux)	22	40
		At risk ($\leq$ 300 lux)	33	60
2	Noise	Not at risk (< 85 dB)	24	43.64
		At risk (> 85 dB)	31	56.36
3	Temperature	Not at risk (< 28°C)	25	45.45
		At risk (> 28°C)	30	54.55
4	Vibration	Not at risk (< 5 m/s ²)	30	54.55
		At risk (> 5 m/s ²)	25	45.45
	Total		55	100

3.1.2 Bivariate Analysis

Table 4. Associations between physical environmental factors and work fatigue among bakery workers at CV “X” in 2019

Independent variable	Exposure category	Work fatigue, n (%)	No work fatigue, n (%)	Total, n (%)	p-value	POR (95% CI)
Illumination	Above TLV (> TLV)	20 (90.9%)	2 (9.1%)	22 (100%)	0.004	0.120 (0.024–0.599)
	At or below TLV ($\leq$ TLV)	18 (54.5%)	15 (45.5%)	33 (100%)		
Noise	Below TLV (< TLV)	11 (45.8%)	13 (54.2%)	24 (100%)	0.001	7.977 (2.127–29.918)

Independent variable	Exposure category	Work fatigue, n (%)	No work fatigue, n (%)	Total, n (%)	p-value	POR (95% CI)
Temperature	Above TLV (> TLV)	27 (87.1%)	4 (12.9%)	31 (100%)	0.17	0.778 (0.245–2.473)
	Below TLV (< TLV)	18 (72.0%)	7 (28.0%)	25 (100%)		
Vibration	Above TLV (> TLV)	20 (66.7%)	10 (33.3%)	30 (100%)	0.006	6.417 (1.577–26.110)
	Below TLV (< TLV)	16 (53.3%)	14 (46.7%)	30 (100%)		
	Above TLV (> TLV)	22 (88.0%)	3 (12.0%)	25 (100%)		

Note: TLV = threshold limit value; POR = prevalence odds ratio; CI = confidence interval. Total sample size = 55 workers, comprising 38 workers with work fatigue and 17 without work fatigue. The POR values and reference categories are reproduced from the original results and should be verified, particularly for illumination and temperature

The bivariate analysis examined the associations between four physical environmental factors—illumination, noise, temperature, and vibration—and work fatigue among 55 bakery workers at CV “X” in 2019. Illumination was significantly associated with work fatigue ($p = 0.004$). Among the 22 workers exposed to illumination levels above the threshold limit value (TLV), 20 (90.9%) experienced work fatigue. Similarly, noise was significantly associated with work fatigue ($p = 0.001$), with 27 of 31 workers (87.1%) exposed to noise above the TLV experiencing fatigue. Vibration also showed a statistically significant association with work fatigue ($p = 0.006$); 22 of 25 workers (88.0%) exposed to vibration above the TLV experienced fatigue. In contrast, temperature was not significantly associated with work fatigue ($p = 0.170$), although 20 of 30 workers (66.7%) exposed to temperatures above the TLV reported fatigue. Overall, the findings indicate that illumination, noise, and vibration were significantly associated with work fatigue, whereas temperature was not statistically significant in this study. These findings suggest that workplace environmental controls, particularly for noise and vibration, warrant attention. However, the retrospective observational design does not establish causality.

3.1.3 Multivariable Analysis

Multivariable analysis was performed to examine the associations between multiple independent variables and work fatigue simultaneously. The analysis consisted of two stages: bivariate screening and multivariable logistic regression modeling. Multiple logistic regression was selected because the study variables were categorical.

Bivariate Screening

Bivariate screening was conducted to identify independent variables eligible for inclusion in the multivariable model. Variables with a bivariate p -value of less than 0.250 were considered candidates for multivariable analysis.

Table 5. Bivariate screening of independent variables associated with work fatigue among bakery workers at CV “X” in 2019

Independent variable	p-value	Eligibility
Illumination	0.0023	Candidate
Noise	0.0014	Candidate
Temperature	0.1691	Candidate
Vibration	0.0042	Candidate

All four independent variables met the screening criterion ($p < 0.250$) and were included in the initial multivariable logistic regression model.

Multivariable Logistic Regression Modeling

The multivariable modeling process began with all four independent variables identified during bivariate screening. Variables with p -values greater than 0.05 were considered for removal, beginning with the highest p -value. Changes in prevalence odds ratios (PORs) were examined to identify potential confounding, using a change of more than 10% as the criterion.

Table 6. Multivariable logistic regression model development and changes in POR

Panel A. Initial model (Model I): all four independent variables included					
Independent variable	p-value	POR	95% CI lower	95% CI upper	
Illumination	0.022	0.118	0.019	0.734	
Noise	0.042	8.478	1.084	66.326	
Temperature	0.823	1.179	0.278	4.995	
Vibration	0.877	0.84	0.093	7.594	
Panel B. Model II: vibration removed					
Independent variable	p-value	POR	95% CI lower	95% CI upper	
Illumination	0.02	0.122	0.021	0.721	
Noise	0.005	7.546	1.832	31.076	
Temperature	0.83	1.172	0.277	4.952	
Vibration	—	—	—	—	
Panel C. Model III: temperature excluded from the model					
Independent variable	p-value	POR	95% CI lower	95% CI upper	
Illumination	0.021	0.124	0.021	0.726	
Noise	0.041	8.381	1.093	64.256	
Temperature	0.823	—	—	—	
Vibration	0.877	0.854	0.096	7.566	
Panel D. Changes in POR after removing variables from Model I					
Independent variable	POR in Model I	POR after vibration removal	Change (%)	POR after temperature removal	Change (%)
Illumination	0.118	0.122	3.39	0.124	5.08
Noise	8.478	7.546	–10.99	8.381	–1.14
Temperature	1.179	1.172	0.59	—	—
Vibration	0.84	—	—	0.854	1.67

Note: POR = prevalence odds ratio; CI = confidence interval. Dashes indicate variables excluded from the relevant model. Percentage changes are reproduced from the original analysis

The initial model included the illumination, noise, temperature, and vibration. Vibration was removed first because it had the highest p-value (0.877). Following its removal, the POR for noise changed by approximately –10.99%, exceeding the pre-specified 10% threshold. Therefore, vibration was considered a potential confounder and was retained for subsequent modeling analyses. Temperature was then evaluated for removal because its p-value was greater than 0.05 (0.823). The reported changes in POR after excluding temperature were below 10%, indicating that temperature did not meet the specified criterion for confounding.

Final multivariable model

Based on the reported results, the final model included illumination, noise, and vibration.

Table 7. Final multivariable logistic regression model for work fatigue among bakery workers at CV “X” in 2019

Independent variable	p-value	POR	95% CI lower	95% CI upper
Illumination	0.021	0.124	0.021	0.726
Noise	0.041	8.381	1.093	64.256
Vibration	0.887	0.854	0.096	7.566
Model statistics				
Statistic	Result			
Omnibus test	0.001			
Nagerkerke R Square	0.396 (39.6%)			

The final multivariable logistic regression model identified illumination and noise as statistically significant factors associated with work fatigue. Illumination had a POR of 0.124 (95% CI: 0.021–0.726; $p = 0.021$), while noise had a POR of 8.381 (95% CI: 1.093–64.256; $p = 0.041$). These findings suggest that illumination and noise were independently associated with work fatigue after adjustment for the other variables retained in the model. However, the direction of the illumination association must be interpreted according to the reference category used in the regression. Vibration

was not statistically significant in the final model ($p = 0.887$), although it was retained because the earlier model comparison suggested that it might act as a confounding variable. Temperature was excluded from the final model because its p -value exceeded 0.05 and its removal reportedly resulted in changes in the PORs of less than 10%. The reported Nagelkerke R^2 of 0.396 indicates that the model's explanatory measure was 39.6%. The remaining 60.4% reflects variation not accounted for by the model's explanatory capacity and may be associated with other factors not included in this study. The reported Omnibus test result ($p = 0.001$) suggests that the model containing predictors performed better than the intercept-only model.

3.2. Discussion

Multivariate analysis identified a statistically significant association between illumination and work fatigue (POR = 0.124, 95% CI: 0.021–0.726; $p = 0.021$). In the bivariate analysis, work fatigue was reported by 90.9% of workers exposed to illumination above the threshold limit value (TLV), compared with 54.5% of workers exposed to illumination at or below the TLV. This finding is broadly consistent with Boyce, who reported that low illumination could reduce work speed and produce fatigue-related changes in prolonged work performance (Boyce, 1970). A field study by van Duijnhoven et al. also examined the relationship between workplace light exposure and momentary exhaustion, providing further evidence that lighting conditions may be relevant to employees' experience of fatigue (van Duijnhoven et al., 2019). From a theoretical perspective, inadequate illumination may increase visual effort, reduce visual comfort, and contribute to visual strain during tasks requiring sustained attention. However, the direction of the adjusted association in the present study must be interpreted according to the regression reference category (Beljikangarlou et al., 2024). The POR of 0.124 cannot automatically be interpreted as showing that inadequate illumination increases fatigue; the original regression coding must first be verified. The high prevalence of work fatigue (69.09%) may be related to the physical demands of bakery production and exposure to environmental stressors in the workplace. In this study, noise was significantly associated with fatigue, whereas inadequate illumination and vibration showed significant associations in the bivariate analysis. The combination of repetitive tasks and potentially unfavorable working conditions may contribute to worker fatigue; however, the cross-sectional design does not establish causality.

Noise was significantly associated with work fatigue in the multivariate analysis (POR = 8.381, 95% CI: 1.093–64.256; $p = 0.041$). In the bivariate analysis, fatigue occurred in 87.1% of workers exposed to noise above the TLV, compared with 45.8% of workers exposed to noise below the TLV. This finding is consistent with that of Techera et al., whose meta-analysis identified noise as one of the workplace environmental factors associated with occupational fatigue (Techera et al., 2016). This finding is also supported by the systematic review by Croy et al. on occupational and environmental noise exposure, which discussed adverse effects extending beyond hearing, including physiological and psychological responses (Y. Lee et al., 2023). Theoretically, persistent noise may increase attentional demands, interfere with communication, and contribute to stress and mental exhaustion, particularly during repetitive production tasks (Nunes Cavalcante da Cunha Lobo et al., 2025). Therefore, the present findings are consistent with the theory that excessive noise can adversely affect workers' well-being and performance. However, the wide confidence interval indicates uncertainty about the magnitude of the association, and the observational design does not establish a causal relationship.

Vibration was significantly associated with work fatigue in the bivariate analysis ($p = 0.006$), with fatigue reported by 88.0% of workers exposed to vibration above the TLV, compared with 53.3% of those exposed below the TLV. However, vibration was not statistically significant in the reported multivariable model ($p = 0.887$). This finding is partly consistent with Ahn et al., who investigated occupational vibration exposure among 45,596 workers in South Korea and reported that vibration exposure and its duration were relevant to work-related fatigue (Ahn et al., 2022). From an occupational health perspective, prolonged vibration exposure may contribute to physical discomfort

and musculoskeletal strain, potentially increasing workers' overall fatigue. In the present study, removing vibration from the initial model changed the POR for noise from 8.478 to 7.546, a decrease of approximately 10.99%. This exceeded the 10% criterion used in the original analysis and suggests that vibration may be a confounding variable (Omar et al., 2025; Rahimimoghadam et al., 2023). Nevertheless, the confounding interpretation should be confirmed using the original regression output and appropriate substantive reasoning; statistical nonsignificance alone does not justify excluding a potentially important confounder. The difference between the bivariate and multivariable findings suggests that the observed association between vibration and work fatigue may be influenced by other workplace factors included in the adjusted analysis. This highlights the importance of distinguishing crude associations from those that remain after adjusting for potential confounders

Temperature was not significantly associated with work fatigue in the bivariate analysis ($P = 0.170$). Fatigue was reported by 66.7% of workers exposed to temperatures above the TLV and 72.0% of those exposed below the TLV. This finding is inconsistent with the broader evidence reported by Lee et al., whose systematic review identified several adverse health outcomes associated with occupational heat exposure (J. Lee et al., 2022). Similarly, Flouris et al. conducted a systematic review and meta-analysis involving workers from multiple countries and found that occupational heat stress was associated with physiological strain and reduced productivity (Flouris et al., 2018). Theoretically, excessive workplace heat can increase cardiovascular and thermoregulatory demands, potentially contributing to fatigue, dehydration, and reduced work capacity in workers. However, the absence of a statistically significant association in the present study does not establish that temperature does not affect fatigue. The small sample size, categorization of temperature exposure, and lack of information on humidity, air movement, workload, and duration of exposure may have limited the ability to detect an association. Thus, the present results differ from those of the broader literature, but the difference may reflect the specific conditions and limitations of this study.

3.3. Research Implications

These findings highlight the need to prioritize noise control and workplace illumination assessment to help reduce worker fatigue. Factory managers should monitor noise levels and implement equipment maintenance, noise reduction at the source, and appropriate hearing protection when required. Workplace illumination should be assessed and adjusted according to the task requirements and applicable occupational safety standards. Vibration should also be monitored because it may influence the association between noise and fatigue. Although temperature was not significantly associated with fatigue, routine monitoring is important for maintaining a safe and comfortable working environment.

3.4. Limitations

This study involved only 55 workers from a single bakery, limiting the generalizability of the findings. Furthermore, its cross-sectional design precludes causal conclusions. Future studies should include larger samples from multiple workplaces.

4. CONCLUSION

This study found that 69.09% of workers at bakery factory CV "X" experienced work fatigue in 2019. Illumination and noise exposure were statistically significantly associated with work fatigue in the multivariable analysis. Illumination had an adjusted POR of 0.124 (95% CI: 0.021–0.726; $p = 0.021$), while noise exposure had an adjusted POR of 8.381 (95% CI: 1.093–64.256; $p = 0.041$). Vibration was identified as a potential confounding variable in the relationship between noise exposure and work fatigue, whereas temperature was not statistically significantly associated with work fatigue ($p = 0.170$). These findings highlight the importance of monitoring and controlling workplace physical environmental conditions to support occupational health and fatigue prevention. However, the direction of the association between illumination and fatigue should be interpreted after verifying the regression reference category and variable coding.

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