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ORIGINAL RESEARCH ARTICLE

Association of Noise Exposure, Age, and Length of Service with Work Fatigue among Furniture Production Workers in Sidoarjo, Indonesia: A Cross-Sectional Study

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ABSTRACT

Furniture production workers are exposed to woodworking-machine noise while performing physically demanding tasks, yet evidence on how noise and individual factors relate to work fatigue in this sector remains limited. This study aimed to examine the association of noise exposure, age, and length of service with work fatigue among furniture production workers. A cross-sectional study was conducted among 40 randomly selected production workers in a furniture industry in Sidoarjo, Indonesia. Workstation noise was measured with a sound level meter in accordance with SNI 7231:2009, and work fatigue was assessed using the Industrial Fatigue Research Committee (IFRC) questionnaire. Associations were tested using the chi-square or Fisher's exact test, and their strength was expressed as prevalence ratios (PR) with 95% confidence intervals (CI). High work fatigue was reported by 60.0% of workers, and 40.0% worked at stations exceeding the threshold limit value of 85 dB(A), with a peak level of 91.0 dB(A) at the circular saw. High fatigue was associated with noise exposure > 85 dB(A) (PR = 2.50; 95% CI 1.47–4.25; $p < 0.001$), age > 40 years (PR = 2.23; 95% CI 1.49–3.34; $p = 0.001$), and length of service > 12 years (PR = 3.67; 95% CI 1.85–7.25; $p < 0.001$). Noise exposure above the threshold limit value, older age, and longer service were associated with high work fatigue, identifying older, long-serving workers at noisy workstations as a priority group for prevention. Engineering noise control, limitation of exposure time with scheduled rest breaks, and the use of hearing protection are recommended.

Introduction

Occupational noise is one of the most widespread physical hazards in manufacturing. Its best-known consequence is noise-induced hearing loss, but a growing body of evidence shows that noise also has non-auditory effects, including annoyance, psychological stress, sleep disturbance, impaired attention and memory, elevated blood pressure, fatigue, and reduced work performance [1], [2], [3]. In Indonesia, the Regulation of the Minister of Manpower No. 5 of 2018 sets the threshold limit value (TLV) for noise at 85 dB(A) for an 8-hour workday and applies a 3-dB exchange rate, so that the permitted daily exposure falls to 4 hours at 88 dB(A) and to 2 hours at 91 dB(A) [4]. Compliance with this standard remains weak in small and medium-sized enterprises, where noise is often measured only occasionally and engineering controls are rarely implemented [5].

The furniture industry illustrates this problem clearly. Wood processing involves cutting, planing, routing, and sanding, each performed with machines that emit high sound pressure levels at close range to the operator. At the same time, furniture work is labour-intensive: workers lift and move

heavy materials, adopt static or awkward postures, and repeat the same movements for long shifts, frequently in semi-open workshops without acoustic treatment [6], [7]. Workers in this sector are therefore exposed simultaneously to an environmental stressor (noise) and to a high physical workload, a combination that places them at particular risk of work fatigue.

Work fatigue is a state of reduced efficiency, endurance, and motivation that results from prolonged physical or mental activity and is not fully relieved by ordinary rest [8]. Its subjective symptoms typically cluster into three patterns: drowsiness and dullness, difficulty in concentration, and physical discomfort [9]. Fatigue matters for occupational health because it slows reaction time, increases errors, lowers productivity, and raises the risk of occupational accidents, particularly when workers operate cutting machinery [10], [11]. Its determinants are commonly grouped into internal factors, such as age, length of service, nutritional status, and health, and external factors, such as the physical work environment, workload, and working hours [12], [13].

Several mechanisms may link noise to fatigue. Sustained noise acts as a non-specific stressor that activates the sympathetic nervous system and the hypothalamic–pituitary–adrenal axis; occupational noise exposure has been associated with higher perceived stress and altered cortisol levels in manufacturing workers [14]. Noise also masks speech and warning signals, so workers must expend additional cognitive effort to communicate and maintain attention, and noise-related annoyance and sleep disturbance reduce recovery between shifts [1], [2]. Consistent with these mechanisms, noise intensity has been associated with fatigue among palm oil mill workers [15], shipyard workers, in whom it correlated with reaction-time fatigue [16], ship industry workers [17], and speedboat crews, in whom noise correlated with physical and mental fatigue [18]. Nevertheless, the evidence is not uniform: no association between noise and fatigue was found among process and engineering workers in another palm oil mill [19].

Age and length of service are the individual factors most often examined alongside noise. Physical work capacity peaks around 25–30 years of age and then declines progressively, with reductions in muscle strength, aerobic capacity, and the speed of recovery, so that an identical task represents a greater relative load for an older worker [12], [11]. Length of service reflects cumulative exposure to noise and repetitive physical loading, but it can also bring adaptation, skill, and more efficient use of energy [20]. The empirical findings are correspondingly inconsistent. Age was associated with fatigue among furniture workers in Jepara [6] and among office workers [21], but not among shipyard or ship industry workers [16], [17]. Length of service was associated with fatigue among furniture workers in Wajo Regency [7] and among waste collectors [13], but not in the shipbuilding studies [16], [17].

These inconsistencies point to three gaps. First, studies in the furniture sector remain scarce, even though it combines high noise with heavy manual work. Second, most previous studies examined each factor separately and reported only p-values, without measures of association that show how much higher the prevalence of fatigue is in each exposure group. Third, small furniture workshops, where unenclosed machines in semi-open rooms create heterogeneous exposures between workstations, have rarely been studied. Evidence that examines noise exposure together with age and length of service in this setting, and quantifies the strength of each association, is therefore needed to guide targeted prevention.

A preliminary survey in the production room of the study company identified sanders, circular saws, and routers as the main noise sources, with a peak level of 91 dB(A) at the sawing machine, exceeding the TLV [4]. Interviews with 15 workers showed that 40% were older than 40 years, several had been employed for more than 12 years, and most complained of annoying noise and tiredness at the end of the shift.

Accordingly, this study aimed to examine the association of noise exposure, age, and length of service with work fatigue among furniture production workers in Sidoarjo, Indonesia.

Materials and Methods

Study design and setting

This analytical observational study used a cross-sectional design and is reported in accordance with the STROBE guidelines. It was conducted in the production room of a furniture industry in Sidoarjo Regency, East Java, Indonesia; the name of the company is not disclosed. The production room is semi-enclosed (the walls do not fully surround the work area), and the sanders, circular saws, and routers are not fitted with noise dampers or enclosures. Workers in the production room typically work 8 hours per day.

Population, sample, and sampling

The study population comprised all 45 production workers. Workers who were present during data collection and willing to participate were eligible. The minimum sample size was calculated using the Slovin formula, $n = N / (1 + Ne^2)$, with N = 45 and a margin of error (e) of 0.05, giving approximately 40 workers; therefore, 40 workers (88.9% of the population) were included. Participants were selected by simple random sampling from the list of production workers, so that every worker had an equal chance of being selected.

Variables and measurements

Noise exposure. Noise was measured with a sound level meter following the procedure of the Indonesian National Standard SNI 7231:2009 on the measurement of noise intensity in the workplace [22]. Measurement points were determined at the workstations in the production area, including the sanders, circular saws, and routers. Measurements were taken during normal working hours with A-weighting, with the microphone positioned at the ear height of the worker, and the result for each workstation was recorded on a noise intensity data sheet and assigned to the workers at that station. Exposure was classified as ≤85 dB(A) (complying with the TLV) or >85 dB(A) (exceeding the TLV) [4].

Age and length of service. Age (completed years) and length of service (years since first employment at the workplace) were obtained by structured interview and categorised as ≤40 vs >40 years and ≤12 vs >12 years, respectively. The cut-off points were set a priori on the basis of the preliminary survey.

Work fatigue. Fatigue was measured using the Indonesian version of the IFRC (Japanese Industrial Fatigue Research Committee) subjective symptoms questionnaire, which was adopted from the literature without modification; no new validation was performed. The questionnaire contains 30 items in three domains of ten items each: weakening of activity, weakening of motivation (concentration), and physical fatigue [9]. Each item is rated on a four-point Likert scale (1 = never, 2 = sometimes, 3 = often, 4 = very often), giving a total score of 30–120 (low 30–52, moderate 53–75, high 76–98, very high 99–120). For analysis, the score categories were collapsed into two groups, low and high work fatigue. The Indonesian version has shown satisfactory validity (item–total correlations) and high internal consistency (Cronbach's α = 0.921) [23]. The questionnaire was completed by the respondents under the supervision of the researchers.

Statistical analysis

Data were analysed in two stages. Univariate analysis described respondent characteristics as frequencies and percentages. Bivariate analysis examined the association of each independent variable with work fatigue. Because all variables were categorical (2 × 2 tables), associations were tested with Pearson's chi-square (χ^2) test of independence; Fisher's exact test was used when any expected cell count was below 5. Statistical significance was set at a two-sided $p < 0.05$. The strength of association was expressed as the prevalence ratio (PR), which is the preferred measure for a common outcome in cross-sectional studies, and the odds ratio (OR), each with its 95% confidence interval (CI). When a cell contained zero, the OR was estimated with the Haldane–Anscombe correction (0.5 added to every cell).

Ethical considerations

The study protocol received ethical approval from the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya (No. EA/4174/KEPK-Poltekkes_Sby/V/2025). Permission was obtained from the management of the company. All participants received an explanation of the study and provided written informed consent before data collection. Participation was voluntary, data were anonymised, and the name of the company is not disclosed.

Results

Characteristics of respondents

Most respondents were aged ≤40 years (72.5%) and had worked for ≤12 years (55.0%) (Table 1). The highest workstation noise level, 91.0 dB(A), was recorded at the circular sawing machine; 16 workers (40.0%) worked at stations exceeding 85 dB(A). Overall, 24 workers (60.0%) had high work fatigue.

Table 1. Characteristics of Furniture Production Workers in Sidoarjo, Indonesia (n = 40)

Characteristic	n	%	Characteristic	n	%
Age (years)			*Workstation noise level, dB(A)*		
≤ 40	29	72.5	≤ 85 (complies with TLV)	24	60.0
> 40	11	27.5	> 85 (exceeds TLV)	16	40.0
Length of service (years)			*Work fatigue (IFRC)*		
≤ 12	22	55.0	Low	16	40.0
> 12	18	45.0	High	24	60.0

TLV, threshold limit value (85 dB(A) for 8 h/day, Regulation of the Minister of Manpower No. 5 of 2018); IFRC, Industrial Fatigue Research Committee questionnaire.

Table 2. Association of Noise Exposure, Age, and Length of Service with Work Fatigue among Furniture Production Workers in Sidoarjo, Indonesia (n = 40)

Variable	Work Fatigue, n (%)		Total (n)	χ^2	p-value	PR (95% CI)	OR (95% CI)
	High	Low					
Noise level, dB(A)							
> 85	15 (93.8)	1 (6.2)	16	12.66	< 0.001	2.50 (1.47–4.25)	25.00 (2.81–222.59)
≤ 85	9 (37.5)	15 (62.5)	24			1.00 (ref.)	1.00 (ref.)
Age, years							
> 40	11 (100.0)	0 (0.0)	11	10.12	0.001[a]	2.23 (1.49–3.34)	28.11 (1.51–521.95)[b]
≤ 40	13 (44.8)	16 (55.2)	29			1.00 (ref.)	1.00 (ref.)
Length of service, years							
> 12	18 (100.0)	0 (0.0)	18	21.82	< 0.001	3.67 (1.85–7.25)	93.92 (4.91–1798.20)[b]
≤ 12	6 (27.3)	16 (72.7)	22			1.00 (ref.)	1.00 (ref.)

Percentages are row percentages. χ^2, Pearson chi-square; PR, prevalence ratio; OR, odds ratio; CI, confidence interval; ref., reference category. [a]Fisher's exact test (one cell with expected count < 5); Pearson χ^2 p = 0.001. [b]Haldane–Anscombe correction (0.5 added to each cell) because of a zero cell.

Association of noise exposure, age, and length of service with work fatigue

The prevalence of high fatigue was 93.8% among workers exposed to >85 dB(A) compared with 37.5% among those exposed to ≤85 dB(A) (χ^2 = 12.66; p < 0.001; PR = 2.50; 95% CI 1.47–4.25) (Table 2). All 11 workers aged >40 years had high fatigue, compared with 44.8% of those aged ≤40 years (Fisher's exact p = 0.001; PR = 2.23; 95% CI 1.49–3.34). Similarly, all 18 workers with >12 years of service had high fatigue, compared with 27.3% of those with ≤12 years (χ^2 = 21.82; p < 0.001; PR = 3.67; 95% CI 1.85–7.25). The ORs were large, with wide confidence intervals, reflecting the zero cells and the small sample size.

Discussion

This study found that most furniture production workers had high work fatigue and that noise exposure above the TLV, age above 40 years, and more than 12 years of service were each significantly

associated with high fatigue. The strongest association was observed for length of service, followed by noise exposure and age. Taken together, these results show that fatigue in this workplace is concentrated in a recognisable group of workers, namely those who work at the noisiest stations and those who are older and have served longest.

The prevalence of high fatigue in this study is notably higher than in several other Indonesian occupational groups assessed with subjective instruments, in which most respondents were in the low or moderate category [23], [18]. This difference is plausible given the working conditions observed. Furniture production combines heavy manual handling and repetitive tasks with continuous machine noise, in a semi-enclosed room where noise is neither controlled at source nor isolated from other workstations. Under these conditions, physical and environmental loads accumulate during the shift, with little opportunity for recovery.

Among the environmental factors, noise exposure showed a clear association with fatigue: workers at stations exceeding 85 dB(A) were 2.5 times as likely to report high fatigue as those at compliant stations, and almost all of them were in the high fatigue category. This finding is consistent with studies among palm oil mill workers [15], ship industry workers [17], and shipyard workers, in whom noise correlated positively with fatigue measured objectively by reaction time [16], as well as speedboat crews, in whom noise correlated with physical and mental fatigue [18]. Because a similar association has been observed with subjective questionnaires and reaction-time tests, and in very different work settings, it is unlikely to be an artefact of a single measurement method.

The association between noise and fatigue can be explained by the non-auditory pathways of noise. Continuous noise acts as a stressor that activates the sympathetic nervous system and the hypothalamic–pituitary–adrenal axis [14], [2], and prolonged activation of these systems increases energy expenditure and muscle tension. Noise also masks speech and warning signals, so workers must invest additional attention to communicate and to operate cutting machines safely. This sustained cognitive effort corresponds closely to the "weakening of motivation (concentration)" dimension of the IFRC questionnaire [9], [1]. In addition, noise-related annoyance and disturbed sleep reduce recovery between shifts, so that fatigue carries over from one working day to the next [1].

Not all studies, however, have found this association. No relationship between noise and fatigue was observed among process and engineering workers in a palm oil mill [19]. Such discrepancies may arise when most workers in a study are exposed to similar noise levels, leaving little contrast between groups, when hearing protection is used consistently, or when fatigue is driven mainly by other factors such as nutritional status. In the present study, exposure varied considerably between workstations because of differences in machine type and in the distance between workers and noise sources. The sawing machine reached 91 dB(A), a level at which Regulation No. 5 of 2018 permits only 2 hours of exposure per day [4], whereas workers typically remain at their stations for a full 8-hour shift. This wide contrast in exposure probably made the association easier to detect. At the same time, workers at the noisiest stations, such as sawing and routing, may also perform the most physically demanding tasks, so part of the observed association may reflect physical workload rather than noise alone.

Turning to individual factors, all workers older than 40 years had high fatigue, compared with fewer than half of younger workers. This agrees with findings among furniture workers in Jepara [6], office workers [21], and cracker factory workers [12]. Physiologically, muscle strength, aerobic capacity, and the ability to recover from exertion decline progressively after the third decade of life [12], [11]. Because the physical demands of furniture work are the same for all workers, an older worker performs the same task at a higher percentage of maximal capacity and therefore accumulates fatigue more rapidly. Age-related changes in sleep quality and in tolerance to noise may further reduce recovery between shifts.

In contrast, no association between age and fatigue was found among shipyard workers [16] or ship industry workers [17]. These differences may partly reflect the measurement method: Rokhati et

al. measured fatigue with a reaction timer, which captures mainly psychomotor slowing, whereas the IFRC questionnaire also captures physical discomfort and reduced motivation, dimensions that are more sensitive to age. The age composition of the workforce also matters. When few workers are older than 40, or when older workers are assigned lighter or supervisory tasks, the contrast between age groups becomes small. In the present study, all respondents were production-room workers, so older workers were exposed to the same manual tasks and noise as younger workers, which may explain why the association was so pronounced.

Length of service showed the strongest association with fatigue, and every worker who had served more than 12 years reported high fatigue. This is in line with studies of furniture workers in Wajo Regency [7], waste collectors in Kendari [13], and cracker factory workers [12]. Long service in the same production room means many years of repetitive loading of the musculoskeletal system and a large cumulative noise dose. Over time, this may reduce physical reserve, increase chronic musculoskeletal complaints, and lower work motivation, all of which are expressed as subjective fatigue.

Some studies have reported no association between length of service and fatigue [16], [17], and others have argued that longer service improves skill and energy management, thereby reducing fatigue [20]. Adaptation is most likely to protect workers when tasks can be performed more efficiently with experience or when experienced workers move to less demanding roles. In the furniture industry studied, tasks are largely manual, noise is not controlled, and long-serving workers remain on the production line, so the cumulative burden appears to outweigh any benefit of adaptation. Furthermore, workers who could not tolerate these conditions may have left the company earlier (the healthy worker survivor effect), so the long-serving workers who remained were probably relatively resilient. If so, the true association may be even stronger than observed.

The three factors examined are unlikely to act in isolation. Older workers tend to be those with the longest service, and long-serving workers have also accumulated the greatest noise dose over their careers. This overlap is reflected in the finding that every worker older than 40 years and every worker with more than 12 years of service had high fatigue. Because the analysis was bivariate, the associations reported here are crude and should be interpreted as identifying a high-risk profile rather than the separate contribution of each factor. From a prevention standpoint, however, this profile is useful, because older, long-serving workers at noisy stations form an easily identifiable group that can be prioritised for intervention.

These findings support applying the hierarchy of controls in furniture workshops. Engineering controls should come first: fitting enclosures, dampers, or low-noise blades to circular saws and routers, maintaining machines regularly to reduce vibration-related noise, and separating the noisiest machines from other workstations with barriers. Administrative controls should limit daily exposure at stations above 85 dB(A) to the permitted durations [4] through job rotation between noisy and quiet tasks and scheduled short rest breaks in a quiet area, which also support recovery from physical fatigue. Hearing protection, in the form of earplugs or earmuffs, should be provided as part of a hearing conservation programme that includes training, supervision of use, and periodic audiometry. Periodic fatigue screening with the IFRC questionnaire is simple and inexpensive and could be used to monitor workers, prioritising those who are older and have served longest, and to adjust their tasks when needed.

This study has several limitations. First, its cross-sectional design does not allow temporal or causal inference, so the findings indicate associations only. Second, the sample was small and drawn from a single industry, which limits generalisability and produced imprecise estimates, particularly for the ORs affected by zero cells. Third, the analysis was bivariate, so the associations are unadjusted and the separate contributions of the correlated factors, age and length of service, could not be distinguished. Fourth, potential confounders such as physical workload, task type, rest duration, sleep

quality, nutritional status, overtime, and use of hearing protection were not measured. Fifth, noise was assessed by area measurement at workstations with a sound level meter rather than by personal dosimetry, which may have caused exposure misclassification. Finally, fatigue was self-reported and dichotomised, which may have introduced response bias and loss of information.

Conclusions

High work fatigue was common among furniture production workers in Sidoarjo. Workers exposed to noise above the threshold limit value, older workers, and workers with longer service were more likely to experience high fatigue, and length of service showed the strongest association of the three factors. Fatigue in this workplace was therefore concentrated among older, long-serving workers at the noisiest workstations. This group can be readily identified and should be prioritized for prevention through noise control at source, limitation of exposure time with scheduled rest breaks, consistent use of hearing protection, and periodic fatigue surveillance.

Future research should involve larger, multi-site samples of furniture workers and use longitudinal designs to clarify the temporal relationship between noise exposure and fatigue. Personal noise dosimetry, objective fatigue measures such as reaction-time tests, and measurement of physical workload, sleep quality, nutritional status, and hearing protection use are recommended, together with multivariable analysis to distinguish the independent contributions of noise, age, and length of service. Intervention studies are also needed to evaluate whether engineering noise controls and scheduled rest breaks reduce work fatigue in this sector.

Declarations

Ethics Approval and Consent to Participate: This study was approved by the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya (No. EA/4174/KEPK-Poltekkes_Sby/V/2025) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before data collection, and permission was obtained from the company management.

Consent for Publication: Not applicable. The manuscript contains no individual personal data; the company is not named and participants are not identifiable.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information that could compromise participant and company confidentiality.

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Declaration of Generative AI and AI-Assisted Technologies: During the preparation of this manuscript, the authors used an AI-based assistant to improve language and structure. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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