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RESEARCH ARTICLE

Physical Workload, Age, Gender, and Work Fatigue among Sawmill Workers

Beban Kerja Fisik, Usia, Jenis Kelamin dengan Kelelahan Kerja pada Pekerja Penggergajian Kayu

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Abstract

Work-related fatigue remains a concern in occupational health, especially in wood sawing activities that require continuous physical effort and repetitive movements. This study investigated the relationship of physical workload, age, and gender with fatigue levels among workers employed in wood sawing industries in Bagelen District, Purworejo Regency. A cross-sectional quantitative approach was applied involving all 80 workers from six selected wood sawing industries during February 2025. Physical workload classification was obtained from pulse rate-based measurements, while fatigue conditions were evaluated using the Subjective Self-Assessment Test instrument. The association between variables was examined using the chi-square test with a significance level of 0.05. Moderate fatigue was identified in 66.3% of workers, while 63.8% had moderate physical workload. Only physical workload showed a significant association with fatigue ($p < 0.001$), whereas age and gender showed no significant association. Workplace strategies focusing on ergonomic improvement and workload control are needed.

Keywords: age, gender, physical workload, wood sawing workers, work fatigue

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Abstrak

Kegiatan produksi pada industri penggergajian kayu melibatkan aktivitas fisik berulang yang berpotensi menimbulkan kelelahan kerja pada pekerja. Penelitian ini dilakukan untuk mengidentifikasi hubungan antara beban kerja fisik, usia, dan jenis kelamin dengan tingkat kelelahan kerja pada pekerja penggergajian kayu di Kecamatan Bagelen, Kabupaten Purworejo. Studi kuantitatif dengan rancangan potong lintang ini melibatkan seluruh pekerja pada enam industri penggergajian kayu sebanyak 80 subjek yang dipilih melalui teknik total sampling pada Februari 2025. Beban kerja fisik ditentukan berdasarkan hasil pengukuran denyut nadi, sedangkan tingkat kelelahan dinilai menggunakan kuesioner Subjective Self-Assessment Test. Analisis hubungan dilakukan menggunakan uji chi-square. Sebanyak 66,3% pekerja mengalami kelelahan kategori sedang dan 63,8% memiliki beban kerja fisik kategori sedang. Beban kerja fisik memiliki hubungan bermakna dengan kelelahan kerja ($p < 0,001$), sementara usia dan jenis kelamin tidak menunjukkan hubungan yang signifikan. Pengendalian kelelahan perlu diarahkan pada pengelolaan tuntutan fisik pekerjaan melalui pendekatan ergonomi.

Kata Kunci: *usia, jenis kelamin, beban kerja fisik, pekerja industri kayu, kelelahan kerja*

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Highlight:

- Higher physical workload (e.g., manual lifting and wood cutting) significantly corresponds to increased worker fatigue.
- The majority of respondents reported moderate fatigue levels, with musculoskeletal discomfort (muscle soreness and physical fatigue) identified as the primary symptom.
- Demographic variables, specifically age and gender, showed no statistically significant effect on occupational fatigue levels.

INTRODUCTION

Occupational fatigue is defined as a decline in workers' physical and mental capabilities, which impairs their capacity to execute tasks optimally and subsequently reduces overall work productivity (Askari et al., 2022). This condition constitutes a critical issue in occupational safety and health, particularly in high-demand occupations involving heavy and repetitive physical labor. Sawmill workers represent a vulnerable demographic characterized by such operational demands, routinely performing tasks such as lifting, handling, and cutting timber using both manual tools and mechanical machinery (Alsayed et al., 2022). These tasks require substantial exertion, non-ergonomic working postures, and repetitive movements, significantly predisposing workers to elevated levels of occupational fatigue.

These job characteristics render sawmill workers highly susceptible to various occupational health disorders, including fatigue and musculoskeletal disorders. A study on sawmill workers in India demonstrated high prevalences of low back, shoulder, and wrist pain, alongside reduced grip strength, driven by continuous manual tasks; these findings underscore the critical need for ergonomic interventions and structured rest schedules to mitigate occupational health risks (Talina et al., 2024). Globally, the

International Labour Organization (ILO) reports that approximately 32% of workers experience fatigue during work hours (ILO, 2018). In Indonesia, occupational fatigue is frequently identified as a contributing factor to workplace incidents, with data indicating that approximately 27.8% of occupational accidents are associated with worker fatigue (Mala et al., 2024). Collectively, these insights highlight that work fatigue remains a prominent occupational health issue, negatively impacting work capacity and elevating the risk of workplace accidents.

Occupational fatigue is a multifactorial condition influenced by both individual characteristics and work-related factors. Occupational determinants, such as physical workload, are associated with heightened fatigue due to an imbalance between task demands and individual physiological capacity (Pamungkas et al., 2022). Both physical and mental workloads contribute to elevated fatigue levels or burnout, ultimately diminishing overall work performance. Furthermore, this discrepancy between job demands and functional capacity induces fatigue that typically presents at low to moderate levels, yet still exerts a long-term detrimental impact on worker endurance (Irfan, 2022).

Additionally, monotonous work tasks, high physical and mental workload intensities, psychological conditions, general health status, environmental factors, and work duration also contribute to the onset of occupational fatigue (Diasih et al., 2025). mong these determinants, this study specifically focuses on physical workload, age, and gender, as these three variables represent readily identifiable characteristics, are frequently associated with occupational fatigue, and have exhibited inconsistent findings in prior literature, thereby warranting further re-evaluation within the context of sawmill workers.

Prior findings regarding the association between work and individual characteristics and occupational fatigue remain inconclusive. Several studies have reported that workers exposed to higher physical workloads experience elevated fatigue levels. This pattern has been documented among workers at PT Galangan Kapal Bontuni and furniture workers at PT Maruki Internasional Indonesia, both demonstrating a positive association between physical workload and occupational fatigue. Beyond physical demand, age was also identified as a contributing factor among furniture workers, aligning with findings in home-based taro cake production workers (Suharmawati et al., 2025; Barend et al., 2025; Santriyana et al., 2023). Conversely, other studies observed no significant association between age or gender and occupational fatigue (Fathonah et al., 2023; Edward, 2022). These inconsistent empirical results suggest that the influence of individual characteristics on fatigue may vary depending on occupational type, physical intensity, and environmental conditions, highlighting the need for further investigation across distinct occupational groups, including sawmill workers.

In addition to the inconsistent findings in prior literature, research examining occupational fatigue among sawmill workers, particularly within the informal sector, remains scarce (Widodo, 2020). Most existing studies on the sawmill industry predominantly center on ergonomic hazards, musculoskeletal disorders, or working posture, whereas empirical investigations specifically examining the relationship between physical workload, age, gender, and occupational fatigue are still limited (Handayani et al., 2025). Informal sector sawmill workers, however, operate under distinct occupational conditions characterized by manual handling of heavy timber, prolonged operation of sawing machinery, and poor implementation of ergonomic and safety standards.

Preliminary field surveys across six sawmill enterprises in Bagelen District indicated that workers frequently experienced muscle pain, difficulty in manual log

handling, and acute exhaustion during overtime. These preliminary observations highlight that occupational fatigue remains a pressing issue requiring empirical scrutiny. Given the scarcity of literature on fatigue determinants among informal sawmill workers, this study addresses this knowledge gap by examining the interplay between physical workload, demographic factors (age and gender), and occupational fatigue. Specifically, this study aims to evaluate the relationships between physical workload, age, gender, and occupational fatigue among sawmill workers in Bagelen District, Purworejo Regency.

METHODS

This quantitative study employed a cross-sectional design, selected to analyze the relationship between physical workload, age, gender, and occupational fatigue among sawmill workers at a single point in time without applying any intervention to the participants. The research was conducted in February 2025 across six active sawmill enterprises in Bagelen District, Purworejo Regency, chosen for their operational continuity and willingness to participate. The study population comprised 80 workers distributed across these six facilities. Because all members of the study population met the eligibility criteria, a total sampling method was adopted to capture a comprehensive assessment of the entire population while minimizing potential selection bias.

The study participants comprised active sawmill workers aged ≥18 years with a minimum tenure of six months, who were present during data collection and provided written informed consent. Exclusion criteria encompassed individuals who were acutely ill during data collection, had a history of medical conditions affecting heart rate (e.g., cardiovascular disease), were taking heart rate-modulating medications, or failed to complete all physical measurements and questionnaire assessments. Primary occupational tasks included manual lifting and material handling, timber cutting using bandsaws and circular saws, stacking processed timber, and loading/unloading operations, thereby ensuring a relatively homogenous profile of physical work exposure across participants.

The independent variables in this study comprised physical workload, age, and gender, while occupational fatigue served as the dependent variable. Physical workload was evaluated using the Cardiovascular Load percentage (%CVL) method based on SNI 7269:2009 standards, determined by measuring working heart rate (WHR) and resting heart rate (RHR) using a calibrated fingertip pulse oximeter following manufacturer guidelines. Measurements were taken with participants seated comfortably and placing their index finger on the sensor until stable readings were obtained for approximately 30–60 seconds. WHR was measured twice during working hours—at 10:00 and 11:00 Western Indonesia Time (WIB)—whereas RHR was measured once at 12:30 WIB following a minimum five-minute rest period devoid of physical activity (Diniaty et al., 2016). The %CVL was calculated using the following formula:

$$\%CVL = \frac{100 \times (\text{Working Heart Rate} - \text{Resting Heart Rate})}{\text{Maximum Heart Rate} - \text{Resting Heart Rate}}$$

Occupational fatigue was evaluated using the Subjective Self-Assessment Test (SSAT) developed by the Industrial Fatigue Research Committee (IFRC) of Japan, as adapted by Tarwaka (2015), this questionnaire comprises 30 items assessing three primary dimensions of fatigue: reduced activity, weakened motivation, and physical exhaustion. Each item was scored on a 4-point response scale ranging from 0 ("never")

to 3 ("very frequently"). Participants completed the questionnaire immediately after finishing their work shift on the day of assessment to reflect post-work fatigue conditions accurately. Total fatigue scores were derived by summing all item scores and categorized into four levels according to standard classification: low (0–21), moderate (22–44), high (45–67), and severe/very high (68–90).

Data analysis commenced with univariate analysis to present participant characteristics and variable distributions. Bivariate associations between physical workload, age, gender, and occupational fatigue were subsequently examined using the chi-square test ($\alpha = 0.05$) via IBM SPSS Statistics version 24. This test was selected as all study variables were categorized, making it appropriate for assessing associations between categorical variables without quantifying effect magnitude or identifying dominant predictors.

This study was approved by the Health Research Ethics Committee of Dr. Moewardi Regional Public Hospital (Protocol code 109/I/HREC/2025, approved in 2025). Prior to data collection, all prospective participants were fully informed regarding the research objectives, procedures, expected benefits, and their rights, including the voluntary nature of participation and the freedom to withdraw at any stage without penalty. Written informed consent was obtained from all subjects involved in the study prior to enrollment.

RESULT AND DISCUSSION

Subject characteristics and variable distribution

Table 1 presents the characteristics of the workers alongside the distribution of all study variables. The workforce composition across the six sawmills was predominantly male, accounting for 62 workers (77.5%), whereas female workers comprised 18 individuals (22.5%). Regarding age distribution, the workforce was dominated by middle-aged to older age groups. The 46–55 age group exhibited the highest participation, comprising 24 workers (30.0%), while the productive age groups of 26–35 and 36–45 years accounted for 20 workers (25.0%) and 18 workers (22.5%), respectively. Additionally, an older cohort aged 56–65 years constituted 11 workers (13.8%). Conversely, younger workers aged 17–25 years represented the lowest proportion, with only 7 individuals (8.8%).

Physical workload evaluation using the Cardiovascular Load (%CVL) method revealed that the workers' workload classifications spanned only three levels. Throughout the study, no workers were categorized under heavy or very heavy workload levels. The majority of workers fell into the moderate workload category (63.8%), whereas the light and somewhat heavy categories comprised 21.3% and 15.0% of the total subjects, respectively. The work fatigue profile measured using the Subjective Self-Assessment Test exhibited a similar pattern. Most workers fell into the moderate fatigue category, totaling 53 individuals (66.3%). A total of 17 workers (21.3%) experienced low fatigue levels, while 10 workers (12.5%) reached the high fatigue category. No subjects were classified into the very high fatigue group.

Further examination of the individual SSAT dimension scores revealed that physical weakening exhibited the highest mean score at 12.613. This value was higher than the mean scores for reduced activity (9.775) and reduced motivation (6.075), indicating that the most prominent complaints among workers in this study were related to physical aspects rather than psychological or activity-related factors.

Table 1. Frequency distribution of research variables

Variable	n	%
Gender		
Male	62	77.5
Female	18	22.5
Age		
Late adolescence (17–25 years)	7	8.8
Early adulthood (26–35 years)	20	25.0
Late adulthood (36–45 years)	18	22.5
Early elderly (46–55 years)	24	30.0
Late elderly (56–65 years)	11	13.8
Physical Workload		
Light	17	21.3
Moderate	51	63.8
Somewhat heavy	12	15.0
Work fatigue		
Low	17	21.3
Moderate	53	66.3
High	10	12.5
Work fatigue domains	**Mean**	
Reduced activity	9.775	
Reduced motivation	6.075	
Physical weakening	12.613	

Note: Based on the %CVL classification, physical workload consists of five categories; however, only three categories were observed in this study: light, moderate, and somewhat heavy. No subjects were identified in the heavy or very heavy categories.

Association between physical workload and work fatigue

Cross-tabulation indicated a trend where fatigue levels increased alongside higher physical workload categories. In the light workload group, subjects were confined exclusively to the low and moderate fatigue categories. A similar pattern was observed in the moderate workload group, although the proportion of moderate fatigue became more dominant. In contrast, the majority of workers with a somewhat heavy workload were categorized into the high fatigue group (83.3%), whereas no subjects in this group experienced low fatigue. The chi-square test confirmed that this distribution pattern was statistically significant ($p < 0.001$), with a Cramér's V of 0.655, indicating a strong association strength.

Table 2. Statistical test result of physical workload and work fatigue

Physical Workload	Work Fatigue								*p-value*
	Low		Moderate		High		Total		
	n	%	n	%	n	%	n	%	
Light	7	41.2	10	58.8	0	0.0	17	100	0.001*
Moderate	10	19.6	41	80.4	0	0.0	51	100	
Somewhat heavy	0	0.0	2	16.7	10	83.3	12	100	
Total	**17**	**21.3**	**53**	**66.3**	**10**	**12.5**	**80**	**100**	

Note: *Chi-square test, significant if p-value< 0.05

Association between age and work fatigue

Statistical analysis revealed that variations in the subjects' age were not accompanied by significant changes in fatigue levels (p = 0.117). A Cramér's V coefficient of 0.283 further indicates a relatively weak association between the two variables. Although the subjects belonged to five distinct age groups, the distribution of work fatigue exhibited a virtually uniform pattern across all categories, with moderate fatigue consistently constituting the largest proportion. Even within the oldest age group (56–65 years)—where no subjects reported low fatigue and a portion experienced high fatigue—this trend was insufficient to demonstrate a statistically significant difference across age groups.

Table 3. Statistical test results of age and work fatigue

Age	Work fatigue								*p-value*
	Low		Moderate		High		Total		
	n	%	n	%	n	%	n	%	
Late adolescence (17–25 years)	3	42.9	4	57.1	0	0.0	7	100	
Early adulthood (26–35 years)	6	30.0	13	65.0	1	5.0	20	100	
Late adulthood (36–45 years)	4	22.2	13	72.2	1	5.6	18	100	0.117
Early elderly (46–55 years)	4	16.7	16	66.7	4	16.7	24	100	
Late elderly (56–65 years)	0	0.0	7	63.6	4	36.4	11	100	
Total	**17**	**21.3**	**53**	**66.3**	**10**	**12.5**	**80**	**100**	

Note: *Chi-square test, significant if p-value< 0.05

Association between gender and work fatigue

Table 4 shows that the analysis of sex did not reveal a statistically significant difference in occupational fatigue levels (p = 0.125). The observed strength of association was also low (Cramer's V = 0.228). Both groups exhibited a comparable distribution pattern, with moderate fatigue being the most predominant category across both sub-groups. Among the 62 male workers, 38 (61.3%) experienced moderate fatigue and 10 (16.1%) experienced high fatigue. Meanwhile, of the 18 female workers, 15 (83.3%) fell into the moderate fatigue category, with no subjects categorized under high fatigue.

Table 4. Statistical test results of gender and work fatigue

Gender	Work fatigue								*p-value*
	Low		Moderate		High		Total		
	n	%	n	%	n	%	n	%	
Male	14	22.6	38	61.3	10	16.1	62	100	0.125
Female	3	16.7	15	83.3	0	0.0	18	100	
Total	**17**	**21.3**	**53**	**66.3**	**10**	**12.5**	**80**	**100**	

Note: *Chi-square test, significant if p-value< 0.05

Work in the sawmill industry possesses distinct characteristics compared to light physical tasks, as the majority of work processes rely heavily on direct physical exertion.

Based on subject demographics, the workforce in this study was predominantly male, with the largest age group falling within the 46–55 years range. This composition reflects the nature of the labor force in the sawmilling sector, which continues to depend significantly on manual labor throughout the production process. Work fatigue measurement indicated that most workers experienced moderate levels of fatigue. Among the three dimensions evaluated via the SSAT instrument, the highest score was recorded for the physical weakening domain. This finding suggests that the predominant complaints reported by workers pertain to reduced physical capacity following work activities, rather than motivational decline or reduced activity. This outcome is understandable given that sawmill operations involve tasks requiring repetitive muscle contractions—such as lifting raw timber, positioning logs, and operating cutting machinery over sustained durations. Similarly, a study by Ihsan et al. (2020) on industrial production workers demonstrated that jobs with high physical demands are frequently associated with the onset of moderate work fatigue.

Based on the %CVL measurements, the majority of workers fell into the moderate physical workload category. Although heavy and very heavy workload classifications were not observed in this study, the presence of workers in the somewhat heavy category indicates that certain tasks in the sawmill industry still impose considerable physical demands. Variations in individual physical capacity, task characteristics, and duration of exposure likely contributed to the observed variation in workload values. Analysis of the relationship between physical workload and work fatigue demonstrated a significant association ($p < 0.001$) with a strong effect size based on Cramér's V coefficient (0.655). These findings indicate that physical workload categories among the subjects are closely linked to their experienced fatigue levels, where workers facing higher physical demands tend to report higher fatigue severity than those with lower physical demands.

In the context of the sawmill industry, this association may be attributed to the nature of work activities that demand repetitive physical exertion. Handling large timber, pushing or pulling materials, and operating machinery in constrained working postures subject muscles to continuous strain. If these activities persist without adequate recovery periods, the body's capacity to maintain performance degrades over time. Physiologically, heightened physical activity increases energy and oxygen demands, forcing the body to elevate its metabolic rate to meet these requirements (Fataruba and Aini, 2022).

The presence of workers experiencing varying workload levels within a single work environment indicates that physical demands in the sawmill industry are not entirely homogeneous. Each worker may encounter different physical strains depending on their assigned tasks throughout the production process. Variations in activity types, work intensity, and exposure duration can lead to distinct physical demands among individual workers, even within the same occupational setting (Pamungkas et al., 2022). Workers who are frequently involved in log handling or tasks requiring high physical effort are likely subjected to higher physical demands than those assigned to lighter tasks. Consequently, workload evaluations in the sawmill industry must account for task-level variations among individual workers rather than relying solely on the general characteristics of the industry as a whole.

Beyond individual physical capacity, working conditions in the sawmill industry underscore the critical necessity of task management throughout the production process. Work fatigue does not stem solely from a single strenuous task; rather, it often results from the cumulative effect of a sequence of repetitive duties performed across a work shift. Continuous physical activity lacking an optimal balance between job demands and physiological recovery is known to elevate the risk of work fatigue (Fataruba and Aini,

2022). Consequently, fatigue mitigation strategies in such occupational settings should focus on workload regulation to ensure job demands remain within the functional limits of workers. This approach is particularly imperative for small-scale enterprises, which frequently face constraints in implementing formal ergonomic control systems (Diasih et al., 2025).

The findings of this study align with Yamaula et al. (2021), who identified a significant relationship between physical workload and work fatigue among manufacturing industry workers. However, Rusila and Edward (2022) reported contrasting results, observing no significant association between these two variables. Such discrepancies may stem from variations in job characteristics, including the degree of mechanization, work patterns, task distribution, and the overall intensity of physical labor involved. Consequently, the relationship between physical workload and fatigue should be interpreted within specific occupational contexts rather than generalized solely across broad industry classifications.

CONCLUSION

Research on sawmill workers in Bagelen District indicates that occupational fatigue is associated with the physical demands of work activities. The majority of subjects fell into the moderate categories for both physical workload and fatigue, with physical impairment emerging as the primary contributing component to overall fatigue scores. Bivariate analysis revealed that physical workload was the sole variable significantly associated with occupational fatigue, whereas individual characteristics—specifically age and gender—did not exhibit statistically significant relationships. These findings suggest that fatigue management strategies among sawmill workers should focus on controlling physical exertion through the implementation of ergonomic work systems and the provision of adequate recovery intervals during work operations.

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