Analysis of risk factors associated with subjective fatigue symptoms among coal mining vehicle operators

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ABSTRACT

Coal mining vehicle operators have negative consequences with health effects such as fatigue. The aim of the study was to analyze the risk factors related to subjective fatigue among coal mining operators. Specifically, it seeks to examine the relationship between work shift, working period, sleep quantity, sleep quality, and personal characteristics, such as age, neck circumference, and body mass index. Data were collected from a coal mining site in South Kalimantan, Indonesia in 2022 with primary questionnaires. A total of 440 workers who worked in the mining and hauling area for at least one year were recruited in this study. This was a cross-sectional study. Quantitative data were obtained to describe the level of subjective fatigue and to analyze the risk factors associated with the work fatigue in coal mining vehicle operators. The fatigue was associated with obesity (OR:1.777, 95% CI:1.0067-2.960), overweight (OR:1.783, 95% CI:1.046-3.040), neck circumference (OR:1.513, 95% CI:1.0983-2.329), sleep quality (OR:4.597, 95% CI:2.762-7.650), and working period (OR:0.545, 95% CI:10.360-0.825) ($p<0.05$ for all). However, fatigue did not significantly affect from sleep quantity and work shift. Ensuring individual health is essential for preserving the opportunity to sleep and allowing the body to recover from fatigue.

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1. INTRODUCTION

Fatigue is a recognized issue in the workplace. Fatigue has become increasingly common in recent decades [1], [2]. The impact of industrial progress is unavoidable, as modern industrial civilization demands quicker output for a multitude of reasons [3]. A typical conceptual definition of fatigue was a state of exhaustion, drowsiness, or weariness brought on by insufficient rest, either in terms of quantity or quality [4]. This affects the viscera, or the central nervous system of an organism, which results in insufficient cellular capacity or system-wide energy to maintain the original level of activity and/or processing by using usual resources [2]. Fatigue manifested in diminished capacity to conduct activities at the desired level due to mental and/or physical lassitude or exhaustion [5], [6]. There are three main kinds of fatigue-related effects: physical (such as briefly and suddenly falling asleep, or "microsleeping"), mental (such as concentration lapses), and emotional (such as irritation).

Reduced levels of attention, coordination, judgment, and motivation, as well as a worsened mood and decreased job satisfaction, are all results of increased levels of fatigue. Job satisfaction is the term used to describe how people feel about their jobs. In addition to increasing the need for sick days, fatigue is linked to long-term health issues like stress, heart disease, mental illness, and digestive issues [7]. In general, fatigue in the workplace may be described by the quantity of work compared to the length of time, as well as the workload from numerous sources, such as lifestyle, workstyle, health problems, organizational structure, work environment, and the work itself [1].

The root causes of fatigue itself are numerous. Coal mining vehicle operators play a crucial role in the extraction and transportation of coal from mining sites, contributing to the overall efficiency and productivity of the operation. Shift patterns, task specifications, and work and environmental conditions are examples of work-related causes [7]. Shift work immediately results in fatigue, increased sleepiness, sleep disturbances, and poor cognition. Shift work's effects on sleepiness and fatigue can affect productivity and accidents [8]. Chronic fatigue is linked to a variety of health problems, including musculoskeletal illnesses, sleep disruptions, burnout, poor well-being, anxiety, and depression [9].

The mining industry is highly diversified, with significant variations in day-to-day operations across different sectors. Especially for coal mining vehicle workers who operate heavy machinery and equipment used in coal mining operations, including continuous/longwall coal machines, drill rigs, excavators, bulldozers, loaders, power shovels, and haul trucks. Another important factor is mine size, which can range from less than 12 working personnel to 1200+ mine production staff. Despite these variations, one common experience shared by mineworkers is worker fatigue [10]. The scope of these studies encompassed various performance measures, including accidents, injuries, reaction times, and cognition [11].

Fatigue, particularly among vehicle operators in the mining industry, presents itself in a notably distinct manner compared to other industrial sectors. Poor sleeping habits, highly repetitive and monotonous tasks, mental/physical demand, intense noise levels, vibration, elevated temperature, low-lighting levels, sleep deprivation, and extended hours of labor are examples of mining-specific duties and environmental conditions that make fatigue a major issue affecting the sector. These factors, along with the mining industry's long hours and shift-work schedule, make fatigue a major concern [11], [12]. The present study aims to explore the risk factors related to subjective fatigue among coal mining operators. Specifically, it seeks to examine the relationship between work shift, working period, sleep quantity, sleep quality, and personal characteristics, such as age, neck circumference, and body mass index (BMI).

2. METHOD

2.1. Study design, settings, and participants

This cross-sectional study was conducted at a coal mining site in South Kalimantan, Indonesia, in 2022, involving 440 workers who had been employed in the mining and hauling areas for at least one year. Quantitative data were used to describe levels of subjective fatigue and to analyze the risk factors associated with work fatigue among coal mining vehicle operators.

2.2. Instruments

The questionnaires were separated into three sections. The first section contains questions about the respondent's personal data, such as age, weight, height, neck circumference, health complaints, and medical history. In addition, this questionnaire also contains matters related to the respondent's work, such as work area, working period, work shifts, and commuting time.

The second section of the questionnaire was about the description of fatigue in workers using the fatigue assessment scale (FAS) questionnaire to measure the level of subjective fatigue symptoms, which contains 10 questions [13]. The FAS is a chronic fatigue assessment questionnaire consisting of 10 questions regarding fatigue symptoms. The questionnaire uses a Likert scale of 1 to 5, with questions 4 and 10 using reverse assessment. Information on a Likert scale of 1 to 5 is as follows: “never” (never felt symptoms) with a score of 1, “occasionally” (feeling symptoms for once a month or less) with a score of 2, “slightly frequent” (feeling symptoms several times a month) with a score of 3, often (feeling symptoms every week) with a score of 4, “always” (feeling symptoms almost every day) with a score of 5. The score generated on each question is then added up to get a total score, which will determine the level of subjective fatigue in the respondent. The total score to be obtained is 10 to 50. The total score of each respondent is categorized into “not tired” with a total score < 22, “tired” with a total score ≥ 22 [14].

The third section of the questionnaire was to determine the quality and quantity of workers' sleep using the Pittsburgh Sleep Quality Index (PSQI) questionnaire [15]. This questionnaire was used in this study to measure the quantity and quality of respondents' sleep in the past month. This questionnaire consists of 19 questions divided into seven components, namely subjective sleep quality, time needed to start sleeping (sleep latency), length of time sleeping (sleep duration), efficiency of sleep habits, sleep disturbances experienced, use of sleeping pills, and impaired body function during the day. Each component has a value range of 0 to 3 points, with a score of "0" indicating no difficulty, to a score of "3" indicating severe difficulty. The seven components are added together to produce a total score ranging from 0 to 21 points [16]. Calculation of a score >5 indicates poor sleep quality and a score ≤5 indicates good sleep quality [17], [18]. The questionnaire was distributed to the workers, who were vehicle operators, using an online platform. Respondents were asked to participate in this study if they were accessible and met the inclusion criteria. In addition, the participant was asked to fill out a consent form upon answering the questionnaire, as their approval to join the study and to ensure the confidentiality of their personal information.

2.3. Data analysis

The data analysis used SPSS version 24.0. Descriptive analysis was carried out to describe the distribution of frequencies and proportions of each research variable, independent and dependent variables. The variables analyzed included subjective work fatigue, age, nutritional status (BMI), neck size, health complaints, sleep quantity, sleep quality, work area, length of work, work shifts, commuting time, and work environment. The results of the descriptive analysis will be presented in the form of a table containing the percentage of each variable and in the form of a narrative containing a description of each table. Inferential analysis was performed to analyze the sample data, and the results were generalized to the study population. The inferential analysis method used is the Chi-square test to test the relationship between variables.

3. RESULTS AND DISCUSSION

This study involved 440 mining operators. The majority of participants were under the age of 34 (n = 227; 51.6%). Most had a normal BMI (n = 254; 57.7%), and a neck circumference greater than 34 centimeters was observed in 268 participants (60.9%). A total of 227 participants (51.6%) reported sleep durations of less than 6 hours and 20 minutes, while the majority (n = 361; 82.0%) reported good sleep quality. Most participants worked in the hauling area (61.4%). Additionally, slightly more participants worked the morning shift compared to the night shift (50.2%), as shown in Table 1.

Table 1. Participants characteristics

Characteristic	Total (n = 440)	%	Mean±SD	Min-Max
Age (Year)			34.6±6.9	21-53
>34	213	48.4		
≤34	227	51.6		
Body mass index (BMI)			24.3±3.3	
Normal	254	57.7		
Underweight	13	3.0		
Overweight	81	18.4		
Obesity	92	20.9		
Neck circumference (cm)			34.5±2.5	
<34	172	39.1		
≥34	268	60.9		
Sleep quantity			6.3±0.6	
>6 hours 20 minutes	213	48.4		
≤6 hours 20 minutes	227	51.6		
Sleep quality score			4.1±1.8	
Good	361	82.0		
Bad	79	18.0		
Working period (Year)			5.7±5.1	1-20
≤5 years	184	41.8		
>5 years	256	58.2		
Working shift				
Morning shift	221	50.2		
Night shift	219	49.8		
Commuting time (minute)			35.3±15.8	

The average age of the 440 respondents was 34.6±6.9, ranging from 21 to 53 years. The average of the body mass index of the respondents was 24.3±3.3. The average neck circumference of the participants was 34.5±2.5 centimeters. The average sleep duration of the participants was 6.3±0.6 hours. The sleep quality score mean was 4.1±1.8. The average working period of the participants was 5.7±5.1 ranging from 1 to 20 years. The participants' average commuting time was 35.3±15.8 minutes, as shown in Table 1.

The relationship between subjective fatigue with sleep quality and sleep quantity, as well as participants' characteristics, such as age, BMI, and neck circumference. Being overweight (OR 1.783, p = 0.034) and obese (OR 1.777, p = 0.027) were associated with more subjective fatigue symptoms than participants of other BMI (i.e., severe underweight, underweight, and normal). Participants with neck size more than 34 centimeters more commonly exhibit subjective fatigue symptoms than those with a size less than 34 centimeters (OR 1.513, p = 0.075). Participants with poor sleep quality more commonly exhibit subjective fatigue symptoms than those with good sleep quality (OR 4.597, p = 0.000). In this study, working periods were found to be associated with subjective fatigue level among operators (OR 0.545; p = 0.005). There was no statistical difference in subjective fatigue symptoms in relation to participants' age, sleep quantity, and work shift, as shown in Table 2.

Table 2. Correlation between factors related to subjective fatigue among mining operators

Variables	Subjective fatigue Yes		No		p-value	OR value (95%CI)
	n	%	n	%		
Age (Year)						
≤34	61	26.9	166	73.1	0.244	0.767
>34	69	32.4	144	67.6		(0.509-1.156)
						1.000
Body mass index (BMI)						
Obese	34	37	58	63	0.027	1.777 (1.067-2.960)
Overweight	30	37	51	63	0.034	1.783 (1.046-3.040)
Underweght	3	27.3	8	72.7	0.853	1.137 (0.293-4.417)
Severe underweight	0	0	2	100	0.999	0.000 (0.000)
Normal	63	24.8	191	75.2		1.000
Neck Circumference (cm)						
≥34	88	32.8	180	67.2	0.075	1.513
<34	42	24.4	130	75.6		(0.983-2.329)
						1.000
Sleep quantity						
≤6 hours 19 minutes	73	32.2	154	67.8	0.256	1.297 (0.859-1.958)
>6 hours 19 minutes	57	26.8	156	73.2		1.000
Sleep quality						
Poor	46	58.2	33	41.8	0.000	4.597 (2.762-7.650)
Good	84	23.3	277	76.7		1.000
Work shift						
Night shift	65	29.7	154	70.3	1.000	1.013
Morning shift	65	29.4	156	70.6		(0.673-1526)
						1.000
Working period						
≤5 years	62	24.2	194	75.8	0.005	0.545
>5 years	68	37	116	63		(0.360-0.825)
						1.000

The present study examines the correlation between sleep quality and the subjective fatigue levels experienced by mining operators. Previous research has indicated that poor sleep quality can serve as a predictor of elevated fatigue levels [19]. One study reported a significant inverse relationship between sleep quality and general fatigue (p<0.001) [20], [21]. Similarly, our findings align with earlier research demonstrating a strong correlation between sleep quality and fatigue levels among healthcare professionals [20]. These results highlight the critical role of sleep quality in occupational fatigue, suggesting that disrupted or inadequate sleep may significantly impair alertness, concentration, and physical endurance. Therefore, improving sleep quality through targeted interventions such as sleep hygiene education, rest break policies, and work schedule adjustments should be considered an essential component of fatigue risk management.

Regarding BMI, it was observed that there was an association between being obese (p = 0.027) and overweight (p = 0.034) with subjective fatigue. The consistent association between obesity status and heightened levels of fatigue has been well-established. Systemic inflammation may play a key role in mediating fatigue in individuals with obesity, as those with greater adiposity have demonstrated increased concentrations of inflammatory markers such as C-reactive protein, TNF-α, IL-6, leptin, and resistin.

Additionally, a reciprocal relationship has been identified between obesity and sleep disorders, further contributing to fatigue [22]. In this particular investigation, a greater number of workers reporting fatigue were found in the group with abnormal nutritional status, compared to those classified as having normal status [23]. These findings highlight the complex interplay between metabolic health, sleep quality, and perceived fatigue. From a practical perspective, this suggests that interventions aimed at weight management and metabolic health improvement may be effective strategies for reducing fatigue among workers in physically demanding industries such as mining. In addition to BMI, neck circumference, a commonly overlooked anthropometric measurement, serves as another important indicator of obesity and related health risks, and may provide further insight into the relationship between body composition and fatigue. Neck circumference is an anthropometric measurement that reflects upper body subcutaneous fat and is known to correlate with obesity, metabolic disorders, and obstructive sleep apnea [24], [25]. BMI has been shown to predict neck circumference, with higher BMI values generally associated with larger neck sizes [26]. In this study, a neck circumference greater than 34 centimeters was found to correlate with obesity and was associated with increased fatigue among participants ($p = 0.075$). This suggests that individuals with larger neck circumferences are more likely to experience fatigue during daily activities [27]. Additionally, fatigue has been identified as a contributing factor to musculoskeletal disorders, making the measurement of neck circumference an important consideration in occupational health assessments [28]. These findings have meaningful implications for workplace health monitoring. Neck circumference, as a simple and non-invasive measure, can serve as an early indicator of fatigue risk, particularly in physically intensive occupations. Larger neck circumference may also point to undiagnosed conditions such as obstructive sleep apnea, which can impair sleep quality and lead to persistent daytime fatigue.

The length of time participants had worked in mining was significantly associated with subjective fatigue levels. This finding supports prior research indicating a link between employment duration and cumulative work-related fatigue [29]. A previous study revealed that the length of employment is correlated with fatigue levels. Workers with longer employment durations tend to experience higher fatigue levels, particularly due to the cumulative effects of prolonged exposure to demanding work conditions [30]. These results underscore the impact of long-term occupational stress on worker well-being, especially in labor-intensive and high-risk industries such as mining. Over time, repeated physical strain, exposure to environmental stressors (e.g., heat, noise, vibration), and mental workload can lead to chronic fatigue, reduced physical resilience, and even burnout. This suggests the importance of implementing preventive strategies that address the needs of long-serving employees.

This study has uncovered that the correlation between the age of laborers and their subjective level of fatigue was found to be statistically insignificant. Nevertheless, this outcome is consistent with a prior study that has demonstrated that there exists no association between age and occupational fatigue amongst employees in the textile industry [31]. These findings suggest that age alone may not be a reliable predictor of fatigue in physically demanding occupations such as mining. Fatigue levels are likely influenced more by factors such as workload, shift patterns, sleep quality, physical fitness, and individual coping mechanisms rather than chronological age.

This study revealed that there was no significant association between subjective fatigue levels and sleep quantity. Participants who reported sleeping less than 7 hours per night experienced moderate fatigue complaints [32]. This result is not consistent with prior research, which attributed fatigue to insufficient rest, often caused by prolonged working hours and disturbances in sleep patterns related to stress, anxiety, and environmental factors such as noise [7]. The lack of a strong correlation in this study suggests that sleep quantity alone may not fully explain subjective fatigue in the mining workforce. Other factors, such as sleep quality, work demands, physical exertion, and individual resilience, may play a more prominent role. It's possible that workers are accustomed to shorter sleep durations or have adapted coping strategies that mitigate the effects of reduced sleep time.

The findings of this study revealed that there was no significant correlation between subjective fatigue levels and work shift. This outcome contrasts with prior research that identified a significant association between cumulative fatigue and shift work among medical professionals ($p<0.05$) [33]. It also contradicts a previous study that reported shift work as a contributing factor to fatigue among mining operators [5]. Moreover, earlier research has shown that shift work can negatively affect workers' personal and family life satisfaction [34]. The lack of association in this study may reflect differences in shift structures, workload distribution, or organizational fatigue management practices at the study site. It is possible that the mining company in question has implemented effective countermeasures, such as regulated shift lengths, adequate rest periods, or shift rotation schedules that mitigate the negative effects typically associated with shift work. Additionally, individual differences in adaptation to shift work, including lifestyle habits and sleep management strategies, may influence how fatigue is perceived and reported. These findings suggest that shift work alone may not universally predict fatigue, and that contextual workplace factors must be considered. Employers should continue to monitor shift-related fatigue risks while also recognizing the role of supportive workplace practices in reducing its impact.

A recent study has highlighted the significant impact of miner fatigue on performance. Fatigue remains prevalent in mining operations due to the physically demanding nature of the work and the challenging environmental conditions unique to the industry. It is frequently identified as a contributing factor in numerous health and safety incidents within mines [35]. Moreover, fatigue can impair cognitive functions such as attention, decision-making, and reaction time, thereby negatively affecting operational performance at mine sites [36]. These findings emphasize the critical need for proactive fatigue management strategies in mining. Addressing fatigue not only supports worker health and safety but also contributes to maintaining productivity and reducing the likelihood of costly errors or accidents.

4. CONCLUSION

The results of the study indicate that the subjective fatigue level experienced by coal mining operators is primarily attributable to their sleep quality, neck circumference, body mass index, and working periods. To mitigate the associated safety risks, it is recommended that preventative measures be implemented through the assessment and improvement of operator sleep quality, as well as the promotion of optimal body weight through health and safety initiatives that include fatigue management components.

In addition, it is recommended that mining companies incorporate routine health screenings that include measurements of BMI and neck circumference, alongside regular evaluations of sleep patterns and fatigue levels. Tailored interventions—such as sleep hygiene education, shift scheduling strategies, and wellness programs targeting nutrition and physical activity—should be developed to address the specific needs of high-risk workers. These combined efforts can support a healthier workforce, enhance operational performance, and reduce the likelihood of fatigue-related incidents in the mining sector.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

All the authors declare that there are no conflicts of interest.

INFORMED CONSENT

The authors have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

This study was approved by the Institutional Review Board at the Faculty of Public Health, Universitas Indonesia, with the number Ket-729/UN2.F10.D11/PPM.00.02/2023 and performed following the principles of the ethical committee Faculty of Public Health, Universitas Indonesia. Digital informed consent was obtained for the publication of this study while the respondents answered the questionnaire through an online form.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [RM]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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