ORIGINAL ARTICLE

Do Work Schedule and Work Position have an Impact on Fatigue among Geothermal Workers during the COVID-19 Pandemic? An Analysis Using Structural Equation Modeling

Caesar Nurhadiono Raharjo, MD,[1*] Suryo Wibowo, MD, MKK, SpOK, SubSp, PsiKO (K),[2,3*]
Aria Kekalih, DR, MD, MTI,[2] Amilya Agustina, MD, SpKP[2] and Muhammad Ilyas, MD, SpOK, SubSp, ToksiKO (K)[2]

[1]*Postgraduate Program of Occupational Medicine, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia*
[2]*Department of Community Medicine, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia*
[3]*Faculty of Medicine and Health Sciences, Krida Wacana Christian University, Jakarta, Indonesia*

ABSTRACT

Objectives. This study aimed to examine the impact of work schedule and work position on fatigue levels among employees at a private geothermal firm in Indonesia during the COVID-19 pandemic. The company has modified its work schedule considering the COVID-19 epidemic to ensure a continuous supply of energy and meet the needs of the public.

Methods. In this cross-sectional study, the dependent variable is fatigue, which is classified as a latent variable. Fatigue is assessed using the Indonesian version of the Swedish Occupational Fatigue Inventory (SOFI). Fatigue is a condition that has five dimensions: lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation. The observed variables in this study include work schedule and work position, which serve as independent variables. Using structural equation modeling (SEM), we assessed the impact of the independent variables on each dimension of fatigue. This approach allowed for the analysis of both the measurement and structural models.

Results. The investigation employed total sampling, involving 132 workers from the company who willingly participated in the study. According to the findings, workers' main fatigue dimension was lack of energy. However, the statistical analysis did not establish a significant influence of work schedule and work position on fatigue.

Conclusion. Based on the findings of the SEM analysis, it is evident that there is no statistically significant correlation between work schedules and job positions with various dimensions of fatigue assessed using the SOFI questionnaire. These dimensions include lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation. While this outcome suggests that work schedules and job positions may not directly influence fatigue levels as measured in this study, it underscores the importance of implementing occupational health and safety management systems. Additionally, promoting good work practices such as offering flexible working hours may help address potential fatigue concerns among employees. However, further research is necessary to explore additional variables that could potentially impact fatigue levels in the context of the COVID-19 pandemic and beyond.

Keywords: dimensions of fatigue, Swedish occupational fatigue inventory (SOFI), work schedules, work positions

** Dr. Raharjo and Dr. Wibowo shared first authorship for this manuscript.*

eISSN 2094-9278 (Online)
Published: June 13, 2025
https://doi.org/10.47895/amp.vi0.6823

Corresponding author: Caesar Nurhadiono Raharjo, MD
Postgraduate Program of Occupational Medicine
Faculty of Medicine
Universitas Indonesia
Jakarta, Indonesia
Email: caesarnurhadiono.raharjo@gmail.com

INTRODUCTION

The COVID-19 pandemic has exacerbated levels of fatigue among workers[1], including those in the geothermal industry, who have a vital role in fulfilling essential public needs. Research indicates that there are concerning levels of work-related fatigue among workers in the power generation industry in Jakarta, with 57.5 percent of workers reporting fatigue.[2] Similarly, a considerable number of workers at the Lahendong geothermal plant in North Sulawesi experience high levels of fatigue, with 68.8 percent of them reporting significant fatigue levels.[3] The study conducted by Arkestdt et al. underscores the impact of different elements, such as high job demands, low social support, supervisory roles, type of work, and work schedule, on levels of fatigue.[4]

Furthermore, researches by Zucchi et al. and Banks et al. highlight the potential psychosocial hazards that can arise during a pandemic, including prolonged changes in schedules or altered work patterns, which can intensify feelings of fatigue.[5,6] These hazards are particularly pertinent in the geothermal industry, where physically demanding tasks are common and workers may experience lengthy shifts or adopt unpredictable work-from-home schemes.[7]

Considering this situation, a private geothermal company in Indonesia has recently modified its work schedule in order to meet the increased electricity demands caused by the pandemic. Surveillance data reveals that around 10 percent of the company's employees reported experiencing fatigue due to the pandemic. In response, the company initiated a fatigue assessment to examine the impact of the new work schedule on worker fatigue. The study aims to determine the impact of different work schedule types and work positions on various dimensions of fatigue experienced by workers.

Roster methods are commonly used in various industries, including geothermal, especially in production settings that operate around the clock.[7] These schedules dictate the duration of days spent at work and the length of each work shift. However, the COVID-19 pandemic has disrupted these schedules, leading to alterations in shift patterns and work arrangements.

Workers in the geothermal industry have diverse responsibilities, encompassing a range of tasks from monitoring and administrative duties to more physical and technical roles. Most workers spend their time in control rooms for 8 hours per shift, where they meticulously monitor control screens to oversee system operations and ensure optimal performance. In this role, they are responsible for monitoring operational parameters such as temperature, pressure, and flow, and responding promptly to any changes. Activities in the control room mainly involve sitting and coordinating via radio.

Additionally, the majority of workers are involved in field tasks that require their physical presence at work sites. One of the primary tasks is performing preventive maintenance and repairs on equipment such as generators, pumps, and pipeline systems. They also conduct routine inspections to detect potential problems or leaks that may disrupt operations. When working in the field, operators must drive light vehicles on roads that often incline and decline, navigating through various road conditions, and potentially being exposed to vibrations caused by the vehicle. They spend hours inspecting geothermal pipeline routes in various areas, often requiring long journeys in vehicles followed by walking to reach remote locations. This activity, depending on the well's location, can take 2-4 hours, sometimes covering distances of 1-3 kilometres.

Moreover, they also carry out routine activities such as daily inspections in generator areas, which are often located in noisy environments and require high vigilance in the surrounding area. Workers must walk around a generator area measuring approximately 100 m^2, which consists of four floors, with each floor requiring manual stair climbing. This activity requires significant physical endurance, especially due to the noisy (>120 dB) and potentially hazardous work environment.

In addition to these field tasks, workers are also involved in maintenance activities in workshops, including various tasks such as welding, painting, and replacing machine components. This is a crucial part of their job to ensure that all equipment and machinery operate safely and efficiently.

Team leaders have additional responsibilities in coordinating and managing teams, which include planning meetings, organizing schedules, and ensuring effective communication among team members. These meetings, which usually last for about two hours each time, are essential for aligning team vision and strategy, and ensuring that all team members have a clear understanding of their tasks and responsibilities.

In a private geothermal company located in Indonesia, the normal work schedule for leader workers is to adhere to a roster schedule. This schedule consists of 5 consecutive days on duty followed by 2 days of rest in the first week, and then 4 consecutive days on duty followed by 3 days of rest in the following week. This pattern continues, with each workday lasting 12 hours. On the other hand, individuals who are not in leadership positions, or non-leader workers, follow a roster schedule where they are on duty for 7 consecutive days and then have 7 days off. During their workdays, they work for a total of 8 hours each day.

During the pandemic, the work schedule for leader workers changes to a scheme of 5 days on duty, followed by 2 days off in the first week, followed by 4 days working from home, and then 3 days off. This work plan referred as a 9-5 work schedule. The schedule for non-leader workers consists of 14 consecutive days on-site, working 12-hour shifts. These 14 days include both day or night hours. After this period, they get 14 days off-site, and then the cycle repeats. This work plan referred as a 14-14 work schedule. A detailed explanation of work schedules and work positions is presented in Table 1.

According to the acknowledgement of leader workers, the working hours during work from home (WFH) are highly

Table 1. Normal and Pandemic Work Schedules and Work Positions

Work position	Normal work schedule	Pandemic work schedule
Leader	• Continuous pattern of 5 days on duty followed by 2 days off, then 4 days on duty followed by 3 days off. • A 12-hour workday	• Continuous pattern of 5 days on duty followed by 2 days off, then 4 days of working from home (WFH) followed by 3 days off, namely 9-5 work schedules. • A 12-hour workday
Non–leader	• Continuous pattern of 7 days on duty followed by 7 days off. • An 8-hour work shift	• Continuous pattern of 14 days on duty followed by 14 days off, namely 14-14 work schedules. • A 12-hour work shift

uncertain. Occasionally, people use off-duty time for work, disrupting their intended rest time. Non-leader workers may have a series of consecutive days with extensive work shifts, followed by prolonged time away from the workplace. The changes in work schedules have significant implications for worker fatigue and necessitate further investigation.

In summary, the COVID-19 pandemic has underscored the importance of understanding and addressing fatigue among workers in the geothermal industry. This study seeks to analyse the effects of changing work schedules on levels of fatigue, with the goal of providing insights into ways for reducing fatigue and enhancing the well-being of workers in response to evolving job demands.

The Swedish Occupational Fatigue Inventory (SOFI) is used to measure five dimensions of fatigue, including lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation.

Lack of energy refers to feelings of diminishing strength, often described as worn out, spent, drained, or overworked.[8] Geothermal workers, particularly those in leadership positions, may spend a considerable amount of time to attending meetings during their travels to and from the site. Additionally, they may also conduct meetings upon reaching their destination, leading to extended working hours both in the office and in the field.

Physical exertion involves whole-body sensations, such as palpitations, sweating, being out of breath, and heavy breathing, which may occur during dynamic work or metabolic exhaustion.[9] While geothermal workers typically have minimal levels of physical labor, particular tasks such as maintenance, flow tests, and roving may demand significant exertion, especially for non-leader workers who work on a 14-14 work schedule. Figure 1 presents a visual representation of the specific physical work tasks carried out by workers in the geothermal industry.

Physical discomfort refers to local bodily sensations resulting from static or isometric workload, such as tense muscles, numbness, stiff joints, and aching.[9] Sedentary activities are common in geothermal work, particularly for leaders who often spend extended periods of sitting in front of computers for daily meetings.

Sleepiness is often associated with night work and is expressed through symptoms like drowsiness, yawning, and falling asleep.[9] Workers who work night shifts on a regular basis, such as those who follow a 12-hour shift, or those who need to be alert while monitoring control rooms, may experience heightened sleepiness. Additionally, leaders may engage in online meetings outside their regular working hours, which can further contribute to fatigue.

Lack of motivation can arise from activities requiring high levels of alertness, monotony, and constant attention.[9] Monotonous tasks such as daily checks, online meetings, and document reviews demand vigilance and may lead to feelings of disengagement or passivity among workers.

Overall, understanding these dimensions of fatigue is crucial for identifying and addressing potential issues in the geothermal industry.

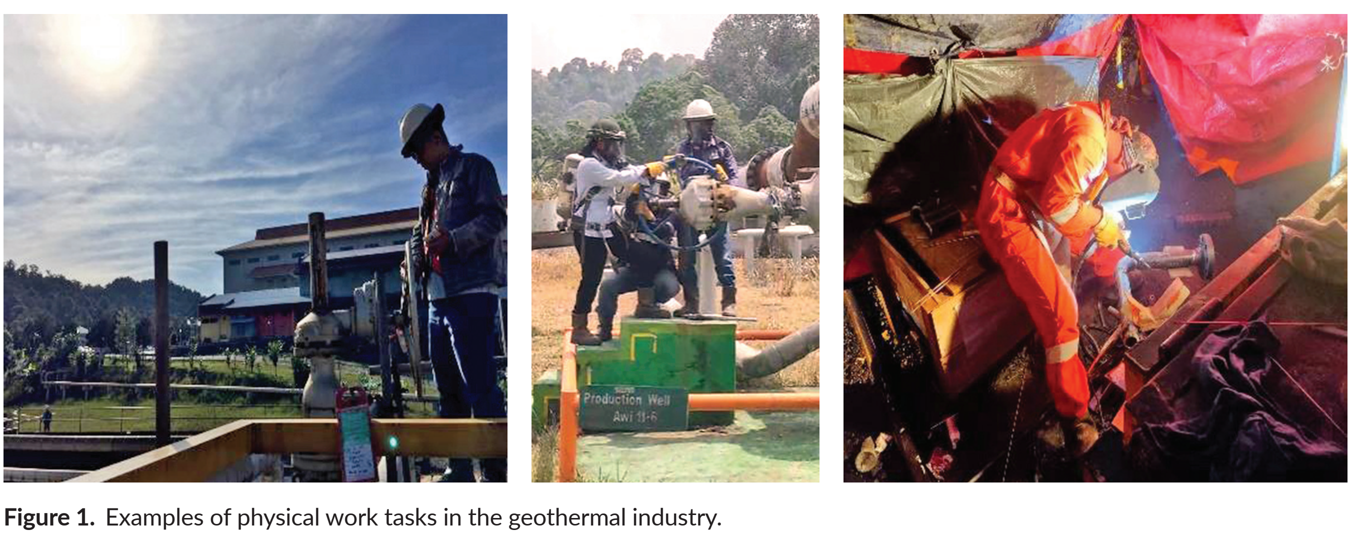

Figure 1. Examples of physical work tasks in the geothermal industry.

Studies conducted by Banks et al.[7] and Arkestadt et al.[10] has firmly established a correlation between fatigue and many work characteristics, including workload, work schedule, position, and social support. Furthermore, an overwhelming amount of work can lead to increased work-related stress, which in turn can have a negative impact on an employee's productivity and overall job contentment.[11] Due to the ongoing pandemic, changes have been made to the geothermal work schedule, resulting in leaders having to take responsibility to maintain uninterrupted output despite worker fatigue. Consequently, our objective is to investigate the impact of work schedules and work positions on various dimensions of fatigue. This study conceptualized fatigue as a complex phenomenon that includes various dimensions such as lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation.

According to the information provided above, the study hypothesis is shown in Figure 2:

1. Hypothesis 1 (H1): The type of work schedule impacts the level of fatigue associated with a lack of energy at work.
2. Hypothesis 2 (H2): The work position impacts the level of fatigue associated with a lack of energy at work.
3. Hypothesis 3 (H3): The type of work schedule impacts the level of fatigue associated with physical exertion.
4. Hypothesis 4 (H4): The work position impacts the level of fatigue associated with physical exertion.
5. Hypothesis 5 (H5): The type of work schedule impacts the level of fatigue associated with physical discomfort.
6. Hypothesis 6 (H6): The work position impacts the level of fatigue associated with physical discomfort.

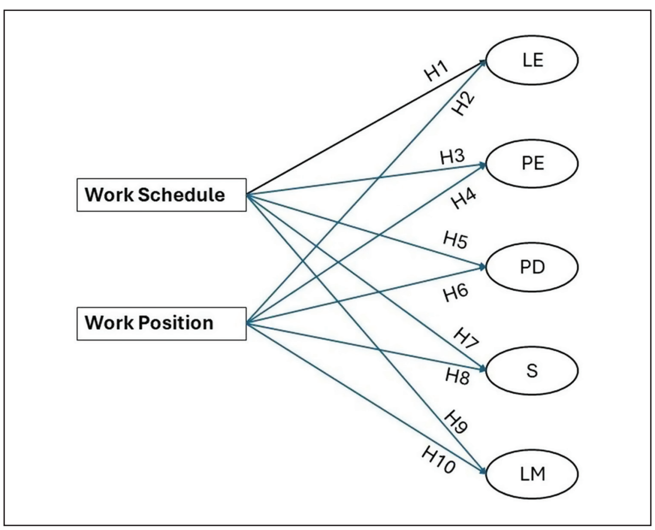

Figure 2. Framework of the study.

The dimensions of fatigue measured by SOFI include Low Energy (LE), Physical Exertion (PE), Physical Discomfort (PD), Sleepiness (S), and Lack of Motivation (LM). Rectangular variables are observable variables, while elliptical variables are latent variables. The hypotheses of this study are labeled as H1 to H10.

7. Hypothesis 7 (H7): The type of work schedule impacts the level of fatigue associated with sleepiness.
8. Hypothesis 8 (H8): The work position impacts the level of fatigue associated with sleepiness.
9. Hypothesis 9 (H9): The type of work schedule impacts the level of fatigue associated with lack of motivation at work.
10. Hypothesis 10 (H10): The work position impacts the level of fatigue associated with lack of motivation at work.

MATERIALS AND METHODS

Study Design and Sampling Framework

This cross-sectional study aims to investigate the association between various occupational factors, including work schedule and work position, and the dimensions of fatigue among employees at a private geothermal company in Indonesia. The study employed a total sampling approach, encompassing all geothermal workers, from December 2021 to February 2022. The inclusion criteria were all individuals employed at the geothermal facility throughout the specified time frame who gave their consent to participate in this study.

The estimated sample size, determined by the maximum likelihood estimation (MLE) approach, indicates that the sample size should be between 100 and 200. Alternatively, it can be calculated as 5 to 10 times the number of estimated parameters or indicators. Given that there are 22 indicators involved in this study, the minimum sample size necessary is 110 samples (5 multiplied by 22).[12] We used total sampling, which led to a final sample size of 132.

Data Collection

Respondents completed a questionnaire online through a link provided by the researcher. Data collection took place between December 2021 and February 2022, utilizing Google Forms. An attempt was made to reduce bias in the completion of the questionnaire by scheduling it on the third day of duty. In addition, instructions were given to improve the understanding of respondents when filling out online forms.

Fatigue Assessment

Fatigue is assessed using the Indonesian version of the Swedish Occupational Fatigue Inventory (SOFI), comprising 20 items. The assessment employs a 7-point Likert scale, allowing respondents to rate their fatigue levels from 0 (not at all) to 6 (very high level of fatigue). This evaluation categorizes fatigue into five dimensions: lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation. Thus, each dimension has a minimum score of 0 and a maximum score of 6.[9]

Data Analysis

The data was organized using Microsoft Excel and analyzed using Stata 17 statistical software. The results of the multivariate normality tests showed that the data did not follow a multivariate normal distribution. As a result, a bootstrap resampling approach was used for maximum likelihood estimation.[8] Prior to examining the correlation between work schedule and work position with the five dimensions of fatigue, we must initially evaluate the validity and reliability of fatigue as a latent variable. Convergent validity was assessed by analyzing the loading factor values, which needed to exceed a threshold of 0.70. In structural equation modeling (SEM), a threshold of 0.5 for the average variance extracted (AVE) is considered appropriate for assessing the convergent validity of latent variable. The construct's reliability was evaluated using composite reliability with a cut-off point of 0.7. The structural model was evaluated using multiple goodness-of-fit criteria, including RMSEA, CFI, TLI, and SRMR.[9] Modifications were made as necessary based on model fit, with subsequent hypothesis testing conducted on the structural model.

Ethical Considerations

This study obtained approval from the Ethics Committee of the Faculty of Medicine, University of Indonesia–Cipto Mangunkusumo Hospital, with approval number KET-145/UN2.F1/ETIK/PPM.00.02/2022, on February 14, 2022. We obtained informed consent from all participants prior to their involvement in the study. We conducted all procedures in accordance with relevant ethical standards.

RESULTS

The characteristics of the subjects is presented in Table 2. Descriptive analysis, utilizing mean and standard deviation, was conducted on the age variable due to its normal distribution. Both groups are primarily engaged in sedentary occupations. The fact that the majority of workers have been employed for more than five years suggests that they are accustomed to the dynamic nature of work in the geothermal industry. However, there is a possibility that this familiarity can lead to monotony

Table 2. Subject Characteristics

	Work schedule		Position	
	9 – 5, n (%)	14 – 14, n (%)	Non-leader, n (%)	Leader, (%)
Age (Mean ± SD)	42.9 ± (7.9)	42.6 ± (6.6)	41.2 ± (7.0)	42.9 ± (4.8)
Gender				
Male	52 (98.1)	79 (100)	102 (99)	29 (100)
Female	1 (1.9)	0 (0)	1 (1)	0 (0)
Department				
Non-Operation	53 (100)	40 (50.6)	70 (68)	23 (79.3)
Operation	0 (0)	39 (49.4)	33 (32)	6 (20.7)
Type of work				
Sedentary	39 (73.6)	43 (54.4)	61 (59.2)	21 (72.4)
Non-Sedentary	14 (26.4)	36 (45.6)	42 (40.8)	8 (27.6)
Years of service				
>5 years	45 (84.9)	76 (96.2)	94 (91.2)	27 (93.1)
0 – 5 years	8 (15.1)	3 (3.8)	9 (8.8)	2 (6.9)
Sports				
Not a routine	36 (67.9)	55 (69.7)	71 (68.9)	20 (68.9)
Routine	17 (32.1)	24 (30.3)	32 (31.1)	9 (31.1)
Have Children <7 years old				
No	37 (69.9)	38 (48.1)	52 (50.4)	23 (79.3)
Yes	16 (30.1)	41 (51.9)	51 (49.6)	6 (20.7)

Note: 9 – 5 and 14 – 14 are groups of work schedule types, SD: standard deviation

Table 3. Overview of Fatigue Dimensions

Fatigue Dimension	9 – 5 Schedule Mean ± (SD)	14 – 14 Schedule Mean ± (SD)	Non-leader Mean ± (SD)	Leader Mean ± (SD)
LE	2.10 ± (1.41)	1.89 ± (1.36)	1.94 ± (1.33)	2.09 ± (1.54)
PE	1.07 ± (1.05)	1.46 ± (1.10)	1.38 ± (1.10)	1.02 ± (1.05)
PD	1.62 ± (1.19)	1.75 ± (1.47)	1.73 ± (1.37)	1.57 ± (1.35)
S	1.93 ± (1.27)	1.86 ± (1.47)	1.93 ± (1.48)	1.74 ± (1.03)
LM	1.63 ± (1.52)	1.27 ± (1.38)	1.41 ± (1.47)	1.44 ± (1.37)

LE: lack of energy, PE: physical exertion, PD: physical discomfort, S: sleepiness, LM: lack of motivation, SD: standard deviation in their work. Despite the presence of sports facilities in the workplace, the majority of workers do not engage in regular exercise, potentially resulting in decreased musculoskeletal flexibility and fatigue. It is noteworthy that most workers with a 14-14 work schedule tend to have more children younger than 7 years old, rendering them more susceptible to fatigue.

According to Ashberg, the dimensions of fatigue can be assessed using SOFI by calculating the average value of each dimension.[8] Subsequently, the dimension with the highest average value is identified as the dominant dimension of fatigue. The dimensions of fatigue among geothermal workers are described in Table 3. After examining the data in Table 3, it became clear that the main factor contributing to worker fatigue is lack of energy. This conclusion was derived by considering the dimension that had the greatest mean among all groups of workers. This discovery emphasizes the need of comprehending the intricate interaction between different dimensions of fatigue and its consequences for the well-being of workers.

The evaluation of the measurement model's performance is presented in Table 4, where discernible favourable outcomes shed light on the model's robustness and reliability. However, two indicators, namely "sweaty" attributed with physical exertion and "numbness" attributed to physical discomfort, demonstrate loading factors that fall below the acceptable level of 0.70. According to Hoyle, scholarly literature indicates that loading factors more than 0.40 may be considered acceptable.[12] However, it is important to recognize that there may be difficulties in achieving convergent validity in some situations. Nevertheless, the fact that the Average Variance Extracted (AVE) value is higher than 0.50 and the Composite Reliability (CR) value is greater than 0.70 confirms that there is sufficient discriminant validity and reliability of the latent construct. This provides assurance in the validity and reliability of the measurement model. However, the initial model's failure to meet the criteria for goodness-of-fit requires a comprehensive refinement procedure. This process involves making revisions based on theoretical insights rather than relying solely on information acquired from the modification index provided by the software.[13,14]

The final model (Figure 3) reveals a detailed understanding of how sleepiness and lack of motivation interact, and how they collectively contribute to worker fatigue. This model introduces a new path that demonstrates a statistically significant influence on fatigue, with a p-value of less than 0.05. This detailed examination helps us better understand the complex nature of worker fatigue and underscores the importance of adopting a holistic approach to treating its

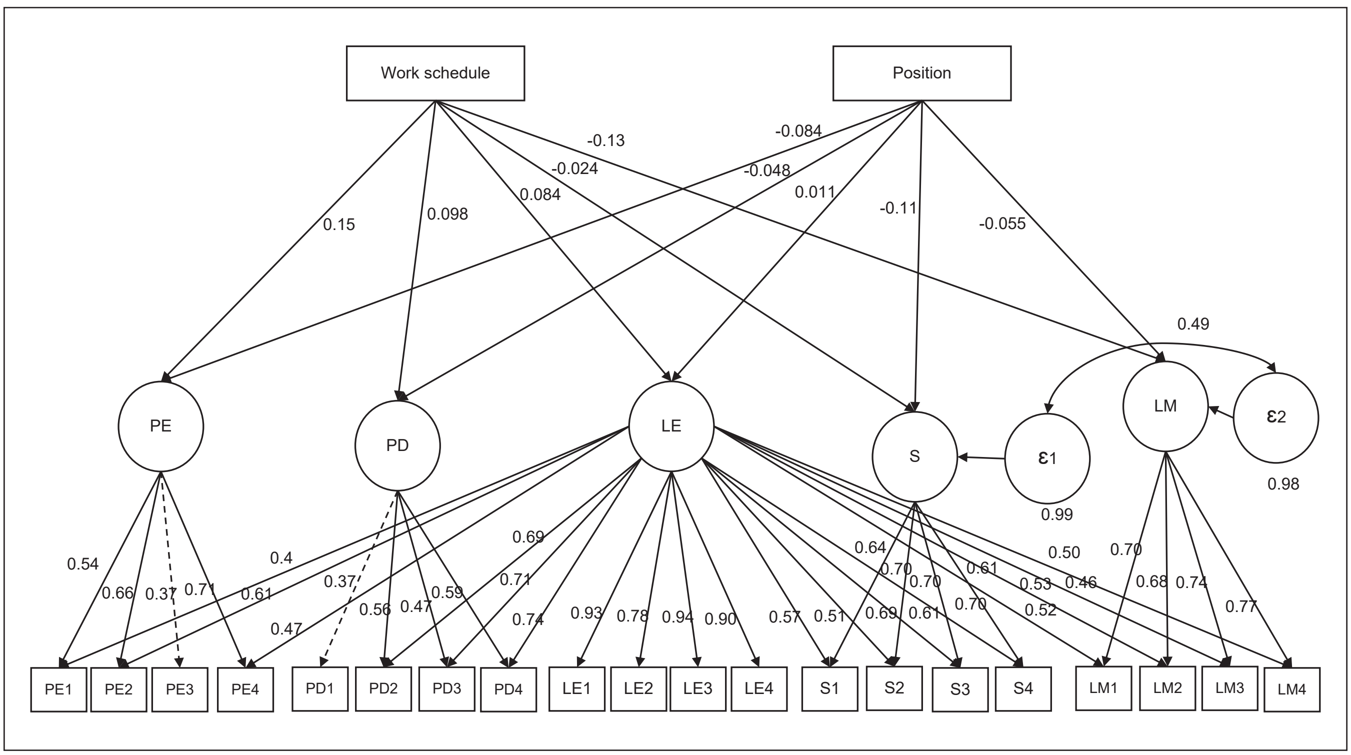

Figure 3. Research model.

LE: lack of energy, PE: physical exertion, PD: physical discomfort, S: sleepiness, LM: lack of motivation, LE1: drained, LE2: overworked, LE3: spent, LE4: worn out, PE1: out of breath, PE2: palpitation, PE3: sweaty, PE4: breathing heavily, PD1: numbness, PD2: aching, PD3: stiff joint, KF4: tense muscles, S1: drowsy, S2: falling asleep, S3: yawning, S4: sleepy, LM1: passive, LM2: lack of concern, LM3: uninterested, LM4: indifferent, ⬭ *: Latent variable,* ▭ *: Manifest variable,* ➔ *: Final model* underlying causes and the impact it has on worker well-being and organizational performance.

In Figure 3, we present a comprehensive depiction of the research model, offering a visual narrative of its iterative modification process. Initially, the model, illustrated by solid arrow lines, encapsulated the conceptual framework underpinning our investigation. However, upon closer scrutiny, it became evident that certain indicators, namely "sweaty" and "numbness," introduced noise and complexity into the model without substantially contributing to its explanatory power. Consequently, through a systematic process of model modification, denoted by dashed arrow lines, we judiciously removed these superfluous indicators to streamline the model's structure and enhance its interpretability.

Following this modification, we conducted a meticulous evaluation of both the initial and modified models' goodness-of-fit, a pivotal step in assessing their adequacy in capturing the observed data. The results of this assessment, detailed in Table 5, unveiled a notable discrepancy: while the initial model fell short of meeting the predefined fit criteria, the modified model showcased significant improvements across a spectrum of fit indices. Despite these advancements, it's worth noting that the p-value remained unchanged throughout the modification process, underscoring the robustness of our findings.

Armed with a modified and empirically validated model, our next endeavour revolves around hypothesis testing—an essential step towards deriving actionable insights from our research findings. By subjecting our modified model to rigorous hypothesis testing, we aim to unearth nuanced relationships and discern patterns that offer invaluable insights into the intricate interplay between work schedule, job position, and worker fatigue dimensions. Through this meticulous analytical process, we endeavour to contribute meaningfully to the existing body of knowledge in the field, ultimately paving the way for informed decision-making and actionable interventions aimed at mitigating worker fatigue and enhancing overall well-being in the workplace.

The p-values derived from the structural equation analysis of the final model were employed to rigorously test the null hypothesis. As illustrated in Table 6, where the p-values exceed 0.05, neither the type of work schedule nor the job position demonstrates statistically significant effects on fatigue dimensions, including lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation.

Table 4. Measurement Model

Latent variable	Indicator	Loading factor	AVE	CR
LE			0.79	0.93
	Drained	0.94		
	Overworked	0.78		
	Spent	0.93		
	Worn out	0.89		
PE			0.66	0.85
	Out of breath	0.71		
	Palpitation	0.87		
	Sweaty	0.62*		
	Breathing heavily	0.86		
PD			0.79	0.92
	Numbness	0.66*		
	Aching	0.89		
	Stiff joint	0.84		
	Tense muscle	0.92		
S			0.77	0.93
	Drowsy	0.87		
	Falling asleep	0.89		
	Yawning	0.85		
	Sleepy	0.87		
LM			0.76	0.92
	Passive	0.86		
	Lack of concern	0.85		
	Uninterested	0.86		
	Indifferent	0.92		

**Less than 0.70*

LE: lack of energy, PE: physical exertion, PD: physical discomfort, S: sleepiness, LM: lack of motivation, AVE: average variance extracted, CR: composite reliability

Table 5. Goodness of Fit

Model fit indices	Cut point	Initial model	Final model
Chi-Square	The smaller the better	603	250
p value	>0.05	0.00	0.00
RMSEA	<0.08	0.13	0.07
CFI	0.90	0.81	0.95
TLI	>0.90	0.78	0.93
SRMR	<0.08	0.38	0.07

RMSEA: Root Mean Square Error of Approximation, CFI: Comparative Fit Index, TLI: Tucker Lewis Index, SRMR: Standardized Root Means Square Residual

Table 6. Hypothesis Test Results

Hypothesis				*p* value
1	Work schedule	→	Lack of energy	0.925
2	Work position	→	Lack of energy	0.940
3	Work schedule	→	Physical exertion	0.278
4	Work position	→	Physical exertion	0.574
5	Work schedule	→	Physical discomfort	0.556
6	Work position	→	Physical discomfort	0.802
7	Work schedule	→	Sleepiness	0.795
8	Work position	→	Sleepiness	0.435
9	Work schedule	→	Lack of motivation	0.231
10	Work position	→	Lack of motivation	0.699

However, notwithstanding these outcomes, it is noteworthy to highlight a distinctive observation within the final model. A compelling revelation emerges, signifying an interdependent effect between the error covariance dimensions of feeling sleepy and lack of motivation. This relationship is characterized by a coefficient of 0.488 and a p-value of 0.000.

DISCUSSION

According to the result of this study, there is no significant correlation between work position and work schedule with various dimensions of fatigue experienced by geothermal workers, such as lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation. These results suggest that factors beyond work position and work schedule may have a greater effect on fatigue levels among workers, consistent with previous research indicating the role of individual and environmental factors on fatigue.[15] This is also consistent with the findings of prior study, which indicate that a physical work environment that fails to foster work-life balance will have an impact on employees' performance and job satisfaction.[16]

Despite the lack of significant associations between work characteristics and fatigue dimensions, lack of energy emerges as a prevalent dimension of fatigue experienced by workers in this study. This underscores the importance of addressing fatigue management strategies in the workplace to enhance employee well-being and productivity.[17]

Furthermore, the study reveals insights into the daily routines and work arrangements of geothermal workers, highlighting factors such as workload, changes in assignments, and sleep quality as potential contributors to fatigue.[18] Interestingly, despite predominantly sedentary work roles, workers have access to occupational health and safety measures, including micro break alarms and flexible working hours, which may mitigate fatigue risks.[19,20] In relation to this matter, amongst the COVID-19 pandemic, fieldwork has been enhanced to incorporate health and safety protocols that may have an impact on individuals in the vicinity.[21,22]

Moreover, the study suggests that implementing effective work systems and providing adequate support for workers, such as health facilities and benefits, could further alleviate fatigue concerns in the workplace.[23] These findings underscore the need for comprehensive fatigue management approaches that consider various factors beyond job characteristics.

However, it is essential to acknowledge the limitations of this study, including the limited number of variables evaluated and the timing of data collection on the third day of work, which may not capture fatigue levels accurately among workers with different work schedules. Future research could explore additional factors influencing fatigue and employ longitudinal designs to capture fluctuations in fatigue levels over time, thereby providing more comprehensive insights into fatigue management in the geothermal industry.

Although the hypotheses regarding the relationship between work position, work schedule, and fatigue dimensions are not supported by the findings of this study, it is essential to explore potential explanations for these unexpected results. One possible explanation could be the complexity of fatigue as a multidimensional construct influenced by various factors beyond job characteristics alone. Previous research has highlighted the role of individual differences, psychosocial factors, and organizational factors in shaping fatigue experiences among workers.[24] For example, individual coping strategies, such as time management skills and self-regulation abilities, may mitigate the impact of work schedule variations on fatigue levels. Moreover, organizational policies and practices, such as the provision of adequate breaks and opportunities for recovery, can influence workers' fatigue experiences independent of their specific job positions or work schedules. Thus, while job characteristics undoubtedly play a role in shaping fatigue outcomes, the interplay between individual, psychosocial, and organizational factors may overshadow their direct effects in certain contexts.[25]

Furthermore, the lack of significant associations between work characteristics and fatigue dimensions in this study may also be attributed to methodological limitations or measurement issues. For instance, the use of self-report measures, such as the Swedish Occupational Fatigue Inventory (SOFI), may introduce response bias or measurement error, potentially attenuating the observed relationships between variables. Additionally, the cross-sectional design of the study limits the ability to draw causal inferences or capture temporal dynamics in fatigue experiences over time. Future research employing longitudinal designs or objective measures of fatigue, such as actigraphy or biomarkers, may provide more robust evidence regarding the relationship between work characteristics and fatigue outcomes.

Moreover, contextual factors specific to the geothermal industry, such as the unique work environment and organizational culture, may influence the observed patterns of fatigue among workers. For example, this private geothermal company often involves remote or isolated work locations, challenging working conditions, and high levels of task complexity, which may contribute to fatigue experiences independent of job position or work schedule. Additionally, organizational norms regarding workload expectations, overtime practices, and safety protocols may shape workers' perceptions of fatigue and their ability to cope with job demands.[25] Thus, future research should consider the role of industry-specific factors in understanding fatigue outcomes among geothermal workers and explore potential avenues for intervention at the organizational level.

In summary, while the hypotheses regarding the relationship between work position, work schedule, and fatigue dimensions were not supported by the findings of this study, several factors may explain these unexpected results. These include the complexity of fatigue as a multidimensional construct, methodological limitations in measurement and design, and contextual factors specific to the geothermal industry. Future research should address these considerations to enhance our understanding of fatigue in the workplace and inform targeted interventions to improve worker well-being and productivity.

CONCLUSION

Based on the comprehensive SEM analysis conducted in this study, the research outcomes reveal that there exists no statistically significant correlation between various work schedules and job positions with the diverse dimensions of fatigue, as evaluated through the SOFI questionnaire. These dimensions encompass a range of factors including lack of energy, physical exertion, physical discomfort, sleepiness, and lack of motivation. Despite the absence of a direct relationship between work schedules, job positions, and fatigue levels, as observed in this investigation, it is essential to recognize the multifaceted nature of fatigue within the context of the geothermal industry during the COVID-19 pandemic.

The findings suggest that while altering work schedules and job positions may not directly influence fatigue levels among geothermal workers, it is imperative to emphasize the implementation of comprehensive occupational health and safety management systems. Such systems play a pivotal role in safeguarding the well-being of employees and fostering a conducive work environment. Moreover, promoting and fostering good work practices, such as offering flexible working hours, emerges as a potential strategy to address and mitigate fatigue-related concerns among workers.

However, it is crucial to acknowledge the complexity of fatigue as a multifactorial phenomenon influenced by various individual, organizational, and environmental factors. Therefore, while the current study sheds light on the association between work schedules, job positions, and fatigue levels, further research is warranted to delve deeper into additional variables that may impact fatigue among geothermal workers. By advancing our understanding of these factors, we can develop more targeted interventions and strategies to effectively manage and mitigate fatigue risks, thereby enhancing the overall health, safety, and well-being of employees in the geothermal industry, particularly amidst the ongoing challenges posed by the COVID-19 pandemic.

Study Limitations

While this study provides valuable insights into the relationship between work-related factors and fatigue, it is essential to acknowledge certain limitations. Firstly, the relatively small sample size of leader workers may restrict the generalization of findings. Additionally, the timing of questionnaire completion, understanding of the questionnaire, and the use of technology can influence assessment results since fatigue may not be experienced at the time of form completion. Moreover, research on fatigue among geothermal workers is still limited, making it challenging to find relevant references for this study. Nevertheless, despite these limitations, the study offers meaningful implications for future research and practical applications.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

Funding Source

None.

REFERENCES

1. Centre for Disease Control and Prevention (CDC). What workers and employers can do to manage workplace fatigue during COVID-19. 2020.
2. Safira ED, Pulungan RM, Arbitera C. Work fatigue of workers at PT Indonesia Power Generating Unit and Services (UPJP) Priok. J Kesehatan. 2020;11(2):265–71.
3. Roya JN, Sumampouw OJ, Pingkan Wulan Kaunang J. The relationship between workload and occupational fatigue in employees of Lahendong Geothermal Power Plant Service Unit. Kesmas. 2021;10(2):141–6.
4. Åkerstedt T, Knutsson A, Westerholm P, Theorell T, Alfredsson L, Kecklund G. Mental fatigue, work and sleep. J Psychosom Res. 2004 Nov;57(5):427–33. doi: 10.1016/j.jpsychores.2003.12.001. PMID: 15581645.
5. Zucchi G, Iori M, Subramanian A. Personnel scheduling during COVID-19 pandemic. Optim Lett. 2021;15(4):1385–96. doi: 10.1007/s11590-020-01648-2. PMID: 33042287; PMCID: PMC7533047.
6. Banks S, Landon LB, Dorrian J, Waggoner LB, Centofanti SA, Roma PG, et al. Effects of fatigue on teams and their role in 24/7 operations. Sleep Med Rev. 2019 Dec;48:101216. doi: 10.1016/j.smrv.2019.101216. PMID: 31630015.
7. Banks S, Dinges DF. Behavioral and physiological consequences of sleep restriction. J Clin Sleep Med. 2007 Aug 15;3(5):519–28.
8. Ahsberg E. Dimensions of fatigue in different working populations. Scand J Psychol. 2000 Sep;41(3):231–41. doi: 10.1111/1467-9450.00192. PMID: 11041305.
9. Åshberg E, Kecklund G, Åkerstedt T, Gamberale F. Shiftwork and diferent dimensions of fatigue. International Journal of Industrial Ergonomics. 2000;26(4):457–65.
10. Åkerstedt T, Kecklund G, Alfredsson L, Selen J. Predicting long-term sickness absence from sleep and fatigue. Journal of Sleep Research, 2007;16(4):341-45.
11. Wibowo S, Sunarno, Gasjirin J, Christian M, Indriyarti ER. Psychological and organizational factors impacting job satisfaction during the COVID-19 pandemic: A study on similar exposure groups in Indonesia. Acta Med Philipp. 2024 Mar 15;58(4):72-82. doi: 10.47895/amp.vi0.3688. PMID: 38966612; PMCID: PMC11219536.
12. Hoyle RH. Handbook of Structural Equation Modeling. Kaplan D, Marcoulides GA, West SG, editors. New York: The Guilford Press; 2012. pp. 103–107.
13. Kline RB. Principles and Practice of Structural Equation Modeling. Fourth Ed. Kline RB, editor. New York: The Guilford Press; 2016. pp. 458–460.
14. Hartwell ML, Khojasteh J, Wetherill MS, Croff JM, Wheeler D. Using structural equation modeling to examine the influence of social, behavioral, and nutritional variables on health outcomes based on NHANES data: Addressing complex design, non normally distributed variables, and missing information. Current Developments in Nutrition. 2019.

15. Rahimian Aghdam S, Alizadeh SS, Rasoulzadeh Y, Safaiyan A. Fatigue Assessment Scales: A comprehensive literature review. Arch Hyg Sci. 2019;8(3):145–53. doi:10.29252/ArchHygSci.8.3.145.
16. Christian M, Gularso K, Samodra GS, Yuniarto Y, Wibowo S, Sunarno S, et al. The mediating and moderating role of work-life balance on performance of distribution center employees. Journal of Distribution Science. 2023;21(11):103-12.
17. Åhsberg E, Gamberale F, Gustafsson K. Perceived fatigue after mental work: an experimental evaluation of a fatigue inventory. Ergonomics. 2000 Feb;43(2):252–68. doi: 10.1080/001401300184594. PMID: 10675062.
18. Goel N, Rao H, Durmer JS, Dinges DF. Neurocognitive Consequences of Sleep Deprivation. Semin Neurol. 2009;29:320–39.
19. Geurts SAE, Sonnentag S. Recovery as an explanatory mechanism in the relation between acute stress reactions and chronic health impairment. Scand J Work Environ Health. 2006 Dec;32(6):482–92. doi: 10.5271/sjweh.1053. PMID: 17173204.
20. Costa G, Sartori S, Åkerstedt T. Influence of flexibility and variability of working hours on health and well-being. Chronobiology International. 2006; 23(6): 1125–137.
21. Christian M, Wibowo S, Yulita H, Melati R, Sunarno S, Titis Perdini F. Two phases of online food delivery app users' behavior in Greater Jakarta during the second year of the COVID-19 pandemic: Perceptions of food safety and hygiene. Environ Health Eng Manag. 2023;10(3):249–59. doi: 10.34172/EHEM.2023.28.
22. Christian M, Yulita H, Nan G, Wibowo S, Indriyarti ER, Sunarno S, et al. A PLS-SEM Analysis of Consumer Health Literacy and Intention to Use Complementary and Alternative Medicine in the COVID-19 Pandemic. In: Radomir L, Ciornea R, Wang H, Liu Y, Ringle CM, Sarstedt M, editors. State of the Art in Partial Least Squares Structural Equation Modeling (PLS-SEM).Cham: Springer International Publishing; 2023. pp. 459–473.
23. Steege LM, Pinekenstein BJ, Arsenault Knudsen É, Rainbow JG. Exploring nurse leader fatigue: a mixed methods study. J Nurs Manag. 2017 May;25(4):276–86. doi: 10.1111/jonm.12464. PMID: 28244184.
24. Härmä M. Workhours in relation to work stress, recovery and health. Scand J Work Environ Health. 2006 Dec;32(6):502–14. doi: 10.5271/sjweh.1055. PMID: 17173206.
25. Yarmohammadi H, Poursadeghiyan M, Rahmani N, Yarmohammadi S, Omidiandost A, Eskandari S. Work-Related Fatigue and the Effective Factors in the Iranian Nurses. Arch Hyg Sci. 2018;7(1):32–8.