Original Article

Journal of Public Health Research

Journal of Public Health Research
2024, Vol. 13(4), 1–8
© The Author(s) 2024
DOI: 10.1177/22799036241287660
journals.sagepub.com/home/phj
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Assessing the relationship between mental workload and work fatigue among oil and gas workers in PT X, Jambi Province, Indonesia: PLS-SEM analysis

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Abstract

Occupational fatigue among oil and gas workers can have perilous consequences related to safety, health, economy, and wellbeing. This makes it necessary to discover major factors related to fatigue and implement appropriate prevention programs and education. Therefore, this study aimed to investigate the relationship between mental workload, sleep quality, and occupational fatigue in oil and gas office workers in Jambi Province, Indonesia. Mental workload, sleep quality, and occupational fatigue were measured using the NASA-TLX, PSQI, and the Indonesian Questionnaire Measuring Feelings of Work Fatigue (KAUPK2), respectively. A PLS-SEM approach was used to determine the association between mental workload, sleep quality, and occupational fatigue. Out of the 116 oil and gas workers in Jambi Province who participated in this study, 58.6% were male, 54.3% had Senior High School or less, 85.3% were not smoking, and 88.8% were married, working experience from 0.17 to 34 years. The mean of body height, weight, and mass index were 165.35 cm, 64.65 kg, and 23.64 respectively. The PLS-SEM model illustrated that the direct effect of mental workload on occupational fatigue was not significant. Meanwhile, the mental workload had a significant effect on sleep quality, which significantly affected fatigue. This indicated that the effect of workload on fatigue was fully mediated by sleep quality. The impact of good sleep on an employee's ability to recover from increased mental workload was substantial. According to this study, introducing mental workload coping methods, routine measurement, and sleep hygiene programs among oil and gas workers can reduce occupational fatigue.

Keywords

SEM-PLS, occupational fatigue, sleep quality, mental workload, oil and gas workers

Date received: 23 May 2024; accepted: 12 September 2024

Introduction

Occupational fatigue is a widespread issue in the workplace, with acute exhaustion being the most pressing worry in the majority of settings. Because of the diversity of background science, the definition and measurement of weariness differ. Occupational fatigue is a change in the psychophysiological control system that regulates task performance, caused by preceding mental or physical efforts. Generally, fatigue is defined as a physiological state where a person is inadequate to perform a task or has decreased ability at a desired level of performance due to reduced mental and physical strength, sleep loss, circadian phase, and workload.[1–3] Several factors that contribute to occupational fatigue include insufficient free time and rest, high work demands, low social support, non-supervisory, female gender, lower age, lack of exercise, inability to stop thinking about work during leisure time, snoring, poor

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sleep quality, sleep deprivation, emotional predisposition, muscular and mental exertion, workload characteristics, overtime and long work hours, social environment at workplace, distress, incomplete recovery, and stressful working condition such as in COVID-19 pandemic.[2–4] Sleep deprivation and workload is the foremost and prevalent cause of fatigue in the workplace. Previous studies discovered that occupational fatigue, mental workload, and sleep hygiene had perilous consequences for workers in oil and gas setting.[5–8] Furthermore, fatigue can have a potentially adverse effect on metabolic and cardiovascular health, risk of cancers, and mental health,[9] mood changes, job stress, cognitive degradation,[10,11] sleep disturbance,[12–14] the incidence of MSDs,[15–17] and absenteeism from work,[18] as well as a safety concern, behavior, performance, and climate.[19–22] It can also affect organizational productivity, ability to perform, decreased human performance level,[23] risk of injury rates, probability rate of the incident, quality of life, wellbeing, accident[6,12,24,25] and at-risk behavior causing death among oil and gas workers. Workers in the petrochemical industry showed little signs of occupational fatigue. But it had a negative impact on their safety practices. A portion of the association between workers safety behavior and occupational fatigue was mediated by the safety atmosphere. A decrease in firefighter fatigue has the potential to increase safety behavior and the perceived safety climate.[24] Mental workload is another paramount predictor that affects fatigue. Generally, the workload has long been considered an important and influential factor in the performance of workers in a complex system. The workload can be physical or mental and both are always interrelated, making them inseparable when a person performs a specific task.[26]

Working more than 40 hours per week and long work hours have been recognized as potential causes of fatigue.[3] This is because long working hours can also decrease required sleep time. Käthner et al.[27] showed the impact of mental workload on fatigue during prolonged usage of a P300 brain–computer interface, indicating workload negatively affected sleep. Multidimensional measures such as NASA-Total Load Index (NASA-TLX) can provide a better measure of workload. More over due to shift work, circadian rhythm disruption, and workload, worker in oil and gas industries are susceptible to occupational fatigue.[1] Based on the background provided above, workload effect on fatigue[1] (hypothesis 1) and has a significant indirect effect on the level of occupational fatigue which is mediated by sleep quality[33,35] (hypothesis 2). The investigation of the association between three variables, sleep quality, occupational fatigue, and mental workload is what makes this study novel. Then, add to the body of knowledge on descriptions and analyses of the important connection between variables measuring mental workload (including of mental demand and frustration parameters) and sleep quality. In addition to the impact of sleep quality (including symptoms like feeling overheated, experiencing nightmares, and other issues) on occupational fatigue.

Methods

Study design

This cross-sectional study was carried out from August to November 2022 at two national oil and gas firms in Muaro Jambi and Jambi City, Jambi Province, Indonesia. A total of 116 respondents were chosen by convenience sampling from oil and gas workers who agreed to participate. These meet the minimum sample for using PLS-SEM analysis.[32] The Research Ethics Commission Faculty of Public Health at UNAND University accepted this study (Ethic Number: 19/UN16.12/KEP-FKM/2022). Respondents signed the informed consent form prior to data collection, ensuring their confidentiality and anonymity.

Kuesioner Alat Ukur Perasaan Kelelahan-2 (KAUPK2) questionnaire, which contains 17 questions about fatigue complaints, was designed to assess the feelings of occupational fatigue in chronically exhausted Indonesian workers. This assessment tool is intended exclusively for Indonesian workers to gage their level of work-related weariness. KUPK is made up of three series: KAUPK1, KAUPK2, and KAUPK3. All three series have 17 statement items and have been shown to be extremely valid and dependable for shifts that are worked in the morning, afternoon, and night. KAUPK2 is a set of 17 questions about subjective complaints that employees may experience. These include difficulty thinking, fatigue from talking, anxiety, never focusing on a task, lack of attention to details, forgetfulness, lack of confidence, carelessness, unwillingness to look at others, unwillingness to work deftly, lack of calmness at work, exhaustion throughout the body, acting lethargic, inability to walk, fatigued before work, diminished thinking power, and anxiety about a particular issue. After work, the respondents finished the questionnaire. A score is assigned to each response based on the following criteria: The responses "Yes, often" receives a score of 3, "Yes, rarely" receives a score of 2, and "Never" receives a score of 1. The degree of work tiredness is classified as follows based on the survey's overall score, which was calculated using an interval scale with three measurement scales: A total KAUPK2 score of less than 23 indicates less fatigue; a score of 23–31 indicates fatigue; and a score of greater than 31 indicates extreme fatigue. The purpose of the Pittsburgh Sleep Quality Index (PSQI) is to assess the general quality of sleep in different clinical populations. The 19 self-reported items on the questionnaire fall into one of seven subcategories: daytime dysfunction, habitual sleep efficiency, subjective sleep quality, sleep latency, length, and interruptions. For clinical purposes, five more questions are added; these are not scored and are appraised by the respondent's bed partner or roommate. The PSQI questionnaire has nine items, five of which were made up of ten sub-items and seven subscales, including subjective sleep quality, sleep length, sleep latency, sleep disruption, habitual sleep efficiency, daytime dysfunction, and usage of sleeping medications. Each variable was weighted equally on a scale from 0 to 3, and the scores for all seven dimensions were added to generate a total score between 0 and 21, where a greater number indicated lower sleep quality.

The NASA-TLX questionnaire was developed by NASA Research Center to measure the total mental workload of oil and gas workers.[28] The NASA-TLX was a 6-item scale designed to measure many components of workload, including Mental Demand, Physical Demand, Temporal Demand, Effort, Performance, and Frustration Level. Two steps were completed to measure workload. In the first step, respondents completed a total of 15 pairwise comparisons across all six dimensions of the instruments to evaluate which features of the NASA-TLX were more important in accomplishing daily tasks. The total score on workload would be calculated by taking the weighted average of points associated with various variables. This test was validated and frequently used for measuring mental workload.[29–31]

Data analysis

Demographic data was analyzed using descriptive statistics. The study hypotheses were tested using the partial least squares structural equation modeling (PLS-SEM) approach. SEM-PLS analysis was used to evaluate the direct effect of mental workload on occupational fatigue and the indirect effect of mental workload on occupational fatigue which was mediated by sleep quality. PLS-SEM analysis can be used with a smaller number of samples where if the minimum path coefficient value expected to be significant is between 0.21 and 0.3 at a 5% significance level it is 69 samples.[32]

When applying the SEM-PLS analysis, evaluating the reflective measurement model is conducted first, followed by evaluating the structural model. The first step in evaluating the reflecting measurement model is to find out how reliable the indicators are for each latent variable when the loading factor value is greater than 0.708. In as far as the loading values fulfill the requirements of internal reliability consistency and convergent validity, the value of loading factor may be regarded as ranging between 0.4 and 0.708. The reliability consistency was then examined using Cronbach's alpha value ranging from 0.6 to 0.95. Another method that a researcher might evaluate the internal consistency reliability of items using Composite Reliability which is suggested that a construct's reliability be at least 0.70. Furthermore, to verify the validity of the model, utilize an Average Variance Extracted (AVE) value >0.5. Lastly, The Heterotrait-Monotrait Ratio (HTMT Ratio) correlation value criterion is used in the final stage to assess discriminant validity; a suggested value is <0.85 or 0.9. When assessing structural models, there are some several variables which should be examined in order to evaluate the goodness of the model; collinearity (VIF <3), R2 and R^2 adjusted values (0.75, 0.50, 0.25, which indicate substantial, moderate, and weak), and Q^2 (>0).[32]

Results

Characteristic of respondents

Demographic information of the 116 respondents was presented in Table 1. The results showed that respondents were aged from 18 to 56 (42.6 ± 9.32) years, half of them were male (58.6%) and ≤senior high school (54.3%). Furthermore, most of the participants were married (88.8%) and not smoking (85.3%). The mean with the standard deviation of body height, weight, and mass index were 165.35 ± 5.45 cm, 64.65 ± 6.89 kg, and 23.64 ± 2.23, respectively. Respondents had working experience from 0.17 to 34 years (with mean and standard deviation 16.23 ± 8.93) years.

An adequate degree of indicator loadings, reliability, and validity was demonstrated by the outcomes of the reflecting measurement model analysis as presented in Table 2. The data were examined to determine the indicator loadings, and Table 2 showed that every item had an acceptable significant factor loading with a coefficient greater than 0.6 on the related construct. This demonstrated that the construct had sufficient item dependability since it could account for more than 50% of the indicator's variance. The composite reliability values were greater than 0.7 for the internal consistency reliability of the mental workload, sleep quality, and occupational fatigue (0.801, 0.782, and 0.923). The AVE values of constructs in Table 3 were 0.657, 0.546, and 0.502, respectively, suggesting that all constructs had an acceptable level of convergent validity. Furthermore, Table 3 demonstrated that the loading factor values of each construct were higher than others. This showed that all constructs had an acceptable level of discriminant validity.

Table 4 displayed each path's significance in the hypothetical model. The results demonstrated that mental workload had a significant positive effect on sleep quality (path coefficient: 0.179; $p=0.0036$), indicating that the quality in sleep increased with mental workload. Conversely, sleep quality significantly had a direct and negative effect on occupational fatigue (path coefficient: −0.405; $p=0.000$), suggesting that occupational fatigue increases with decreasing sleep quality. Moreover, the direct effect of mental workload on fatigue was not significant (path coefficient: −0.035; $p=0.709$). As evidenced by a small negative coefficient that was quite close to zero (−0.035), meaning that

Table 1. Demographic characteristics ($n = 116$).

Characteristic	Category	Number (n)	Percentage
Gender	Male	68	58.6
	Female	48	41.4
Education	≥Vocational degree	53	45.7
	≤Senior High School	63	54.3
Smoking	Yes	17	14.7
	No	99	85.3
Marital	Married	103	88.8
	Single	13	11.2
Age (year)	Mean (±SD)	42.6 (9.32)	
	Range	18–56	
Body height (cm)	Mean (±SD)	165.35 (5.45)	
	Range	149–176	
Body weight (kg)	Mean (±SD)	64.65 (6.88)	
	Range	45–92	
Body mass index	Mean (±SD)	23.64 (2.23)	
	Range	18.83–31.10	
Working experience (year)	Mean (±SD)	16.23 (8.93)	
	Range	0.17–34	

Table 2. Assessing reflective measurement model.

Latent variable	Indicator	Reliability		Validity	VIF		R^2	R^2-adj	Q^2
		Outer loading	Composite reliability	AVE	Outer	Inner			
Mental workload	Frustration level	0.909	0.801	0.657	1.128	1.033	0.171	0.156	0.197
	Mental demand	0.700			1.128				
Sleep quality	Too hot	0.716	0.782	0.546	1.122	1.033	0.032	0.024	
	Too bad dream	0.766			1.249				
	Other reason	0.733			1.230				
Fatigue (KAUPK2)	Difficulties in expressing an opinion	0.692	0.923	0.502	2.079	-			
	Difficulty to speak	0.740			2.321				
	Face problem not calmy	0.712			2.061				
	Uneasy to determine the way to do the job	0.700			2.190				
	Uneasy to recall the experiences quite recently	0.648			1.805				
	Not certain of the rightness of what his state	0,703			1.895				
	Unable to do the job seriously	0.702			2.190				
	Not enthusiastic to communicate with people	0.712			2.106				
	Unable to work adeptly	0.801			2.990				
	Concerned at work time	0.730			2.205				
	Not adept	0.711			2.484				
	The way to solve the problem is not as good as earlier	0.639			1.684				

increased or decreased mental workload had no effect on occupational fatigue. From these, It was identified that the effect of mental workload on occupational fatigue is fully mediated by sleep quality because all segments of this indirect path were significant ($p < 0.01$). Accordingly, the first hypothesis of the study is rejected, which means workload

Table 3. Discriminant Vvalidity.

HTMT	Mental workload	Sleep quality	Occupational fatigue
Mental workload			
Sleep quality	0.307		
Occupational fatigue	0.171	0.538	

Table 4. Hypotheses test results of SEM-PLS model. The relationship between mental workload and work fatigue among oil and gas workers in PT. X Jambi Province, Indonesia.

Path		Coeff	St. Dev	*T*-stat	*p*-Value
From	To				
Mental workload	Sleep quality	0.179	0.086	2.093	0.036*
Sleep quality	Fatigue	–0.405	0.079	5.163	0.000*
Mental workload	Fatigue	–0.035	0.093	0.374	0.709

*Sig alpha 0.05.

Table 5. Correlation matrix between latent variables.

Latent variable	Mental workload	Sleep quality	Occupational fatigue
Mental workload	1		
Sleep quality	0.179	1	
Occupational fatigue	–0.107	–0.412	1

had no direct effect on occupational fatigue. In contrast, the second hypothesis is accepted, which means the effect of workload on occupational fatigue was totally mediated by sleep quality. The conclusions from Table 5 were in line with the results of correlation matrix between latent variables on Table 4 where mental workload also had positive correlation on sleep quality ($r = 0.179$), following the negative correlation between sleep quality and occupational fatigue ($r = -0.412$) and negative correlation between mental workload and occupational fatigue ($r = -0.107$). These strengthen our finding related to the the hypothetical model of the research.

Discussion

Using the SEM-PLS method, this study was carried out to validate and elucidate a hypothesized relationship between mental workload, sleep quality, and occupational fatigue among oil and gas worker in Jambi Province, Indonesia. The two hypothesis were that (1) workload directly affected fatigue and (2) sleep quality acted as a mediator between mental workload and occupational fatigue. Consequently, workload had no direct impact on occupational fatigue, rejecting the study's first prediction. The second hypothesis, on the other hand, is approved, meaning that sleep quality acted as a complete mediator between the workload and occupational fatigue. According to model in this research (Figure 1), there were only two selected indicators which significantly positive measure mental workload namely frustration level (loading factor = 0.909) and mental demand (loading factor = 0.700) meanwhile the remaining indicators which is not included in the model where the loading factors value < 0.6 (physical demand, temporal demand, performance, and effort). This can be explained as follows how insecure, discouraged, irritated, stressed, and annoyed they were and how mentally demanding the task was to describe mental workload on workers at PT. X Jambi City, Indonesia. For the second latent variable, feel too hot (loading factor = 0.716), have bad dreams (loading factor = 0.766), and other reasons (loading factor = 0.733) were pillars supporting quality of sleep. One possible explanation for the correlation between these indicators and the likelihood of experiencing work tiredness is as follows. Fatigue at work may result from exposure to heat in the workplace and surroundings. The temperature in Jambi City is the ninth highest among Indonesian cities. Moreover, workers who experience bad nightmares may find it difficult to get a good night's sleep.

Considering the findings of the research that work fatigue is influenced by several indicators such as not being as good at solving problems as before, not being skilled, being anxious at work, not being able to work well, not being enthusiastic in communicating, not being able to do work seriously, not being sure about the truth, being anxious about remembering, facing problems of not being calm, difficulty speaking, difficulty in expressing opinions, and anxiety in determining how to do work. High or low levels of mental demands and levels of frustration do not directly influence work fatigue. This difference is possible due to different types of personality traits consisting of neuroticism, extraversion, friendliness, conscientiousness, openness to experience. Apart from that, differences in results from other studies are possible due to differences in measuring instruments and types of work among oil and gas workers in Jambi Province.

These results were in line with previous investigations.[33,34] The mental workload was measured using the NASA-TLX which had been recognized as a valid and reliable instrument for assessing mental workload. The mental workload had no significant direct effect on occupational fatigue at 95% CI. The calculation results obtained a minimum NASA-TLX score of 13.33 and a maximum of 87.33 with an average of 72.52 and standard deviation of 8.27.

The total effect was still not significant, indicating that workers had a fairly high-level workload, their tendency was to argue they had a fairly good quality of sleep and did not feel too tired. However, a previous report[35] stated that mental workload was a risk factor for occupational fatigue. This discrepancy might be due to the nature of the work carried out by hospital service personnel as compared to oil and gas workers. Many studies showed that medical workers had high physical, psychological stress, and

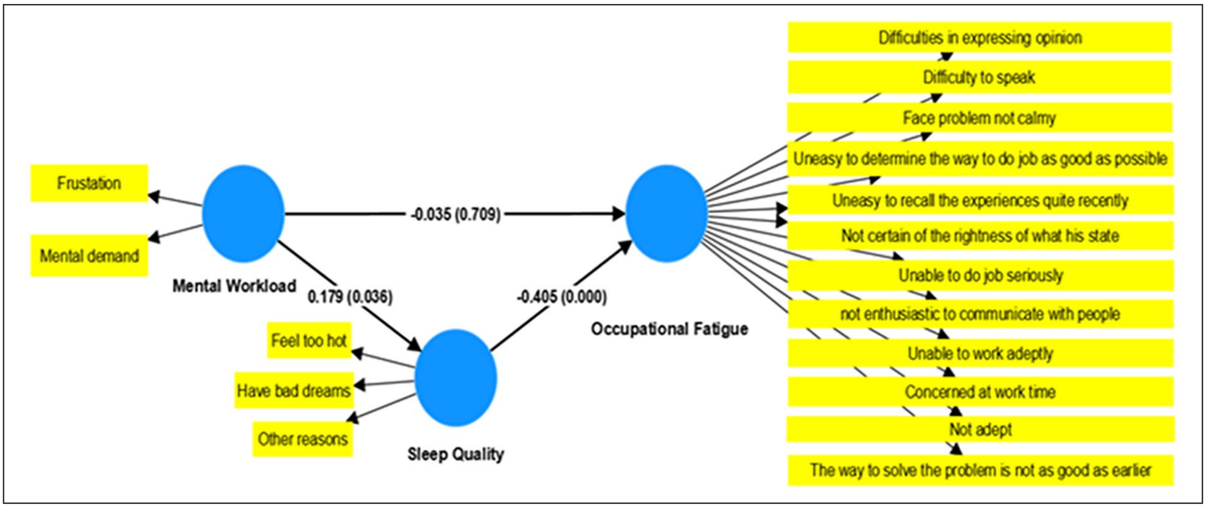

Figure 1. Model of the occupational fatigue among oil and gas workers in PT. X Jambi Province, Indonesia.

mental workload. This was because working in a clinical setting as a stressful environment imposed a high level of physical and mental demand.[36–38] The results showed that workload had a significant indirect effect on fatigue with sleep quality interventions. When someone experienced a fairly high level of mental workload, their tendency was to think that they had a fairly good quality of sleep and did not feel too tired. In this case, the effect of sleep quality was very significant.

In this study, sleep quality had a significant direct effect on occupational fatigue at 95% CI. It was postulated that when workers had good sleep quality, they were less likely to feel tired. Therefore, good sleep hygiene was found to be important for the productivity of workers.[39] Sleep is vital for survival and optimal day-to-day cognitive functioning, and insufficient sleep is due to sleep deprivation, sleep restriction, and sleep disorder. Insufficient and sleep disorders are highly prevalent in the population and oil and gas workplace and associated with significant morbidity, mortality, physiological problems, sleep disorder, cardiometabolic stress, and cognitive impairment which have been identified as underlying factors in increased risk for accidents, obesity, type 2 diabetes, and coronary health disease.[40] Furthermore, sleep quality problems are often associated with shift duty and the night shift.[8] In this instance, getting enough sleep enhances the likelihood that employees in the oil and gas industry will recuperate and regain physical fitness, which will lessen the stress they endure at work.

This study found that mental workload had a significant direct effect on sleep quality at 95% CI. When the workload was high, the quality of their sleep tended to be good. Workers in this study tended to experience higher-quality sleep due to their increased mental exertion. Workers attempt to get enough sleep to make up for the mental strain they endure. Consistent with the previous study[33] discovered that SEM model results indicated that workload had a large impact on sleep quality and that exhaustion had a considerable impact on sleep quality, but there was no significant direct relationship between workload and fatigue. So, the quality of sleep completely mediates the effect of effort on exhaustion. This may be influenced by individual characteristics and types of work. This difference is possible due to different types of personality traits consisting of neuroticism, extraversion, friendliness, conscientiousness, openness to experience.

In addition this validates the results according to Benson et al.,[8] that workers should be subjected to appropriate supervision at work, industry-wide dangers should be properly assessed, and employees should always be required to undergo mandatory medical testing to determine their current health. This also covers the risks associated with work-related exhaustion and level of workers fitness, sleep quality and mental workload.

Furthermore, the effect of mental workload on occupational fatigue was mediated by sleep quality. The urgency, management, and strategies for optimizing sleep opportunities among oil and gas workers had also been investigated and discussed.[5] This study had several limitations due to its cross-sectional nature from which causation cannot be inferred. The data were collected from a limited number of workers in the oil and gas company in Jambi Province, which can influence the generalizability of the results. Furthermore, other factors may affect the association found in this study, including work stress, shift work and family role conflict, personality traits, and heat stress exposure due to the hot ambient temperature.

Conclusion

This study showed that sleep quality was a complete mediator of the effect of mental workload on occupational fatigue. Therefore, implementing mental workload coping strategies, sleep hygiene programs, and education to improve knowledge among oil and gas workers can reduce fatigue.

Significance for public health relevance to public health further references on the intervening factors influencing fatigue in oil and gas workers are provided by this study. Combining initiatives to enhance sleep hygiene and quality to fortify worker health promotion initiatives.

Acknowledgments

The authors would like to thank all of the staff members of the national oil and gas company who participated in the research as well as Prof. Doni Hikmat Ramdhan, Ph.D from Universitas Indonesia for his review.

Author contributions

Data analysis was supervised by David Kusmawan, who also came up with the manuscript proposal. Design and idea of the study were aided by Dody Izhar and Budi Aswin. The literature review was completed by all authors, who also produced the manuscript's initial draft, assisted with revisions, and read and approved the final document before it was submitted.

Availability of data and materials

This published article contains all of the data generated or analyzed during the study.

Data availability statement

Further questions can be posed to the corresponding author. The original contributions made during the study are contained in the article and supplementary material.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research received a grant from PNBP funds from the Faculty of Medicine, Jambi University with grant number 215/UN21.11/PT.01.05/SPK/2022.

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