Journal of Social Research

P-ISSN:2827-9832
E-ISSN: 2828-335x
Vol. 5, No. 7, June 2026
http://ijsr.internationaljournallabs.com/index.php/ijsr

Microsleep as a Risk Factor for Unsafe Behavior: A Systematic Literature Review

Elga Alifqiah Ihsan*, Hendra Djamalus
Universitas Indonesia
Email: elgaalifqiah@office.ui.ac.id*

Keywords:
microsleep;
unsafe behavior;
fatigue
safety behavior;
occupational safety

Abstract

Microsleep is a brief, unconscious episode of sleep that reduces alertness and slows reaction time, potentially triggering unsafe behavior. This condition significantly contributes to workplace and traffic accidents, particularly in high-vigilance sectors. This study aims to identify groups vulnerable to microsleep and the forms of unsafe behavior resulting from it based on a systematic review of literature published over the past five years. A systematic literature review (SLR) was conducted on 23 national and international articles relevant to microsleep, safety behavior, and fatigue. Vulnerable groups include drivers, pilots, heavy industry workers, maritime workers, healthcare personnel, and patients with sleep or neurological disorders. The identified unsafe behaviors include loss of focus, delayed responses, poor decision-making, reduced safety compliance, and increased accident risk. Microsleep clearly triggers various forms of unsafe behavior among vulnerable populations. Integrated prevention strategies, such as fatigue management and strengthening the safety climate, are essential to reduce its impact on occupational safety.

INTRODUCTION

The implementation of occupational safety and health (K3) has become a top priority in modern industrial operations due to its significant impact on worker productivity and well-being. It is estimated that more than 2.78 million work-related deaths occur every year, with occupational accidents being the largest contributor to this figure (ILO, 2021). High-risk industrial sectors, such as transportation, construction, and mining, rely heavily on human vigilance to prevent fatal incidents. However, data show that human error remains a contributing factor in nearly 80% to 90% of workplace accidents (World Health Organization, 2022). This is also supported by root-cause analyses of workplace accidents, which often point to unsafe behavior. Unsafe behavior includes workers ignoring standard operating procedures (SOPs), failing to use proper personal protective equipment (PPE), and working under conditions of decreased concentration (Cooper, 2020). One study stated that unsafe behavior among workers is not only triggered by motivational or environmental factors but is also strongly influenced by workers' neurophysiological conditions, especially levels of fatigue and cognitive alertness (Pratama et al., 2023).

One hidden threat contributing to unsafe behavior among workers is the phenomenon of microsleep. Microsleep is defined as an involuntary brief sleep episode lasting between 1 and 15 seconds, often unnoticed by the individual experiencing it (Skiba et al., 2020). This phenomenon is triggered by the accumulation of fatigue, sleep deprivation, and monotonous or repetitive tasks. During the microsleep phase, the brain stops processing sensory information from the environment, which directly disrupts an individual's control over the task at hand

(Higgins et al., 2021). Workers who experience microsleep while performing their duties may face various adverse effects. The impact of microsleep goes beyond drowsiness; it can lead to a drastic decline in the brain's executive functions, including reaction time, decision-making, and risk assessment (Bougard et al., 2021). Workers who experience microsleep tend to exhibit unsafe behaviors due to a sudden loss of situational awareness. The National Safety Council (NSC) notes that workers who experience fatigue leading to microsleep have a 13% higher risk of work-related injuries than fit workers (NSC, 2023).

Systematic studies on the transition from microsleep events to unsafe behavior among workers remain limited. In addition, gaps exist in the measurement methods used in previous studies, particularly between subjective methods, such as questionnaires, and objective methods, such as EEG and infrared sensors. Studies that specifically discuss microsleep as a trigger for unsafe behavior are spread across various scientific domains, including occupational medicine, industrial psychology, and safety engineering. There is also variation in findings regarding the extent to which microsleep affects certain types of unsafe behavior across different industrial sectors (Abe et al., 2022).

These variations and the diversity of explanations regarding the influence of microsleep on unsafe behavior among workers indicate the need for a systematic review of existing studies using the systematic literature review method. This approach is necessary to synthesize findings from various primary studies and provide a comprehensive and structured overview.

This study aims to conduct a systematic review of global literature published over the past five years to analyze the functional relationship between microsleep incidents and the emergence of unsafe behaviors in the workplace. The results of this review are expected to serve as a reference for companies in developing more effective Fatigue Risk Management System (FRMS) policies based on scientific evidence.

RESEARCH METHODS

This study uses *the Systematic Literature Review* (SLR) method. SLR is the process of identifying, assessing, and interpreting all available research evidence with the aim of providing answers to specific research questions (Kitchenham & Charters, 2007). This research protocol is prepared following the PRISMA 2020 standard to ensure that the review process is carried out systematically and transparently.

Research Questions

To guide the review process, research questions were prepared using **the PICOS** (*Population, Intervention, Comparison, Outcome, Study Design*) framework:

- **RQ1:** What are the demographic characteristics and industry sectors most vulnerable to *microsleep occurrences* in the literature over the past five years?
- **RQ2:** What are the forms of unsafe *behavior* that arise as a direct consequence of *microsleep*?
- **RQ3:** How effective are the measurement methods (subjective vs. objective) used to detect the relationship between *microsleep* and unsafe behaviors?

Literature Search Strategy

Literature searches are conducted on reputable electronic databases, namely: Scopus, ScienceDirect, PubMed, and Google Scholar. The keywords used in the search using the Boolean operator (AND/OR) are as follows:

("microsleep" OR "brief sleep onset" OR "sleepiness") AND ("unsafe behavior" OR "unsafe act" OR "human error") AND ("occupational safety" OR "workplace accident")

Inclusion and Exclusion Criteria

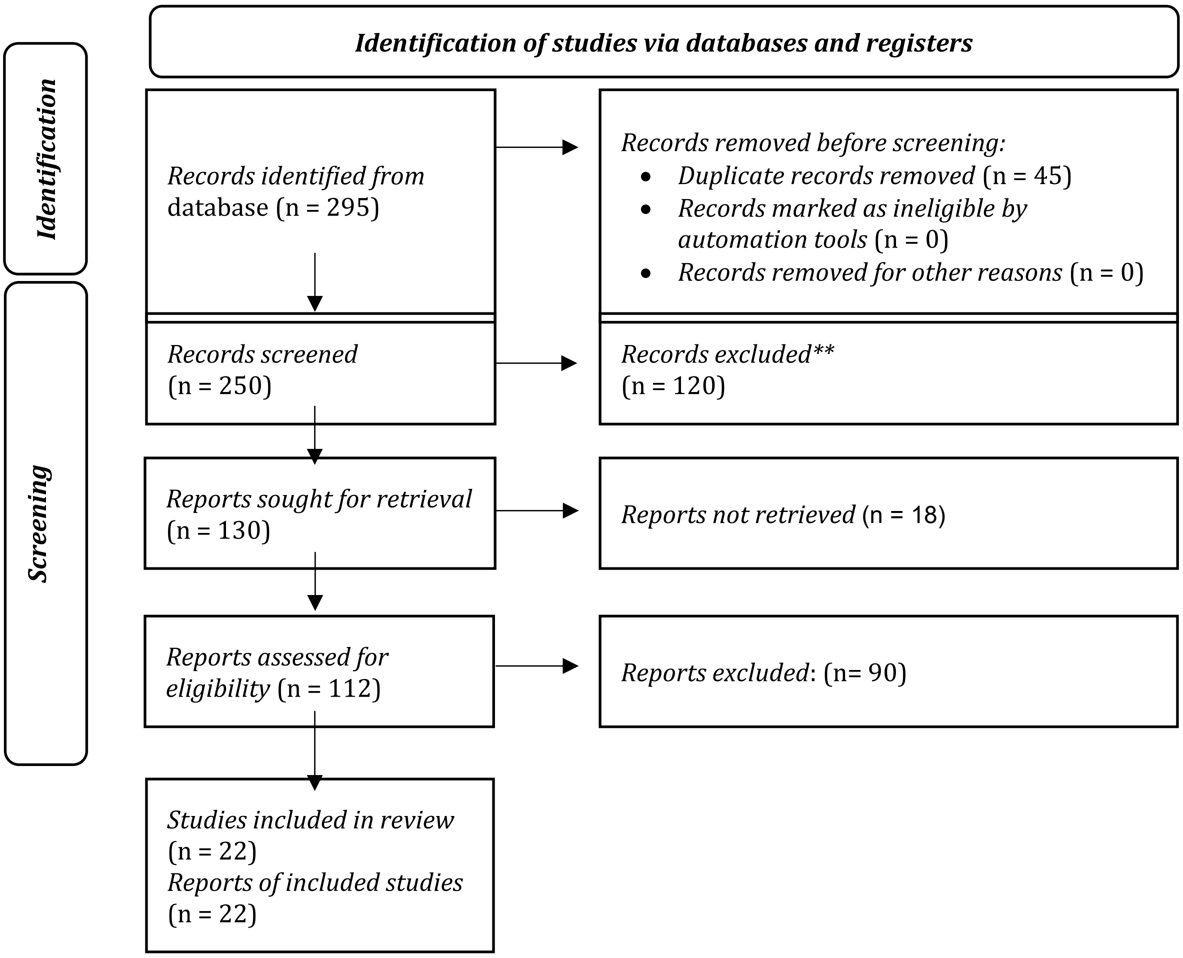
To maintain the quality of the synthesis results, the selection criteria are set as follows:

Table 1 Inclusion and Exclusion Criteria

Criteria	Inclusions	Exclusion
Time Range	Journals published in the last 5 years (2021–2026)	Issues under 2021
Document Type	Peer-reviewed primary research journal articles	Reviews, books, posters, editorials, or proceedings
Language	Indonesian and English	Other than Indonesian and English
Study Focus	Discuss the relationship between *microsleep* and insecure behavior	Discussing sleep disorders in general without any relation to work behavior
Access	Articles available in *full-text*	Only abstracts are available

Selection Stages (PRISMA Procedure)

The study selection process is carried out through four main stages based on the PRISMA protocol. The identification stage begins with collecting search results from various databases and removing duplicate documents. Furthermore, at the *Screening* stage, the title and abstract are checked to adjust the article to the inclusion criteria. The *Eligibility stage involves reviewing the* full-text to ensure that the content matches the research question. Finally, at the *Included* stage, a final list of valid articles is set for qualitative and quantitative analysis.



Picture1. Article Selection Flow Chart (PRISMA 2020)

Quality Assessment

Each article that passes the selection stage is assessed for quality using *the Critical Appraisal Skills Programme* (CASP) or JBI *Critical Appraisal Tools* instrument. This assessment aims to ensure that the synthesized article has a robust methodology and valid results.

Data Extraction and Synthesis

The data extraction process was carried out by mapping key information from the selected articles into a summary table that included the author's identity, research objectives, industry location, methodology, and key findings related to the influence of *microsleep* on unsafe behavior. The data was then analyzed using the *Narrative Synthesis* method by grouping relevant findings to answer the research questions descriptively. This approach aims to synthesize the literature in depth to understand the pattern of relationship between momentary loss of consciousness and the risk of workplace safety failure

RESULTS AND DISCUSSION

The article selection process uses the PRISMA guidelines. Search results from Google Scholar, PubMed, ScienceDirect, and Scopus databases obtained 295 articles. After the removal of 45 duplicate articles, 250 articles were obtained for the screening stage. A total of 120 articles were eliminated based on titles and abstracts, leaving 130 articles for retrieval process. A total of 18 articles were not successfully obtained, so 112 articles entered the eligibility stage. After the full text assessment, as many as 90 articles were removed because they did not meet the inclusion criteria. Thus, 22 articles were obtained used in *this systematic literature review*.

Article Characteristics

Microsleep as a Marker of Sleepiness in Obstructive Sleep Apnea Patients

Morrone et al. (2019) conducted an observational analytical study involving 112 patients with untreated obstructive sleep apnea (OSA) to evaluate the association between microsleep and sleepiness levels. The results showed that microsleep occurred in all groups with short sleep latency, most borderline groups, and some groups with normal latency. Patients with a microsleep latency of less than 5.6 minutes had a 1.93 times higher risk of falling asleep during the Maintenance of Wakefulness Test (MWT). The number of microsleep episodes was also higher in patients with impaired alertness. This study concluded that microsleep detection could be used as an objective marker of sleepiness and wakefulness disorders in patients with OSA, thereby helping to identify those at greater risk of decreased vigilance.

Another relevant study was conducted by Des Champs de Boishebert et al. (2021), involving 98 patients with OSA and hypersomnia. This study compared the effectiveness of microsleep (MS) and sleep onset latency (SOL) as markers of sleepiness through the Maintenance of Wakefulness Test. The results showed that microsleep occurred in 62.2% of patients during the MWT, with microsleep latency positively correlated with sleep onset latency ($r = 0.72$; $p < 0.0001$), but not associated with subjective sleepiness scales or other polysomnographic parameters. The use of both SOL and MS showed nearly the same diagnostic performance in assessing subjective sleepiness. The study concluded that microsleep frequently occurred during the MWT in patients with sleep disorders and could serve as a physiological marker of the transition from wakefulness to sleep, although it was not necessarily related to subjective sleepiness.

Risk Factors for Traffic Accidents in Two-Wheeled Vehicle Drivers

A cross-sectional quantitative study conducted by Karima (2023) involving 100 online motorcycle taxi drivers in Samarinda City aimed to identify factors associated with traffic accidents. Using the Spearman test, the results showed that accessing messages, calls, music, smoking, potholes, muddy roads, wet roads, and nearly falling on slippery roads were not associated with traffic accidents. However, nearly falling on damaged roads showed a significant association with traffic accidents ($p = 0.002$). This study concluded that damaged road conditions were the main factor related to traffic accidents among online motorcycle taxi drivers. Therefore, increased driver awareness and government efforts to improve road conditions were needed.

A broader study on driving safety behavior was conducted by Rachmawati et al. (2021) involving 50 production planning workers at PT Yuasa Battery Indonesia. This cross-sectional quantitative study analyzed the relationship between individual factors, including age, knowledge, attitude, driving skills, and education, and driving safety behavior. A total of 56% of workers showed unsafe riding behavior. The chi-square test revealed significant relationships between age ($p = 0.002$), knowledge ($p = 0.000$), attitude ($p = 0.000$), and driving skills ($p = 0.000$) and safe riding behavior, while education was not associated with safe riding behavior ($p = 1.000$). This study concluded that age, knowledge, attitude, and driving skills were related to two-wheeled driving safety behavior. Therefore, improved education and safe riding skills were needed to reduce unsafe behavior while driving.

Risk Factors for Microsleep in Online Motorcycle Taxi Drivers

A quantitative descriptive study with a cross-sectional approach conducted by Nadapdap, Jabbar, and Pamungkas (2023) involved 40 online motorcycle taxi drivers in Antapani selected using accidental sampling. The study used a validated questionnaire on microsleep risk factors, including work duration, smartphone use, and microsleep while driving. The results showed that 23 respondents (57.5%) sometimes experienced microsleep while driving in the morning. A total of 25 respondents (62.5%) worked more than 8 hours per day, and 39 respondents (97.5%) used smartphones for more than 4 hours per day. This study concluded that microsleep among online motorcycle taxi drivers was influenced by fatigue due to long working hours and excessive smartphone use. Prevention efforts included education on adequate rest, regulation of working hours, routine health checks, and increased awareness of driving safety..

Fatigue Management for Microsleep Prevention in Utility Drivers

Duna, Iashania, and Ganang (2023) conducted descriptive quantitative research and interviews with facility drivers at PT XX to evaluate fatigue potential and accident prevention efforts. The study identified fatigue as a contributing factor to bus collision incidents involving water trucks. The findings emphasized the need for continuous implementation of Job Safety Analysis (JSA), standard operating procedures (SOPs), a fatigue management system, and fatigue testing to prevent microsleep and work accidents. This study concluded that effective fatigue management played an important role in preventing microsleep and minimizing the risk of work accidents among utility drivers in mining environments.

Technology-Based Microsleep Detection System

Maqdis, Adiwilaga, and Munawir (2024) developed an ESP32 microcontroller-based microsleep detection system using the Random Forest method. The system used MPU6050 sensors to detect drowsiness in motorcyclists. The results showed that the system detected drowsiness at head angles of 10°–30° with 100% accuracy, while normal conditions at angles of 0°–6° also produced 100% accuracy. The system provided an alert through a buzzer when signs of microsleep were detected. This study concluded that a microcontroller-based microsleep detection system using Random Forest was effective in detecting drowsiness in motorcyclists and had the potential to reduce the risk of traffic accidents caused by microsleep.

Madona and Lumban Tobing (2023) developed a pulse sensor-based smart helmet for the early detection of microsleep in motorcyclists. The system involved five test subjects and 25 trials. The results showed that the smart helmet using pulse sensors detected microsleep based on a heart rate of less than 60 bpm. The system activated a vibrator and speaker as warnings when the rider was detected to be drowsy. The test results showed that the system worked according to the configuration in all 25 trials. This study concluded that a pulse sensor-based smart helmet was effective for the early detection of microsleep in riders and could help improve driving safety and prevent accidents caused by drowsiness.

Further research by Sangeetha et al. (2023) developed a deep learning approach to detect microsleep using various forms of EEG signals. This study analyzed the accuracy of microsleep detection in driver data using a Deep Neural Network (DNN) and machine learning. The results showed that the combination of cleaned EEG signals and a DNN significantly improved microsleep detection compared with traditional machine learning methods. The system distinguished micronap and non-micronap conditions more effectively. This study concluded that an EEG signal-based deep learning approach was effective for automatically detecting microsleep and could potentially be applied to real-time sleep monitoring systems to improve driving safety.

Malafeev et al. (2021) developed an automatic detection system for microsleep episodes using deep learning based on EEG and EOG data. The study involved 76 patients with EEG and EOG data from the Maintenance of Wakefulness Test. The Convolutional Neural Network (CNN) algorithm and the CNN-LSTM combination showed performance close to human expert judgment in detecting microsleep. Detection of wakefulness and microsleep episodes was excellent, while the detection of microsleep episode candidates and drowsiness episodes had lower accuracy due to low inter-rater reliability. This study concluded that EEG- and EOG-based deep learning was effective for the automatic detection of microsleep, with performance close to expert scoring, and had potential for use in alertness monitoring and sleepiness-related risk prevention.

Microsleep and Neurological System Dysfunction in Parkinson's Disease

Doppler et al. (2021) conducted an observational analytical study involving 27 patients with Parkinson’s disease and 13 healthy controls to analyze the relationship between microsleep disorders and noradrenergic system dysfunction. The results showed that patients with Parkinson’s disease had lower Cyclic Alternating Pattern (CAP) rates and A indices than healthy controls. Sleep microstructure disorders were significantly correlated with decreased noradrenaline transporter density in brain areas that regulate arousal and alertness. This study concluded that microsleep and sleep microstructure disorders in patients with Parkinson’s disease were associated with dysfunction of the noradrenergic system, which plays a role in regulating alertness and sleep–wake cycles.

A translational study by Lima et al. (2023) analyzed the relationship between macro-sleep and microsleep dysfunction in Parkinson’s disease as potential biomarkers. This literature review analyzed human, animal, and computational models related to Parkinson’s disease. The results showed that sleep disorders in Parkinson’s disease were associated with changes in sleep architecture, REM and non-REM sleep disturbances, decreased gamma power, and abnormalities in basal ganglia synchronization. Micro- and macro-sleep dysfunction had the potential to serve as early biomarkers of Parkinson’s disease. This study concluded that microsleep and macro-sleep disorders were closely related to neurological mechanisms in Parkinson’s disease and had potential for use as biomarkers for diagnosis and the development of more effective therapies.

Microstate EEG Changes During Sleep Transitions

Diezig and team (2022) conducted an experimental observational study involving 45 healthy subjects at a young age to analyze the relationship between microstate EEG dynamics and dream-like experiences during sleep transitions. The results showed that dream-like experiences during sleep transitions were associated with an increase in microstates in the superior and middle frontal gyrus and precuneus, while microstates in the high-level visual areas experienced a decrease. A link was found between a decrease in cognitive control and changes in EEG activity during the sleep transition. In conclusion, changes in the EEG microstate during the sleep transition showed a decrease in cognitive control and changes in consciousness associated with the appearance of dream-like experiences in the early stages of sleep.

Applications of IoT and Artificial Intelligence in Road Safety

Bhattacharya, Jha, and Nanda (2022) conducted a state-of-the-art review of the application of the Internet of Things (IoT) and Artificial Intelligence in road safety. This study analyzes the use of IoT, Machine Learning, RFID, real-time cameras, and Android applications to monitor driver behavior, vehicle conditions, roads, bridges, and vehicle theft prevention. The results of the review show that IoT allows real-time safety system updates, creating a smarter and more efficient road safety system. Artificial Intelligence is able to detect driver behaviors such as drowsiness and microsleep through real-time cameras and high-resolution imagery, as well as help monitor road and bridge conditions. In conclusion, the integration of IoT and Artificial Intelligence has great potential in improving road safety through real-time monitoring, early detection of driver behavior, and supervision of road infrastructure, although there are still some limitations in the implementation of technology that need to be further developed.

The Dangers of Microsleep in Flight

Dewa (2024) conducted a descriptive qualitative study to analyze the impact of the dangers of microsleep when conducting cross country flights at the Indonesian Aviation Academy Banyuwangi. The research involved pilots and cadets through interviews and literature studies related to microsleep, fatigue, boredom, and prevention during cross country flights. The results show that microsleep can cause serious incidents in cross country flights because it reduces the pilot's ability to make decisions and respond to emergency situations. Prevention is done through adequate rest, creating a comfortable cockpit atmosphere, stretching, and bringing food and beverages during the flight. In conclusion, microsleep is a serious hazard in cross country aviation that can increase the risk of flight incidents, and prevention can be done through fatigue management and improved pilot comfort during flight.

Occupational Safety Risk Analysis in Various Industries

In the manufacturing industry, research by Ssemuddu and team (2026) used Structural Equation Modeling (SEM) to analyze the influence of safety integration and production pressure on safety performance in the cement industry. Involving 238 workers during 3 months of data collection, this study analyzed the variables of safety integration (labor safety accountability, management safety accountability, and contractor safety management) and production pressure (normalization of unsafe practices, disruptions in safety protocols, and production pressure intensity). The results showed that Labor Safety Accountability had a significant effect on all aspects of safety performance ($p<0.001$). Contractor Safety Management and Management Safety Accountability also showed significant influence. Production Pressure Intensity and Disruptions in Safety Protocols have a negative impact on safety performance. In conclusion, the integration of occupational safety significantly improves safety performance, while production pressure reduces the quality of work safety in the cement industry.

In the health sector, research by Ferreira and Rodrigues (2026) conducted a multilevel quantitative study involving 500 healthcare workers in two hospital units in Northern Portugal. This study analyzes the relationship between safety climate and safety performance indicators, including doctors, nurses, diagnostic and therapeutic technicians, operational assistants, and technical assistants. Safety climate shows a positive relationship with safety motivation, safety behaviors, and safety knowledge, as well as a negative relationship with time pressure. Technical assistants reported lower levels of safety climate, safety knowledge, and safety participation as well as higher time pressure. Non-shift workers have a better perception of safety climate and safety knowledge than shift workers. In conclusion, the safety climate plays an important role in improving safety performance in the hospital environment, and the differences between professional groups and work schedules indicate the need for a more specific safety approach.

In the elevator industry, Li and Li (2026) conducted a longitudinal three-wave time-lagged study with a multilevel moderated mediation model involving 466 elevator technicians in 61 work teams. This study analyzes the influence of job stressors (workload, lack of autonomy, and role ambiguity) on safety behavior through psychological distress, with team safety climate moderation. The results showed that psychological distress mediated the relationship between job stressors and safety behavior. Team safety climate moderates this relationship, where the negative influence of psychological distress on safety behavior becomes weaker in teams with a strong safety climate. In high safety climate conditions, the indirect relationship between job stressors and unsafe behavior becomes insignificant. In conclusion, psychological distress is an important mechanism that links work stress with a decrease in work safety behavior, and a strong team safety climate is able to reduce the negative impact of psychological stress on safety behavior.

Risk Analysis of Work Accidents at Altitude on Ship Operations

Öztürk and team (2025) conducted a risk analysis study using the integrative approach of SLIM (Success Likelihood Index Methodology), IT2FS (Interval Type-2 Fuzzy Sets), and FEM (Finite Element Method) to analyze the risks in working activities on commercial ships. The SLIM method is used to measure Human Error Probability (HEP), IT2FSs for uncertainty modeling, and FEM for biomechanical analysis of fall injuries. The results of the study show that the factors of Leadership and Supervision, Fatigue/Workload, and Risk Acceptance are the highest performance shaping factors (PSF) that most affect human error. FEM analysis shows that even falling from relatively low altitudes can cause fatal injuries depending on the configuration and trajectory of the fall. In conclusion, the integration of SLIM, IT2FS, and FEM methods is effective for analyzing work risks at height in ship operations, and this approach assists maritime authorities and ship operators in reducing the number of accidents and improving maritime occupational safety standards.

RQ1: What are the demographic characteristics and industry sectors most vulnerable to microsleep occurrences in the literature over the past five years?

Based on the results of the literature synthesis, the incidence *of microsleep* is most commonly found in individuals working in the transportation sector, high-risk industries, as well as jobs that require high alertness in a long duration. The most vulnerable groups include vehicle drivers, pilots, industrial technicians, maritime workers, and healthcare workers. The main factors that affect this vulnerability are work fatigue, high work pressure, lack of sleep, work monotony, and high concentration demands.

In the land transportation sector, online motorcycle taxi drivers are one of the groups with a high risk of *microsleep* due to long work durations and excessive use of smartphones. Research by Nadapdap et al. (2023) shows that 62.5% of drivers work more than 8 hours per day and 97.5% use smartphones for more than 4 hours per day, thus increasing the incidence of *microsleep* while driving. In addition, research by Karima (2023) also shows that road conditions that are damaged and almost fall on slippery roads are related to the high risk of traffic accidents in online motorcycle taxi drivers.

In the aviation sector, *microsleep* is a serious threat to aviation safety. Dewa (2024) explained that pilots who experience *microsleep* during cross-country flights experience a decrease in decision-making and response skills to emergency conditions. Boredom factors, fatigue, and lack of rest time are the main causes of this condition.

The heavy industry worker group also showed a high vulnerability to unsafe behavior due to *fatigue* and work pressure. Research by Ssemuddu et al. (2026) shows that production pressure intensity and disruption to *safety protocols* have a negative effect on *safety performance* in the cement industry. Similar findings were also explained by Li and Li (2026) who found that *workload, role ambiguity*, and lack of work autonomy increase *psychological* *distress* which then has an impact on decreasing *the safety behavior* of high-risk industrial workers.

In the maritime sector, shipworkers who work aloft have a high risk of human *error* due to *fatigue/workload*. Öztürk et al. (2025) found that *the fatigue/workload* factor is the *main performance shaping factor* that increases the *probability of human error* and the risk of fatal accidents due to falling from heights.

In addition to the transportation and industrial sectors, the group of patients with neurological disorders and sleep disorders is also a population susceptible to *microsleep*. Morrone et al. (2019) and Des Champs de Boishebert et al. (2021) found that patients with obstructive sleep apnea (OSA) had a higher frequency of *microsleep* due to impaired *vigilance* and *daytime sleepiness*. In Parkinson's disease patients, *microsleep disorders* are associated with dysfunction of the noradrenergic system that regulates arousal and alertness (Doppler et al., 2021; Lima et al., 2023).

Demographically, the majority of the research involved the productive age group who were actively working in sectors with high vigilance demands. This shows that *microsleep* is not only related to biological factors, but is also greatly influenced by work factors, work environment, and operational stress.

RQ2: What are the forms of unsafe *behavior* that arise as a direct consequence of *microsleep*?

The results of the study show that *microsleep* is closely related to the emergence of various forms of unsafe behavior that can increase the risk of work accidents and traffic accidents. These unsafe behaviors are generally in the form of decreased alertness, delayed response, decision making errors, non-compliance with safety procedures, and motor control disorders.

In the transportation sector, *microsleep* causes drivers to lose focus for a moment, increasing the risk of accidents. Research by Madona and Tobing (2023) shows that a decrease in pulse rate of up to <60 *beats per minute* (bpm) is an indicator that the driver is starting to experience drowsiness which has the potential to cause a loss of control of the vehicle. *The smart helmet* system developed is able to provide early warning through vibration and sound to prevent unsafe driving behavior.

In the industrial work environment, unsafe behavior due to *microsleep* and *fatigue* is shown through decreased *safety compliance* and *safety participation* of workers. Li and Li (2026) found that *psychological distress* due to *workload* and *role ambiguity* makes workers more susceptible to unsafe actions. A low *safety climate* strengthens the relationship so that the risk of unsafe behavior increases.

Research by Duna et al. (2023) on mining drivers shows that *fatigue* and *microsleep* are the causes of operational vehicle collision incidents. Fatigue conditions cause workers to fail to maintain vigilance and are unable to respond quickly to dangerous situations.

In the maritime sector, unsafe behavior appears in the form of *human error* when working at height. Öztürk et al. (2025) show that *fatigue/workload* and *risk acceptance* increase the probability of work errors that can lead to fatal falls on the ship.

In the health sector, Ferreira and Rodrigues (2026) found that time pressure is negatively correlated with *safety climate* and *safety behavior* of health workers. High work pressure can reduce adherence to safety procedures, increasing the risk of unsafe behavior in a hospital environment.

In addition, in patients with sleep and neurological disorders, microsleep causes impaired *vigilance* and decreased cognitive control. Diezig et al. (2022) found that there were changes in the EEG *microstate* during the sleep transition related to decreased cognitive control and consciousness. This condition explains why individuals who experience *microsleep* tend to be unable to maintain focus and response to the surrounding environment.

Overall, unsafe behavior due to microsleep is mainly characterized by decreased alertness, delayed response to hazards, operational errors, and decreased compliance with occupational safety and driving safety procedures.

RQ3: How effective are the measurement methods (subjective vs. objective) used to detect the relationship between *microsleep* and unsafe behaviors?

The literature shows that objective methods have a higher level of effectiveness than subjective methods in detecting microsleep and its relationship with insecure behaviors. The objective method is able to provide physiological and behavioral data in real-time so that it is more accurate in identifying the transition from conscious to *microsleep*.

The most widely used objective methods in the study include *electroencephalography* (EEG), *electrooculography* (EOG), *pulse sensors*, computer vision-based cameras, as well as *machine learning* and *deep learning*. Research by Sangeetha et al. (2023) shows that the combination of *cleaned* EEG and *Deep Neural Network* is able to improve the accuracy of *microsleep* detection compared *to traditional machine learning methods. Similar results were found by Malafeev et al. (2021) who used a combination of CNN and LSTM based on EEG and EOG to detect microsleep* with performance close to *expert scoring*.

In the study of Diezig et al. (2022), changes in the EEG *microstate* during the sleep transition successfully identified a decline in cognitive control before the individual entered the full sleep phase. This shows that EEG is a very sensitive objective tool for detecting neurological changes related to *microsleep*.

Computer vision-based methods also show high effectiveness. Saputra et al. (2021) reported 93.9% accuracy in detecting drowsiness using the Haar Cascade Classifier and CNN. Meanwhile, Maqdis et al. (2024) found that the use of MPU6050 sensors and the Random Forest algorithm was able to detect changes in the position of the rider's head with 100% accuracy.

In addition, the use of pulse sensors on smart helmets developed by Madona and Tobing (2023) is able to detect a decrease in bpm as an indicator of drowsiness and automatically provide early warnings to the rider. The IoT and AI technologies discussed by Bhattacharya et al. (2022) also show great potential in real-time safety monitoring through the integration of sensors, cameras, and machine learning.

In contrast, subjective methods such as questionnaires, interviews, and *self-reports* are more widely used to identify risk factors and individual perceptions of microsleep. Nadapdap et al. (2023) used questionnaires to assess risk factors for microsleep in online motorcycle taxi drivers, while Dewa (2024) used interviews to evaluate the impact of *microsleep* on pilots. Although the subjective method is easier to apply and cheaper, this method has limitations in the form of perception bias, *underreporting*, and dependence on respondents' awareness of the sleepiness condition experienced.

Research by Morrone et al. (2019) and Des Champs de Boishebert et al. (2021) shows that objective indicators such as *microsleep latency* in the *Maintenance Wakefulness Test (MWT) are more accurate in assessing vigilance disorders* than subjective sleepiness scales. This confirms that physiological measurements have a higher sensitivity in detecting *microsleep conditions*.

Overall, objective methods based on physiological sensors, EEG, computer vision, and artificial intelligence have been shown to be more effective in detecting *microsleep* and unsafe behaviors than subjective methods. However, a combination of the two methods is still necessary in order for individual risk factors, psychological conditions, and work environment contexts to be understood more comprehensively.

CONCLUSION

Based on the review of 22 articles that met the inclusion criteria, microsleep was identified as a brief decline in consciousness that was closely related to the emergence of unsafe behavior in various occupational sectors and high-risk activities. The groups most vulnerable to microsleep included workers in transportation, aviation, heavy industry, maritime sectors, and healthcare, as well as individuals with sleep and neurological disorders. The main factors influencing microsleep included work fatigue, long working hours, production pressure, sleep deprivation, work monotony, and high vigilance demands.

Microsleep clearly contributed to various forms of unsafe behavior, such as loss of focus, delayed responses, decision-making errors, decreased adherence to safety procedures, human error, and increased risks of occupational and traffic accidents. This condition showed that microsleep was not only an individual physiological problem but also an important factor in occupational and transportation safety.

The study also showed that objective measurement methods, such as EEG, EOG, heart rate sensors, computer vision, machine learning, and deep learning, were more effective in detecting microsleep than subjective methods. AI- and IoT-based technologies were proven to improve the accuracy of real-time microsleep detection. Nevertheless, subjective methods remained important for identifying psychological, behavioral, and work-environment risk factors.

The practical implication of these findings was the need for companies to adopt a scientifically evidence-based Fatigue Risk Management System (FRMS). This system should integrate objective detection technologies, strengthen the workplace safety culture, and provide ongoing education to workers regarding the risks of microsleep and its prevention.

REFERENCES

Abe, T., et al. (2022). Impact of sleep deprivation on workplace safety: A systematic review. Journal of Occupational Health.

Bhattacharya, S., Jha, H., & Nanda, R. P. (2022). Application of IoT and artificial intelligence in road safety. In 2022 Interdisciplinary Research in Technology and Management (IRTM). IEEE. https://doi.org/10.1109/IRTM54583.2022.9791529

Bougard, C., et al. (2021). Effects of sleep deprivation and fatigue on cognitive performance in industrial contexts. Sleep Medicine Reviews.

Cooper, M. D. (2020). Behavioral safety: A framework for success. Safety Science.

Des Champs de Boishebert, L., Gormand, F., Pradat, P., Bastuji, H., Ricordeau, F., Le Cam, P., Stauffer, E., Petitjean, T., & Peter-Derex, L. (2021). Microsleep versus sleep onset latency during maintenance wakefulness tests: Which one is the best marker of sleepiness? Clocks & Sleep, 3(2), 259–273. https://doi.org/10.3390/clockssleep3020016

Dewa, J. R. (2024). Analysis of the impact of the danger of microsleep when actively flying cross country at the Indonesian Aviation Academy Banyuwangi.

Diezig, S., Denzer, S., Achermann, P., Mast, F. W., & Koenig, T. (2022). EEG microstate dynamics associated with dream-like experiences during the transition to sleep. Brain Topography. https://doi.org/10.1007/s10548-022-00943-4

Doppler, C. E. J., Smit, J. A. M., Hommelsen, M., Seger, A., Horsager, J., Kinnerup, M. B., Hansen, A. K., Fedorova, T. D., Knudsen, K., Otto, M., Nahimi, A., Borghammer, P., & Sommerauer, M. (2021). Microsleep disturbances are associated with noradrenergic dysfunction in Parkinson's disease. Sleep. https://doi.org/10.1093/sleep/zsab040

Duna, B. I. S., Iashania, Y., & Ganang, N. M. A. (2023). Fatigue management to prevent microsleep in the utility driver. Journal of Mining Engineering, 23(2), 34–39.

Ferreira, J., & Rodrigues, M. A. (2026). Towards a safer hospital environment: A multilevel analysis of safety climate and performance.

Higgins, J. S., et al. (2021). Asleep at the wheel: The physics and physiology of microsleep. National Highway Traffic Safety Administration (NHTSA).

ILO. (2021). World statistics: Health and safety at work. International Labour Organization.

Karima, W. A. (2023). Factors that affect traffic accidents in two-wheeled online motorcycle taxi drivers in Samarinda City [Thesis, Mulawarman University].

Li, S., & Li, Y. (2026). Severing the health-impairment chain: Psychological distress and cross-level safety climate associations with safety behavior.

Lima, M. M. S., dos Santos Lima, G. Z., Targa, A. D. S., Torterolo, P., & Cavarsan, C. F. (2023). Macro and micro-sleep dysfunctions as translational biomarkers for Parkinson's disease. International Review of Neurobiology. https://doi.org/10.1016/bs.irn.2023.08.008

Madona, P., & Tobing, A. L. (2023). Early detection of microsleep in motorcycle helmet based on pulse sensor. Journal of Electronics System Engineering Technology.

Malafeev, A., Hertig-Godeschalk, A., Schreier, D. R., Skorucak, J., Mathis, J., & Achermann, P. (2021). Automatic detection of microsleep episodes with deep learning. Frontiers in Neuroscience, 15. https://doi.org/10.3389/fnins.2021.642134

Maqdis, S. A., Superman, A., & Munawir. (2024). Design of microsleep detection system in 32 bit microcontroller-based motorists with random forest method. JIKO (Journal of Informatics and Computers), 7(2), 131–137. https://doi.org/10.33387/jiko.v7i2.8539

Morrone, E., D'Artavilla Lupo, N., Trentin, R., Pizza, F., Risi, I., Arcovio, S., & Fanfulla, F. (2019). Microsleep as a marker of sleepiness in obstructive sleep apnea patients. Journal of Sleep Research. https://doi.org/10.1111/jsr.12882

Nadapdap, R. P. F. A., Jabbar, J. M., & Pamungkas, M. (2023). Risk factors for microsleep in online motorcycle taxi drivers in Antapani in 2023.

NSC. (2023). Fatigue in the workplace: Causes and consequences. National Safety Council.

Öztürk, O. B., Kartal, Ş. E., Turna, İ., Pirim, A. E., Güvercin, Y., & Yaylaci, M. (2026). An integrated interval type-2 fuzzy SLIM and FEM model for working aloft risk analysis in shipboard operations.

Pratama, A., et al. (2023). Analysis of human factors in industrial work safety. Journal of Public Health.

Sangeetha, S. K. B., Mathivanan, S. K., Muthukumaran, V., Pughazendi, N., Jayagopal, P., & Uddin, M. S. (2023). A deep learning approach to detect microsleep using various forms of EEG signal. Mathematical Problems in Engineering, 2023, Article 7317938. https://doi.org/10.1155/2023/7317938

Saputra, C. A., Erwanto, D., & Rahayu, P. N. (2021). Detection of four-wheeled sleepiness using the Haar Cascade Classifier and Convolutional Neural Network. JEECOM, 3(1), 1–7.

Skiba, V., et al. (2020). Microsleep episodes and operational safety. Sleep Medicine.

Ssemuddu, J. B., Kajjoba, D., Olupot, P. W., Kirabira, J. B., & Okure, M. (2026). Structural equation modeling of safety integration and production pressure effects on safety performance in cement manufacturing. Scientific Reports, 16, 5801. https://doi.org/10.1038/s41598-026-36696-8

WHO. (2022). Global status report on occupational safety. World Health Organization.