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Findings from a systematic review of fatigue interventions: What's (not) being tested in mining and other industrial environments

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Abstract

Background: Fatigue negatively impacts mineworker health and safety. In this paper, we identify fatigue interventions tested on industrial shiftworkers and explore their effects and the factors that may influence application in an industrial setting such as a mine site.

Methods: This review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. A structured, systematic search of the literature was conducted to identify relevant studies published between 1980 and 2020. Researchers independently conducted article screening and study quality appraisals against pre-established criteria, and then extracted data and conducted a narrative synthesis of the included studies.

Results: Seven intervention studies, out of 1651 articles initially screened, were retained for narrative synthesis. Four studies tested the alerting effects of bright-light treatment, one evaluated the effectiveness of blue-light blocking glasses at improving daytime sleep quality and nighttime

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Zoë Dugdale: Lead author; protocol development; article screening; quality assessment; data collection and narrative synthesis; draft preparation and editing; coordination of coauthors; internal reviews. Brianna Eiter: Article screening; quality assessment; data collection and narrative synthesis; draft preparation and editing; internal reviews. Cammie Chaumont Menéndez: Article screening; editing; critical evaluation of arguments and subject matter. Imelda Wong: Article screening; editing; critical evaluation of the subject matter and review in larger context of the literature. Tim Bauerle: Protocol development; article screening; editing; critical evaluation of arguments and subject matter.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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vigilance, and two examined whether sleep hygiene and alertness management trainings improved sleep quality or alertness. There was substantial evidence for the use of bright-light treatments to improve night shiftworker alertness, but insufficient evidence to draw conclusions about the effectiveness of blue-light blocking glasses and sleep hygiene and alertness management trainings due to the small number of studies included. Shiftworkers were mostly male and employed in industrial subsectors such as production and manufacturing, oil and gas, and transportation. No mining-specific intervention studies were identified.

Conclusions: Future research is needed to identify effective fatigue risk management interventions for the mining industry as well as best practices for implementing these interventions with mineworkers.

Keywords

bright light; fatigue risk management; mining industry; shiftwork; shiftworkers; sleep; training; workplace intervention

1 | INTRODUCTION

Work-related fatigue and sleep deficiency remain key occupational health and safety concerns in many industries and industry subsectors. According to the National Sleep Foundation,[1] healthy adults should sleep 7–9 h per day, but in the United States, 30% of workers on standard day schedules (e.g., 9 a.m. to 5 p.m.) and 44% of night shiftworkers (e.g., 10 p.m. to 6 a.m.) report insufficient sleep (≤6 h per day).[2] Short sleep duration has become more prevalent among US workers over the past several decades but varies substantially by industry and occupation.[3] Night shiftworkers in industrial sectors like transportation and warehousing are more likely (70%) to report short sleep duration than night shiftworkers in industries such as recreation, arts, and entertainment (10%).[2] When workers are tired and fatigued, workplaces may see more absenteeism and presenteeism[4] and safety critical events such as near-misses, injuries, and fatalities.[5]

In mining operations, fatigue is thought to be a significant contributor to safety critical events[5] due to the nature of the mining environment and the job tasks that mineworkers perform. Mining workplace factors that are associated with increased risk for fatigue-related safety critical events include nonstandard shift-work schedules,[6] physically and mentally demanding or monotonous work tasks,[7] and environments that can sometimes be hot,[7] poorly lit,[8] and loud.[7] Since many of these factors occur simultaneously in mining, it can be challenging to mitigate the sources of worker fatigue, resulting in workers having elevated or exacerbated fatigue risk and the potential for cognitive impairment and serious injury or death.[7]

Interventions such as short naps,[9] bright light,[10] and strategic caffeine use[11] have been associated with improved sleep and reduced fatigue in workers, but most have been tested in nonindustrial settings, such as in healthcare,[10] aviation,[12] and policing.[13] Few fatigue intervention studies have been conducted in settings where workers have similar job tasks and levels of education to mineworkers, such as in ground transportation and oil and gas extraction.[14–16] To date, the scientific literature related to fatigue intervention has not been comprehensively synthesized to demonstrate what interventions have been tested with and are most effective for industrial shiftworkers.

This review aims to identify fatigue interventions that have been tested in mining and other comparable trade industries. This paper also narratively explores the effectiveness of the interventions and factors influencing their use in the field. Results from this review can be used to inform future directions in fatigue risk management in the mining sector.

2 | METHODS

This review followed a protocol developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.[17] The review protocol was not registered with any groups such as Cochrane or Prospero.

2.1 | Article eligibility criteria

Criteria for inclusion and exclusion of studies can be found in Table 1. We defined an intervention as a discreet strategy or set of actions intended to change the outcomes of interest.[18,19] We included interventions designed to (1) promote or improve sleep or mitigate fatigue that were (2) implemented in a workplace setting, and (3) used an experimental or quasi-experimental design with either a between- or within-group comparison. To maintain comparability with the mining workforce, workplace populations were restricted to adult workers (over 18 years old) in industrial-type jobs where formal education ended at the high school level or less and little to no related work experience is required, and where workers receive anywhere from a few days to a year of job training and job tasks involve considerable psychomotor ability (e.g., reaction time, response orientation, and rate control). These objective population parameters were informed by Occupational Information Network (O*NET) data.[20] O*Net is an occupational data repository sponsored by the US Department of Labor/Employment and Training Administration and includes occupation-specific information for nearly 1000 jobs encompassing the entire US economy. The research team used the O*Net database to create a list of occupations that had certain job-level requirements in common with workers in the mining industry. These included required level of education, work-related experience, job training, and psychomotor ability. This list of occupations was referenced by researchers during the study screening process. Articles were limited to the English language and published between 1980 and 2020. No limit was set for country.

2.2 | Information sources and search strategy

Relevant studies were identified by conducting structured searches in electronic journal databases, consulting two subject matter experts, and manually reviewing the reference lists of a sample of fatigue intervention studies and reviews. The following thirteen databases were selected based on their content and scope: MEDLINE, EMBASE, PsychInfo, CAB Abstracts, CINAHL, NTIS, Scopus, NIOSHTIC-2, ProQuest Central, GoogleScholar, MedNar, Web of Science, and Open Access Theses and Dissertations (to identify references to include). The search strategy was designed to retrieve references across four key elements: (1) work schedule (e.g., shiftwork); (2) occupation/industry (e.g., miner/mining);

(3) outcomes (e.g., sleep or fatigue); and (4) interventions (e.g., planned naps). Our final search terms are presented in Table 2. Search strategies were adapted minimally to meet the input and syntax requirements of each database. Complete search profiles for each database, along with our O*Net population parameter methodology, are available upon request.

2.3 | Study selection

Covidence, a web-based systematic review platform, was used for the article screening process. Random pairs of researchers (Z. D., B. M. E., C. C. M., T. B.) independently screened the titles and abstracts following pre-established inclusion and exclusion criteria (Table 1). Full text screening was completed by the entire study team. Disagreements during both phases of screening were resolved through structured group discussions. After screening concluded, to confirm no relevant studies were missed, two subject matter experts reviewed the list of included studies, and the lead author (Z. D.) hand-searched the reference sections.

2.4 | Quality appraisal

We developed and pilot-tested a study quality appraisal tool (Table 3) to categorize the level of confidence that could be assigned to conclusions about study interventions described in the included literature. This tool was adapted from the NIH Quality Assessment Tool for Before-After (Pre-Post) tudies[21] and from tools published in the workplace intervention literature.[22,23] Criteria were selected to address study objectives and ethics, study design, appropriateness of the referent group, study population attrition, and statistical analyses. Two researchers (Z. D. and B. M. E.) used the quality appraisal tool to independently conduct critical appraisals of each eligible study. Studies were categorized as very high (100% of criteria met), high (80%–99% of criteria met), medium (50%–79% of criteria met), or low (0%–49% of criteria met).[22] We retained studies rated medium or higher for data extraction and narrative synthesis.

2.5 | Data extraction and synthesis

We used a modified version of the Cochrane Data Collection Form for Intervention Reviews.[24] Two researchers (Z. D. and B. M. E.) worked independently to extract the following data from the included studies: study details (author[s], year, country, objective, research design, length) and descriptions of the workplace setting and worker occupation/industry, the intervention being tested, the outcome measures used, and study conclusions and limitations. The data extraction forms were then compared for consistency, and any disputes were resolved through structured discussions between the two researchers. Meta-analysis and comparing effect sizes were untenable due to the heterogeneity of interventions, study designs, referent groups, outcome measures, and the documentation of findings between studies. Due to these variations, a narrative synthesis approach modeled after Popay et al.[25] was taken to describe study characteristics, identify explanations for the size and direction of effects, and outline potential considerations related to intervention implementation.

3 | RESULTS

Figure 1 depicts the number of records identified and then included and excluded through the various phases of our systematic review. A total of 2104 articles published between 1980 and 2020 were identified through database searching, and an additional 4 articles were identified by subject matter experts and from hand-searching the reference sections of relevant literature. After removing 457 duplicate articles, 1651 articles remained for screening, of which 1540 were excluded during the title/abstract screening. Among the 111 articles screened during the full text review, 103 were removed and reasons for exclusion were documented (this information is available upon request). One additional article was removed during the study quality appraisal.[26] During the screening and quality appraisal of studies, inter-rater reliability ranged from moderate to high (see Table 3 for study fulfillment of quality criteria). Seven studies were ultimately retained for data extraction and narrative synthesis.[14–16,27–30]

3.1 | General study characteristics

Table 4 details general characteristics of the seven retained studies. All but one study[14] reported participant sex. In the six remaining studies, workers were on average mostly male (85%). Across all studies, workers were employed in the production and manufacturing,[27–30] oil and gas,[15,16] or transportation[14] industries. Both studies led by Bjorvatn[15,16] involved night shiftworkers (though different working populations) on an oil platform in the North Sea. The populations in Itani et al.[27] and Lowden et al.,[28] respectively, were workers on rotating shifts in a vehicle manufacturing plant in Japan and operators at a truck production plant in Sweden. Long-haul truck drivers from four Finnish midsized logistic companies were sampled in Pylkkönen et al.,[14] and Sadeghniiat-Haghighi et al.[29] recruited operators at a ceramic production plant in Iran. Sasseville et al.[30] followed mail sorters working the night shift at Quebec City's Canada Post warehouse distribution center. None of the included studies were conducted in the mining industry.

3.2 | Interventions

Five studies tested a lighting or light-related intervention,[15,16,28–30] and two evaluated the effectiveness of workplace sleep hygiene and alertness management trainings, respectively.[14,27] Sleep or fatigue outcomes were measured in each study using subjective or objective measures, or a combination of both. The predominant objective measure was actigraphy,[14,16,28,30] while the predominant subjective measures were the Karolinska Sleepiness Scale and different versions of a sleep diary.[14–16,28]

3.2.1 | Lighting interventions—Four of the lighting studies assessed the effects of bright-light treatments on sleep, alertness, and adaptation/readaptation to work and home life,[15,16,28,29] and one study tested whether blue-light blocking glasses improved sleep duration and efficiency and subjective nighttime vigilance in night shiftworkers.[30]

Two of the bright light treatments were delivered on an oil platform during both a scheduled work shift and also at home while the worker was off duty,[15,16] and two were delivered only while workers were on shift.[28,29] Bright light treatment was individually scheduled based on subjective sleep diary and interview responses[15,16] or was provided during regularly scheduled work breaks.[28,29] Bright light treatments were either delivered to workers as they sat in front of specially designed light boxes (10,000 lux)[15,16] or were administered in retrofitted breakrooms via fluorescent ceiling tubes that provided indirect white light (2500 lux) by an up-light armature[28,29] for a period of 20[28,29] or 30[15,16] min.

Studies that delivered bright light interventions via fluorescent ceiling tubes and up-light armatures in retrofitted breakrooms[28,29] reported greater improvements in sleep among workers than studies where workers sat in front of specially designed light boxes.[15,16] In Sadeghniiat-Haghighi et al.,[29] during normal lighting conditions, self-reported sleepiness was elevated at the 24:00 and 04:00-h timepoints and peaked at 02:00 h. After bright light treatment, subjective sleepiness ratings decreased at the same timepoints, and there was no late-night (02:00 h) sleepiness peak. Similarly, in Lowden et al.,[28] bright light treatment significantly suppressed melatonin levels during the night shift, particularly at 02:00 h, compared to the normal light condition. In Bjorvatn et al.,[15] bright light exposure significantly reduced workers' sleepiness at home but resulted in no real effect during the night shift. Nevertheless, bright light did reduce sleepiness during the late-night hours compared to the no treatment condition, as indicated by subjective ratings collected at individual timepoints during both conditions.[15] In addition, compared to the no treatment condition, workers reported improved "quality of day" the day following bright light treatment.[15,16]

One study tested more than one intervention.[16] In this crossover study, three conditions were tested throughout the year (placebo, melatonin, and bright light). A melatonin (3 mg) or placebo capsule–both identical in size and color–was administered to each oil rig worker with instructions to take 1 h before bedtime during the two 4-day periods of the study. Compared to bright light, which only provided limited objective improvements in sleep during the night shift, and the placebo, melatonin substantially reduced subjective sleepiness levels and improved "quality of day" ratings during the following day shift (but not the night shift), with workers reporting 15–20min of additional sleep per day.[16] The authors note that while melatonin has "acute soporific (sleep-inducing) effects," it is unlikely this influenced the results since objective measurements indicate melatonin increased sleep onset latency (p. 212).

A worker's ability to adapt to night work and readapt to day life following their return home was also examined in some of the lighting studies. While bright light was found to facilitate workers' subjective adaptation to night work to some degree (from 3.1 to 2.6 days), workers' readaptation back to day life after receiving bright light was more substantial, with workers readapting in roughly 3 days rather than 5.[15] Similarly, when compared to bright light, melatonin reportedly reduced the number of days it took workers to readapt to day work (from 5.0 to 3.7 days) but did not reduce the number of days it took workers to adapt to night work (from 2.5 to 2.7 days).[16]

Blue-light blocking glasses were tested with mail sorters in a relatively bright (500 lux) mail distribution center to see whether the glasses would induce a circadian phase delay during the day, improving workers' daytime sleep duration and efficiency and potentially influencing their subsequent adaptation to and subjective vigilance during the night shift schedule.[30] Two groups of workers participated, and two types of glasses were tested–blue-blocking security glasses with the summer group and a custom pair for the fall-winter group. Both glasses were designed to block short wavelengths of light, but the custom pair permitted a small amount (≤25%) of 540-nm light to filter through the lenses to the eyes to prevent interference with workers' ability to perceive color. The glasses were donned immediately upon (summer group) or up to 2 h before (fall-winter group) the end of shift and worn until workers returned home. While the time to don was determined based on time of year due to seasonal differences in environmental light, workers in both groups were instructed to wear the glasses whenever they were outside of the work facility before 16:00 h to avoid circadian resynchronization to a diurnal schedule. After wearing the blue-light blocking glasses, actigraphy parameters indicated workers in both groups had significantly longer sleep durations (summer group = 32 additional minutes, fall-winter group = 34 additional minutes), and their sleep efficiency improved by 1.95% and 4.56%, respectively. For the fall-winter group, there was no significant overarching time effect in workers' visual analog scores of their subjective vigilance from the last 150min of any night shift; however, subjective alertness did significantly improve on the last day of the experimental night-working weeks.

3.2.2 | Training interventions—Both training interventions were delivered to workers while on-shift via an in-person, predominantly lecture-style format, for a duration of 1 h[27] and 3.5 h,[14] respectively. Using an experimental design with a "no treatment" comparison group, Itani et al.[27] examined the effectiveness of a sleep hygiene education training on sleep status among manufacturing workers engaged in rotational shiftwork. The training was provided to a large group of workers ($N = 287$) and was based on a document developed by a working group within the Japanese Ministry of Health, Labour and Welfare entitled, "Sleep Guidelines 2014 for Health Promotion." Workers in attendance were provided a corresponding leaflet with a series of easy-to-follow sleep guidelines. The Japanese version of the Pittsburgh Sleep Quality Index (an assessment of sleep quality and disturbances) and the Epworth Sleepiness Scale (a measure of self-rated daytime sleepiness) were the indices used to assess changes in overall sleep status. No significant improvements in subjective sleep propensity and quality were found between workers who received the sleep hygiene training and those who did not.[27]

In a two-armed randomized controlled trial, Pylkkönen et al.[14] examined whether an alertness management training would reduce long-haul truck drivers' on-duty sleepiness and improve their sleep between work shifts. Four companies participated and each hosted two trainers who delivered the training session to 4–9 drivers per session. The training began as a lecture and then transitioned into an interactive workshop with written exercises and group discussions. Trainers provided workers with minimally tailored sleep-related recommendations, such as how to develop better sleep habits and manage sleepiness while on-duty. Drivers were provided a 2-month consultation period with the trainer and were asked to complete a series of self-evaluation assignments at different periods over the following months. Most workers returned their self-evaluation activities (93.1%), but none of them took advantage of the 2-month consultation period with the trainers. Alertness management training did not result in any significant improvements in sleepiness or prior sleep during night and early morning shifts compared to the day and evening reference shifts.[14]

4 | DISCUSSION

This review aimed to identify and then report the effectiveness of fatigue-related interventions that have been tested with workers on nonstandard shiftwork schedules in mining and comparable industries. We identified lighting or light-related strategies and workplace sleep hygiene and alertness management trainings in nonmining industries. To use these interventions in mining, we introduce a series of practical considerations below.

4.1 | Practical considerations

4.1.1 | For lighting interventions—Lighting is critically important in mining operations, as miners rely heavily on visual cues to detect hazards and safely perform their jobs. Due to the lack of natural light in underground mines, mineworkers must rely on artificial light sources, such as hard hat cap lamps or area lights, to visually inspect their work environment.[31] These artificial light sources emit lower levels of ambient light than natural daylight and even other workplaces (e.g., hospitals) with artificial lighting.[32] These low light levels can lead to circadian disruption and an increased likelihood of fatigue in mineworkers.[33] Fatigue risk is further exacerbated for miners working nonstandard hours due to the circadian desynchronization that occurs when workers are awake at night. Since lighting is known to influence circadian rhythmicity, scheduled bright light treatments have been recommended as a potential tool for reducing fatigue in a range of occupations where night work is common.[10,34] There are several factors to consider, however, when implementing a lighting intervention in an industrial workplace setting such as a mining operation.

To begin, knowing when to deliver a lighting intervention is important but sometimes difficult in a nonlaboratory, workplace setting. In the laboratory, bright light has been shown to facilitate the adaptation of the circadian rhythm when the exposure is properly timed.[34] Core body temperature, melatonin levels, actigraphy, and polysomnography are examples of objective measurements used to assess circadian rhythmicity and to determine the best time for bright light exposure. But collecting these measures is often impractical in a workplace setting, such as a mine site, because it can conflict with work tasks, be counteracted by environmental light, be too long or intensive, or too burdensome for workers and management.[16] As such, it can be easier for worksites to use subjective data (e.g., sleep diary responses) to time the bright light exposure. Notably, this is how bright light exposures were scheduled in both intervention studies led by Bjorvatn[15,16] that were included in our systematic review. Had objective measures been used to inform exposure timing, worker circadian rhythms may have adapted more quickly and produced more robust effects, similar to those observed in controlled laboratory experiments.[34,35] However, notable improvements in sleep and alertness were still reported in both studies that used subjective measures, and it should be noted that sometimes practical decisions must be made when implementing an intervention, such as bright light, in a real-life industrial workplace setting, such as a mine site.

The provision of an adequately long bright light treatment to workers is an additional consideration. In some previous laboratory studies, duration of bright light treatment has ranged from 3 h (5200–7500 lux)[35] to 7.5 h (7000–12,000 lux).[34] While none of the studies included in our review had an exposure duration within that range, Sadeghniiat-Haghighi et al.[29] and Lowden et al.[28] still reported significant reductions in shiftworkers' subjective sleepiness after short exposures (20 min) to bright light during rest breaks. However, Lowden et al.[28] suggested that short exposure times in their study may have reduced the reported effects, such that increased exposure times likely could have translated into even lower self-reported sleepiness levels among workers. Similarly, Bjorvatn et al.[16] used a shorter, but high intensity (10,000 lux), treatment and noted that the improvements they observed in sleepiness levels were reduced compared to studies where longer exposure durations were used.[36] While there could be beneficial alerting effects to longer light treatments, the findings of this review suggest that short, bright light treatments are still an effective means for improving alertness among shiftworkers during night shifts. Further, extending the duration of a treatment may impede job tasks and productivity demands, particularly in industrial settings like a mine.

The location of bright light treatment is another logistical consideration. In our review, bright light treatments led to significant improvements in sleep when they were administered in retrofitted breakrooms via fluorescent ceiling tubes and up-light armatures.[28,29] For application in an industrial environment, considering practicality and cost, worksites may favor designating select spaces for the provision of bright light to workers.[28,29] For mines, this could mean utilizing a breakroom and/or a pre-shift meeting space to deliver short, unobtrusive bright light treatments to mineworkers during shift breaks.

4.1.2 | For training interventions—Occupational health and safety training is one approach commonly used to change worker behavior.[37] In mining, annual training is federally mandated for mine workers and operators under the regulation *Training and Retraining of Miners* from the US Department of Labor's Code of Federal Regulations (30 CFR Parts 46 and Part 48).[38] Training is also institutionalized in other industries and sectors (e.g., transportation, oil and gas), and is a common component of more general workplace health and safety programs. The two training studies in our review did not show that their specific sleep hygiene and alertness management trainings improved worker sleep and alertness. There are several factors to consider when designing training for a worksite that may improve training effectiveness. To begin, it is important to identify the purpose and intent of the training, as well as the best method for delivery. Training can be designed to be information-based with the intent to communicate "news, knowledge, and facts" to workers; alternatively, training can be designed to be education-based and deliver information to workers in ways where it is "developed, learned, and used"[39] (p. 200). Because education programs require more in-depth design, engagement, and application, they are better positioned to result in long-term changes in shiftworkers' behavior than trainings focused on disseminating information.[39] In Itani et al.,[27] a large group of workers (N = 104) passively listened to a lecturer present sleep guidelines and sleep-related lifestyle habits; workers were also given a corresponding four-page leaflet to review during the lecture but otherwise did not actively participate during the training. Since there was no interactive component, this sleep hygiene education training was more informational in nature, which is one possible explanation for the reported lack of improvement in worker sleep post-training.

To be effective, training must also be practical for workers, meaning the materials provided should be relevant and acceptable to the specific group of workers receiving the training.[39] Workers are likely to dismiss or rebuff recommendations that feel irrelevant or unhelpful, given the contexts of their job tasks or organizational structure.[39] In Pylkkönen et al.,[14] most of the training materials were identical for the different groups of long-haul truck drivers, despite conceivably varied levels of "readiness for change," as indicated by the fact that none of the drivers took advantage of the consultation period offered by the trainer and some did not return their completed self-evaluation assignments. Furthermore, since all were relatively experienced drivers, the more basic-level material provided to them lacked relevancy and may have been more impactful for novice drivers. Participant selection queries related to intervention effectiveness were also noted in Itani et al.,[27] where researchers used a "population approach" to assign the intervention group, meaning all interested and available workers on the day of the training were permitted to attend, not necessarily the workers who most needed the sleep hygiene recommendations. More focused training for workers at higher risk for fatigue may result in greater intervention-related improvements but should be considered with caution and care so as not to harm or stigmatize workers.

Finally, it is critical to consider factors related to time when designing training–specifically, the frequency and duration of the training. Wong et al.[40] suggest that short, one-time lectures are not likely to result in sustained behavior change, while more consistent, long-term efforts to provide sleep hygiene and alertness management trainings at worksites may yield more improvements in sleep and alertness among workers over time. This provides a possible explanation for why no substantial improvements in sleep and alertness were reported in the two training studies as they were designed to be short and nonrecurrent, likely for feasibility reasons.

4.2 | Strengths and limitations

A strength of this systematic review is that it is the first to examine sleep- and fatigue-related interventions that can be applied to mining. Several research gaps were also highlighted, giving our synthesis product the potential to guide future research about fatigue risk management in the mining industry and with other similarly structured industrial occupations. In terms of limitations, our literature search strategy erred on the side of specificity over sensitivity, and while it is possible that the restriction of some search terms to only "title" or "abstract" in some of the database searches limited the search and therefore resulted in some missing studies, efforts were made to amend this by securing subject matter expert review of the final reference list and by hand-searching reference sections. Additionally, the population parameters we adhered to were intended to maintain relevance with the mining industry, but this meant that studies with nondescript shift working populations with no industry or occupation identified were excluded. Nevertheless, the final list of included studies that met the a priori inclusion criteria is considered comprehensive and exhaustive.

As for study limitations, besides those discussed previously relating to intervention design and implementation, the applied nature of these intervention studies meant that certain more rigorous approaches characteristically used in clinical settings were often or altogether untenable, including the blinding[14,15,28,29] and random[27] and balanced[30] allocation of workers. Small sample sizes were also documented in two of the included studies.[14,30] Real-life constraints are imminent when conducting applied research, particularly in the workplace. Rather than being limited by those constraints, this review is instead strengthened by highlighting the factors that should be considered when intervening on fatigue in a real-life, industrial workplace setting.

4.3 | Concluding remarks

The goal of this systematic review was to identify sleep and fatigue interventions for potential use in the mining industry. While no studies conducted in mining were found, relevant studies carried out in related industries were identified. Notably, studies of only two intervention types–lighting and training–were identified out of several frequently documented in other industries and sectors (e.g., planned naps, rest breaks, strategic caffeine use). Our synthesis suggests that bright light exposure may be a promising intervention for reducing self-reported sleepiness and increasing alertness in industrial shiftworkers. The one identified study on blue-light blocking glasses reported that the glasses may be useful for improving the sleep duration and efficiency of night shiftworkers in industrial sectors, but more focused research on this is needed and regarding their effect on workers' on-duty subjective vigilance. Future research related to sleep hygiene and alertness management training is also needed, as only two training intervention studies were identified in this review and both studies reported that their respective sleep hygiene and alertness management trainings did not substantially improve the sleep and alertness of shiftworkers. Since training remains a critical occupational health and safety tool for many industries, including mining, future sleep hygiene and alertness management trainings should be designed to be purposeful, participatory, and sustained over time to deliver the greatest benefits to mine workers. Further, both lighting and training interventions should be customized as much as possible for specific workers and with consideration for contextual factors within the workplace environment.

Critically, no studies identified in our review were conducted in mining. More robust quality research needs to be conducted to assess whether interventions like bright light and sleep hygiene and alertness management trainings can be effective fatigue risk management strategies in mining-specific environments. Other fatigue interventions and risk management strategies should also be explored further in mining contexts, including those commonly used in nonindustrial environments, such as planned naps, rest breaks, caffeine administration, physical activity, melatonin, and meditation. Moreover, to further encourage a multilayered approach to fatigue risk management in mining, the testing of other fatigue-related interventions across similar industrial settings would be of great benefit to the mining industry, as strategies used in other industrial work environments may be more easily adapted and implemented for mining contexts. Accompanying this intervention work should also be studies that evaluate the implementation of these varied interventions in industrial settings, since ease of use and acceptability play a large role in the adoption and long-term use of an intervention in the workplace.

DATA AVAILABILITY STATEMENT

The data that support the findings of this systematic review are available from the corresponding author upon reasonable request.

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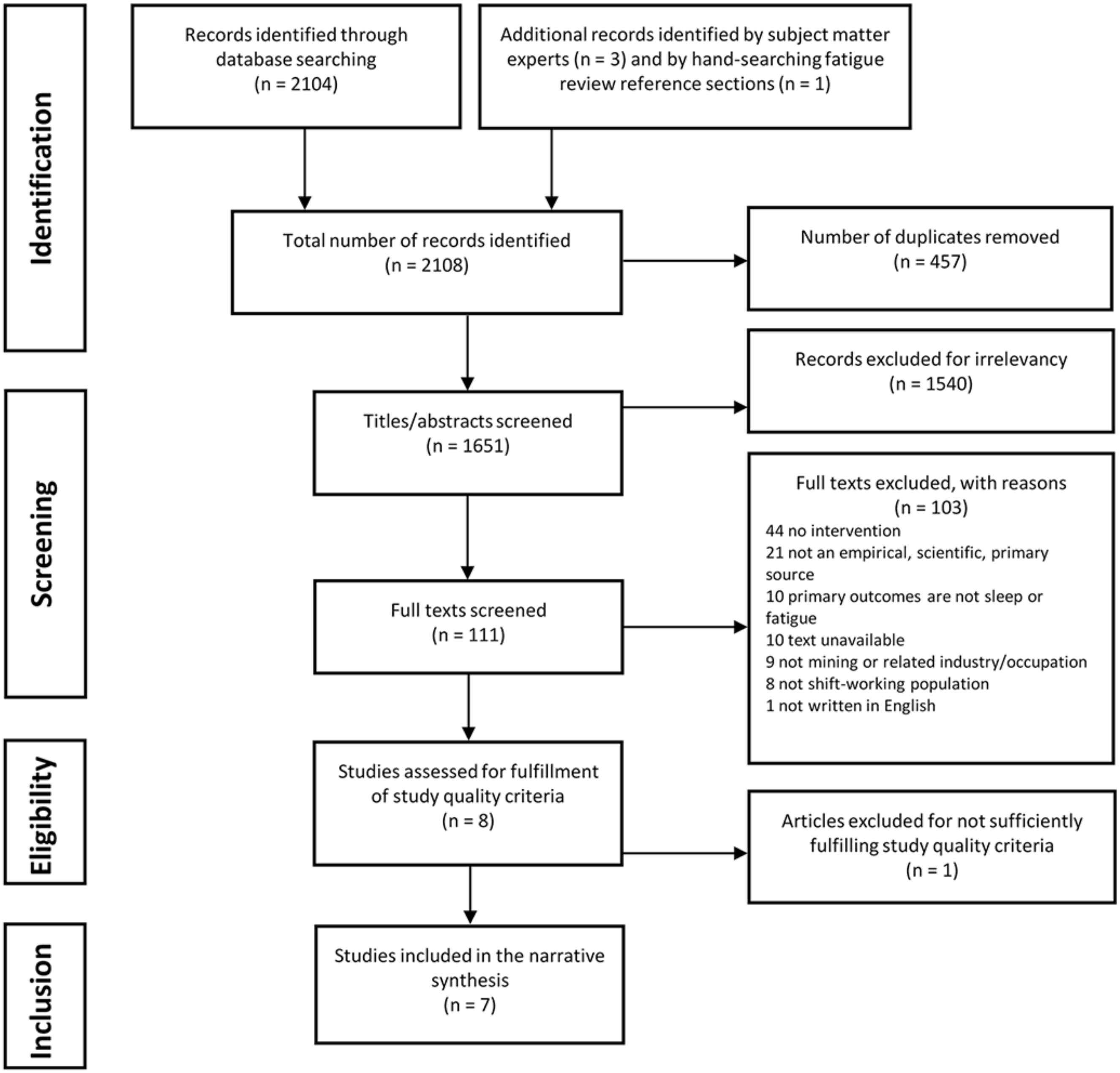

FIGURE 1.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the study identification and selection process

TABLE 1

Criteria for the inclusion and exclusion of articles during screening

	Inclusion	Exclusion
Publication type	Original research published in peer-reviewed journals	Magazine articles Book chapters Conference proceedings Dissertations Non-peer-reviewed publications
Population	Shiftworkers in industries or occupations identified by the authors as comparable to mining, based on O*Net data (e.g., oil and gas, ground transportation, construction, manufacturing, production)	Non-shiftworkers
Intervention	A discreet intervention was tested and aimed to reduce fatigue or improve sleep or alertness	No changes measured pre- and post-intervention Naturalistic studies Nonintervention studies that described best practices and/or made recommendations Studies where a shift change was considered the intervention Studies where the methodology was described in another paper
Setting	The intervention was primarily implemented in an applied, workplace setting	Laboratory studies
Outcomes	Sleep or fatigue were the primary outcome(s) Specific measures of sleep or fatigue were included	Studies where sleep or fatigue were not explicitly measured and described as the primary outcome(s)

TABLE 2

The identified terms included in the search strings

Work schedule		Occupation/industry		Outcomes		Interventions
Shiftwork schedule/OR (shift* ADJ2 work*) OR shiftwork* OR (shift* ADJ2 schedule*) OR (night* ADJ2 work*) OR nightwork* OR nightshift* OR night shift* OR (irregular ADJ2 schedule*) OR (overnight ADJ2 work*) OR (shift* ADJ2 length*) OR (work* ADJ2 hour*)	AND	Mining OR miner* OR mineworker* OR mineworker* OR truck* OR (commercial ADJ2 driving) OR (commercial ADJ2 driver*) OR farm* OR agriculture* OR manual labor* OR physical labor* OR industrial work* OR industrial labor* OR factory worker* OR fish* OR (gas ADJ5 industry*) OR (oil ADJ5 industry*) OR (extraction ADJ5 industry*) OR (processing ADJ5 industry*) OR manufacturing OR construction OR blue collar	AND	Work schedule tolerance/OR sleep* OR fatigue* OR wakeful* OR exhaustion OR circadian rhythm OR alertness OR attention OR attentiveness OR burnout OR burnout	AND	Intervention* OR prevention OR countermeasure* OR policy OR policies OR start time* OR end time* OR (restricted ADJ5 activities) OR schedule change* OR light* OR nap OR naps OR napping OR rest* OR breaks OR caffeine OR caffeinated OR coffee OR stimulant* OR change* OR (before ADJ5 after) OR shift scheduling OR roster scheduling OR rotation OR secondary task* OR shorten* OR duration

TABLE 3

Study fulfillment of quality criteria during study quality appraisal

	Quality criteria										Rating	Fulfillment of criteria
First author, year	**1. Was the study objective clearly stated?**	**2. Did the authors address ethical considerations related to participation?**	**3. Was there a suitable or comparable referent group?**	**4. Was the intervention clearly described?**	**5. Were the sleep-related outcome measures of interest prespecified and clearly defined?**	**6. Was the loss to follow-up (attrition) after baseline 20% or less?**	**7. Did the statistical methods examine changes in the outcome measures of interest from before to after the intervention?**	**8. Was the outcome measure(s) of interest taken at least once before the intervention and then over the course of the study?**	**9. Were the study's conclusions for the outcome(s) of interest clearly substantiated by data and did they directly address the research question(s)?**	**10. Did the authors discuss limitations that directly addressed the research question(s)?**	-	-
Studies contributing to the narrative synthesis												
Bjorvatn et al., 1999	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10	Very high
Pylkkönen et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10	Very high
Sadeghniiat-Haghighi et al., 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	10	Very high
Bjorvatn et al., 2007	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	9	High
Lowden et al., 2004	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	9	High
Sasseville et al., 2009	Y	Y	Y	Y	Y	Unclear	Y	Y	Y	Y	9	High
Itani et al., 2018	Y	Y	Y	Y	N	Unclear	N	N	N	Y	5	Medium
Studies excluded during the quality appraisal												
Bonnefond et al., 2001	Y	Unclear	N	Y	N	Unclear	Unclear	Y	N	Y	4	Low

Note: Very high = 100% of criteria met, high = 80%–99% of criteria met, medium = 50%–79% of criteria met, low = 0%–49% of criteria met.[22] Studies rated medium or higher were retained for data extraction and narrative synthesis.

TABLE 4

General characteristics of included studies

Intervention type	Study author	Industry/ sector	Study design	Study funding	Aim	Participants and setting	Intervention	Outcome measures	Author's conclusions
Lighting	Bjorvatn et al.[15]	Oil and gas	Pre-post design	None reported	To evaluate whether bright light treatment facilitates adaptation to 14 days of consecutive night work and subsequent readaptation to day life at home	Shiftworkers at an oil platform in the North Sea	Workers received bright light treatment (10,000 lux) via a specially designed light box for 30 min per day during the first four nights on the night shift and the first 4 days following their return home	Karolinska Sleep Diary, KSS, ATS, clinical interview	Scheduled bright light exposure over a few days can be used to help oil platform shiftworkers adapt to night work and then re-adapt back to day life when they return home
	Bjorvatn et al.[16]	Oil and gas	Randomized controlled crossover design	None reported	To assess the effects of bright light and melatonin on night shiftworkers' sleep and sleepiness levels and their ability to adapt to night work	Shiftworkers at an oil platform in the North Sea	During the first 4 days of the night shift and the first 4 days of the day shift, workers were exposed to 30 min of bright light (10,000 lux) per day via a specially designed light box and either took a melatonin or placebo capsule 1 h before bedtime	A customized sleep diary, KSS, ATS, clinical interview, 5-min serial reaction time test, Actiwatch recorder	Sleep and sleepiness modestly improved with melatonin and bright light, but not to the same degree as reported in controlled simulated nightwork studies
	Lowden et al.[28]	Production and manufacturing	Crossover design	The Swedish Work Environment Fund and the Volvo Powertrain Cooperation	To assess whether bright light administered during shift breaks increases alertness, suppresses melatonin, and improves sleep during night work and during the readaptation to day work	Operators at a truck production plant in Sweden	Workers were either exposed to 20 min of bright light (2500 lux at eye level) via ceiling tubes in a retrofitted breakroom or to normal light (300 lux) in a nonretrofitted breakroom during 4 consecutive weeks	Karolinska Sleep Diary, KSS, 5-point work strain scale, Actiwatch, salivary melatonin samples	Bright light clearly improved night shiftworkers' alertness and their overall sleep and melatonin levels, further supporting the use of photic stimulation to help workers adapt to night work
	Sadeghniiat-Haghighi et al.[29]	Production and manufacturing	2 × 2 crossover design	None reported	To evaluate the effects of bright light treatment on workers' sleepiness levels during the night shift	Operators at a ceramic production plant in Iran	During night shift breaks, workers either received a short (20 min) exposure to bright light (2500 lux) via ceiling tubes in a retrofitted breakroom or were exposed to normal light (300 lux) in a nonretrofitted breakroom	SSS	Bright light exposure during night shift breaks resulted in a significant decrease in workers' sleepiness, indicating that bright light may be an effective sleepiness countermeasure for night shiftworkers
	Sasseville et al.[30]	Production and manufacturing	Pre-post design	Fonds de la Recherche en Santé du Québec	To evaluate whether blocking short wavelengths of light below 540 nm using	Night shift mail sorters at Quebec City's Canada Post	During the 2-week experimental phase, workers wore blue-blocker glasses whenever	Actigraphy watch, visual analog scales derived from	Blue-light blocking glasses appear to improve sleep duration and

Intervention type	Study author	Industry/ sector	Study design	Study funding	Aim	Participants and setting	Intervention	Outcome measures	Author's conclusions
				(FRSQ) and Institut de Recherche en Santé Sécurité au Travail IRSST)	blue-light blocking glasses improved the daytime sleep quality and nighttime vigilance of night shiftworkers	warehouse distribution center	they were outside and either just before leaving the workplace at the end of their shift (summer group) or 2 h before the end of the night shift (fall-winter group) due to seasonal environmental lighting conditions	a French translation of the SSS	efficiency in night shiftworkers but did not seem to affect subjective vigilance over time
Training	Itani et al.[27]	Production and manufacturing	Experimental design	Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Number 25460816	To examine the effectiveness of a sleep hygiene training at improving the sleep of rotational shiftworkers	Factory workers at a vehicle manufacturing plant in Japan	Workers attended a 1-h sleep hygiene lecture and received a take-home leaflet with recommendations for improving sleep habits	Baseline survey and follow-up survey, PSQI, ESS	The sleep hygiene training did not substantially improve workers' sleep quality
	Pylkkönen et al.[14]	Transportation	Two-armed RCT	The Finnish Environment Fund (grant nos. 109378 and 115510), the SalWe Research Program for Mind and Body, and the NordForsk Nordic Programme on Health and Welfare	To evaluate whether a nonrecurrent alertness management training improves driver alertness and alertness-related behaviors, such as sleep habits and use of sleepiness countermeasures, during night and early morning shifts	Long-haul truck drivers from four middle-sized logistic companies in Finland	Workers attended a 3.5-h alertness management training that included both a lecture and an interactive workshop portion. Workers were offered a 2-month consultation period with the trainer and were asked to complete self-evaluation tasks 2 and 4-5 months after the training	KSS, sleep log, actigraphy	The alertness management training did not result in any improvements in on-duty alertness or alertness-related behaviors for drivers, but certain changes to the training's design could yield more positive findings in the future

Abbreviations: ATS, Accumulated Time with Sleepiness Scale; ESS, Epworth Sleepiness Scale; KSS, Karolinska Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; RCT, randomized controlled trial; SSS, Stanford Sleepiness Scale.