Mining, Metallurgy & Exploration (2026) 43:1973–1986
https://doi.org/10.1007/s42461-026-01502-6

Work Schedules and Sleep Hours: a Synthesis of Select Guidelines and Recommendations to Reduce Fatigue-Related Risk in Mining and other Safety-Critical Sectors

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Received: 5 May 2025 / Accepted: 4 February 2026 / Published online: 6 March 2026

Abstract

Timing and duration of work can affect sleep opportunity and impact safety, with long hours prolonging exposure to fatigue risk factors, shortening sleep opportunities, and potentially misaligning natural sleep rhythms. These issues are especially relevant in the mining industry, where long working hours and continuous operations often require work outside a traditional 9-to-5 schedule. As a result, mine workers may face increased fatigue-risk, highlighting the importance of a fatigue-focused approach to work schedule design. This paper provides a synthesis of select work schedule and sleep duration recommendations relevant to industrial sectors like mining while contextualizing the results within the larger scope of fatigue risk management. A grey literature review identified 38 documents where the most common recommendations across documents, including those for the mining sector, were for shifts up to 12 h in duration with at least 10 h off between shifts, up to 7 consecutive shifts with a maximum of 56 working hours per week, and at least 24 h off between work sets. For sleep hours, the most common health-based recommendations were 7–9 h per 24-hour period and at least 5 h for safety-based recommendations. Importantly, many guidelines offered more stringent recommendations under conditions common in mining (i.e., early and night shifts). Several documents acknowledged needing to balance operational demands with efforts to mitigate fatigue risk, offering contingency-based strategies to help manage both. This synthesis gives mining safety practitioners context with which to influence schedule designs informed by industry-specific recommendations, while referencing other sectors with similar demands.

Keywords Work-schedule · Fatigue · Sleep · Fatigue-risk · Mining

1 Introduction

1.1 Background

Shift work—or, working arrangements outside of the more common 9 AM to 5 PM Monday through Friday schedule — is often characterized by long working hours and can lead to shorter sleep durations followed by increased safety risk [1]. Limited sleep has cost the U.S. economy up to an estimated $411 billion per year due to increased mortality and sickness, and reduced work performance and skill acquisition [2]. Furthermore, sleep problems have been estimated to account for 13% of work injuries [3], and short sleep duration has been associated with poor health outcomes [4, 5].

Longer working hours negatively impact workers and are associated with negative health outcomes such as cardiovascular disease and obesity [6, 7] and can increase injury risk [8]. A recent meta-analysis showed that working arrangements with features such as shifts longer than 12 h, working four or more consecutive shifts, and night shifts each increased the risk for an occupational injury by approximately 34% compared to a single 8-hour morning shift [9]. Additionally, emerging evidence suggests that long working hours and night shifts are associated with increased risk for cancer [10–13]. While there are some mixed results amongst studies, longer working hours appear

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to be a potential contributor to decreased performance and increased absenteeism [14].

Furthermore, long working hours, insufficient sleep and shift work have all been associated with increased risk for fatigue [15]. These risks may be especially relevant in the mining industry, where approximately 17.3% of workers report working more than 60 h per week compared to only 7.3% in the general U.S workforce [16]. In addition, mine workers are more likely to work non-day shift schedules (e.g., night, rotating) than the general population and are more likely to report inadequate sleep when compared to other manual labor industries [17, 18]. When considered as a whole, these conditions suggest that the work schedule demands in mining may contribute to elevated fatigue risk and increased potential for fatigue related safety incidents.

To better understand how these risks emerge, it's important to consider the relationship between work and sleep. Work and sleep are interconnected in that the number of hours worked directly impacts the time of day and number of hours available for non-work activities, including sleep. This window of time is sometimes referred to as a worker's *sleep opportunity* [19]. As the number of daily hours worked increases, sleep opportunity decreases. Similarly, the time of day in which work takes place impacts *when* sleep can take place. For example, night shifts (e.g., working hours from 6 PM to 6 AM) constrains workers to sleep during daytime hours. This can be at odds with a worker's circadian rhythms or 'the biological clock' that drives the propensity to sleep during the night. Both the duration and time of work can affect sleep opportunity and ultimately impact safety, with long hours conferring increased safety risk through prolonged exposure to fatigue risk factors (workload, heat, harassment, etc.) at work, shorter sleep opportunities, and potentially misaligned natural sleep rhythms.

1.2 Objective

From a practical perspective, the following questions may emerge for health and safety practitioners: (1) How many work hours in a day or week are *too* many to be considered safe? and (2) how much sleep is considered *not enough* to be safe? Clear, precise, and singular answers that apply to every work context may not be directly achievable. However, general information is available to assist in work schedule design. For example, multiple biomathematical models have used human performance data for shift schedule design across a variety of work schedules [20]. Additionally, numerous guidance and recommendation documents have been published on these topics to aid health and safety specialists in mitigating risks associated with short sleep and long working hours at their respective job sites. The scope and nature of such guidance varies, but many represent synthesized findings from scientific studies or input from subject matter experts to make recommendations or implement maximum limits on work hours and minimum limits for sleep hours required to safely perform work. These guidelines often provide a suggested baseline for managing work-related fatigue risk via sleep opportunity, from which additional controls or contingencies could be implemented.

However, for health and safety professionals wishing to access or act on such guidance, several challenges emerge, including the large number of available documents, the wide range of document types and sources, lack of accessibility, complexity in deciphering actionable information, and variability in what is recommended between two or more documents. Combinations of these factors can make it difficult for occupational health and safety practitioners to be informed and implement guidance in the workplace. Therefore, the purpose of this paper was to provide a summary and synthesis of select work schedule and sleep duration recommendations for industrial work—defined here as work commonly found in settings such as mining, which typically involves physically demanding tasks, long working hours, and the routine use of heavy machinery or other operational infrastructure to support continuous operations [18, 21]. The results are presented in a standardized format and are contextualized within the larger scope of fatigue risk management. This paper does not evaluate the quality or appropriateness of the recommendations, but rather focuses primarily on summarizing and synthesizing numeric time-based recommendations for work schedule arrangements and sleep duration to aid in decision making.

2 Method

2.1 Literature Search

A grey literature search was conducted to identify original documents containing guidelines and recommendations which focused on specific limitations for hours of work or parameters for work schedules, with the search conducted globally and not limited to any specific countries. Grey literature refers to information produced by governments, academia, industry, and non-governmental organizations that is not commercially published, frequently taking the form of reports, fact sheets, webpages, or policy documents and often serve as valuable resources for practitioners [22]. A strategy similar to the AACODS (Authority, Accuracy, Coverage, Objectivity, Date, Significance) checklist [23] was employed in late 2023 to critically appraise the identified documents and assess their overall quality. These documents included meta-analyses, systematic reviews, guidance notes, recommended practices, and consensus or position statements. Following general principles from previously published grey literature searches [24, 25], the search strategies included customized search engine queries, targeted websites, consultation with content experts, and citation management collections of professional contacts.

Because grey literature is not typically indexed by traditional databases (e.g. PubMed) [26], both Google and Google Scholar advanced search features were used to query multiple combinations of terms related to fatigue (fatigue, fatigue management, fatigue risk, drowsy, etc.) along with terms meant to identify documents of interest (recommendations, guidelines, position statements, etc.). For example, one search string used was *fatigue guidelines OR guidance OR recommendations OR policies "work*"*, replacing the term 'fatigue' with 'fatigue management' in a follow-up search, and so on. Subsequent efforts were made to search for relevant documents on the webpages of industry trade associations (e.g., National Mining Association), research advocacy groups (e.g., Finnish Institute of Occupational Health), local and (inter)national governments (e.g., WorkSafe Australia), and other bodies concerned with industrial work or health and safety (e.g., National Safety Council). This was achieved through (a) deriving a preliminary a priori list of national and international trade, safety, government, or other health and safety bodies associated with the general workforce or specific industries and occupations (see Sect. 2.2 below), (b) using the search functions on their respective websites, and (c) leveraging Google search features to further investigate these websites for specific keywords (e.g., "fatigue site:https://www.nsc.org/"). Finally, professional contacts, networks, and citation databases—including those of the authors—were solicited for additional relevant documents.

2.2 Inclusion and Exclusion Criteria

For the work schedule guidelines and recommendations search, non-grey literature such as peer-reviewed publications was not included because the aim of this review was to synthesize formal work-schedule and sleep recommendations issued by government agencies, industry bodies, and other authoritative organizations. These types of guidelines are typically found in grey literature rather than in peer-reviewed journals, making grey literature the appropriate data source for this analysis. After the initial pool of search results was identified, the authors reviewed and excluded documents based on the following criteria: released or published in 1999 or prior, less reliable or less professional sources (e.g., opinion pieces, blog entries, etc.), no specific numerical recommendations for work schedule thresholds, guidelines for non-industrial populations (e.g., hospitality), and either exclusively containing or wholly based on legal requirements for work schedules. Legal documents were excluded because this review aimed to summarize non-obligatory health and safety protective guidance, i.e., the type of recommendations likely to be sought or followed in the absence of prescriptive regulations, or when existing regulations are vague, insufficient, or not explicitly tied to fatigue risk.

2.3 Academic Literature on Sleep Duration

To balance the focus on work schedules in these documents, the grey literature search was supplemented with a separate post-hoc search for peer-reviewed academic literature pertaining to sleep duration recommendations for adults. The search included meta-analyses, systematic or other comprehensive reviews, consensus statements, position statements, and other similar documents, and used search terms related to sleep (e.g., *sleep*, *sleep hours*, *sleep duration*, *amount of sleep*, etc.) along with terms related to document types of interest (e.g., *recommendations*, *guidelines*, etc.). Similar exclusion criteria were applied to focus on documents grounded in current literature: articles released or published in 1999 or prior, and articles without a specific numerical recommendation for hours of sleep (i.e., number of hours within a 24-hour period) were omitted.

2.4 Data Extraction and Analysis Approach

Once a final pool of documents was achieved, authors extracted specific numerical recommendations across all documents and arranged them into meaningful and similar categories, which were derived based on their significance to shift schedule aspects concerning variability within a 24-hour cycle (i.e., 'daily' components) or those across a broader work week or 'block' (i.e., 'block' components). Additionally, during the data extraction process we found that specific numerical values represented different types of recommendations across documents: straight-forward unambiguous limits with single values that ought not be exceeded ("Recommended Limit"), single value risk factors which if exceeded could increase work-related fatigue risk for workers and additional controls may be needed ("Risk Factor"), and multiple thresholds of values arranged along a single continuum in which risk of safety incidents increases gradually from low to medium then high ("Spectrum of Risk"). For documents in the latter category, we used the numerical value indicated for the highest risk category within our dataset and throughout the paper (e.g., highest maximum hours per shift; lowest minimum time off between shifts).

Frequencies for specific recommendation values were calculated across different shift schedule aspects and are arranged in the results by daily and block components. Because not all documents contained specific recommendation values for each shift schedule aspect, results reflect information only on the documents for which data was available (i.e., pairwise omission). While some documents provided recommendations for specific shift types (e.g., night shifts, early shifts, etc.), a majority of recommendations were provided without specifying any specific shift type. In the results, we distinguish between recommendations for 'any shift type' and those pertaining to a specific work context or arrangement.

3 Results

A total of 38 work schedule guidelines and recommendations documents were included (Table 1) [27–64]. Detailed information on the documents can be found in Supplementary Material 1. The most common work schedule recommendations came from regulatory agencies (n = 21, 55%) and in the form of guidance documents (n = 24, 63%), with regulatory agency guidance documents making up more than a third of all documents identified (n = 14, 37%). Trade associations were the next most common source (n = 8, 21%). The remaining 9 documents (24%) were published by either non-regulatory health and safety associations (e.g., British Columbia Forest Safety Council) or research or advocacy groups (e.g., Finnish Institute of Occupational Health). Documents mostly came from entities in Australia (n = 15, 39%), the United States (n = 9, 24%), and the United Kingdom (n = 8, 21%), with three additional documents from international bodies (e.g., International Labour Organization) and one document each from Canada, Finland, and New Zealand. The most common industries covered were general industry workers or all working populations (n = 10, 26%), mining (n = 9, 24%), and rail and/or transit (n = 8, 21%), with the remaining 11 divided between oil and gas extraction (OGE) (n = 5), forestry (n = 3), and utilities (n = 3).

Table 1 Work schedule search result documents by document type and source type

Source	Guidance Document	Research Report	Statement	Row Totals
Government	**15**	**2**	**5**	**22**
Health and Safety Association	1	0	0	1
Regulatory Agency	14	2	5	21
Industry	**7**	**2**	**3**	**12**
Health and Safety Association	3	1	0	4
Trade Association	4	1	3	8
Nonprofit	**2**	**2**	**0**	**4**
Research, Advocacy, or Service	2	2	0	4
Column Totals	24	6	8	38

The documents reviewed included a wide range of recommendations. We identified 7 different components of work schedules for which at least some of the documents provided specific numerical guidance (Tables 2 and 3). Recommendations for these aspects of working schedules were further broken down into subcategories of recommendations such as recommendations for specific types of shifts or work blocks. The aspects of working schedules and subcategories described throughout this paper are defined in Table 2.

3.1 Shift Schedules: Daily Components

3.1.1 Maximum Shift Duration

Among the 35 documents with shift duration recommendations for any shift type, most recommended a maximum of 12 h per shift (n=27), with fewer recommending 10 (n=2), 14 (n=5), or 16 h (n=1). Recommendations exceeding 12 h were mainly from documents in forestry (n=2) or rail/transit (n=2), while all mining (n=8) and general industry documents (n=9) recommended 12 h or less. Notably, 6 documents recommended both a maximum shift duration of 12 h and a *combined* shift and commute duration of 13 h, effectively recommending a shorter than 12-hour shift if the daily roundtrip commute exceeds one hour.

Fifteen documents that recommended a 12-hour maximum shift duration also provided additional recommendations for specific shift types. Of these, the most common was for night shifts (n=10), where 6 documents (4 mining, 2 general industry) recommended 8 h, and 4 documents (all rail/transit) recommended 10 h. Additionally, 5 documents (3 general industry) recommended 8-hour shifts for monotonous or demanding work, and 4 rail/transit documents recommended 10 h for early start times (5–7 AM) and 8 h for 'very' early start times (before 5 AM). Therefore, these 15 documents effectively recommended reducing maximum shift durations by 2–4 h for night shifts, early starts, or monotonous/demanding work.

3.1.2 Minimum Time off between Consecutive Shifts

Of the documents with recommendations for minimum time off between any shift type (n=31), the most common recommendation was for at least 10 h of non-work time (n=14) between the end of one shift and the start of another. A substantial number of documents recommended more time off—either 11 h (n=3) or 12 h (n=9)—while relatively few recommended less time off, i.e. 8 h (n=5). OGE (n=2)

Table 2 Work schedule categories

Category	Description	Sub-Categories	Example
Shift Length	Maximum number of consecutive hours worked with or without breaks in a single time period or shift, usually within 24 h.	All / any shift, night shift, early shift, shifts with monotonous or demanding tasks, total shift and commute time.	12 h (day); 10 h (night / early shifts); 8 h (shifts starting before 05:00) (LRSSB, 2021)
Time Off of Work Between Consecutive Shifts	Minimum number of consecutive non-work hours between consecutive work periods for the purpose of recovery time and sleep opportunity.	All / any shift, night shift.	8 h off prior to returning to work (API, 2019)
Time of Day	Particular window of clock time in which scheduled work is to take place.	Any work, shift start and/or end time.	Work performed between 2 AM and 6 AM; Shift end after 10 PM and before 6 AM; Morning shifts starting before 6AM (Safe Work Australia, 2013)
Number of Consecutive Shifts	Maximum number of shifts or work periods occurring on consecutive days within the same block / set without a 'reset break' of at least 24 h of non-work time.	All / any schedule, night shifts (any), early shifts, 8 h shifts (any and night), 12 h shifts (any and night)	Limit consecutive work days to a maximum of 5 to 7 days; 6 + night shifts (8 h); 5 + night shifts (10 h); 4 + night shifts (12 h) (NSW Resources Regulator, 2019)
Work Hours per Block	Maximum number of work hours within the same block / set without a 'reset break' of at least 24 h of non-work time.	Any work hours per 7 days, night work hours per 7 days, average of any work hours per 4–13 weeks.	60 h in 7 days; 180 h in 3 weeks (average) (Responsible Minerals Initiative, 2023)
Time Off of Work Between Blocks	Minimum amount of non-work time in between consecutive work blocks / sets.	Hours off (any shift), hours off after night work block, hours off after rotating work block, hours off every 7 days	At least 32 h (LITA, 2019)
Work Breaks	Minimum frequency and duration of allotted non-work time within a given work shift.	Any shift, day, night, high vigilance tasks	5–15 min every 1–2 h (HSE, 2006)

and rail/transit ($n = 2$) made up the majority of the 8-hour minimum recommendations, although rail/transit ($n = 4$) along with utilities ($n = 2$) comprised most of the 12-hour recommendations. Additionally, all four rail/transit documents that recommended a 12-hour minimum rest between any shift type also recommended a minimum of 14 h off between consecutive night shifts.

3.1.3 Daily Work-Rest Cycles

Taking the daily shift duration and time off factors together ($n = 29$), most documents recommended a work-rest cycle of 10–12 maximum hours of work followed by 10–12 minimum hours off ($n = 22$), largely made up of documents from general industry ($n = 7$) and mining ($n = 6$). Comparatively, several documents recommended 14–16 h of work and/or 8 h off ($n = 8$), which mostly came from rail/transit ($n = 3$), OGE ($n = 2$), and forestry ($n = 2$).

3.1.4 Time of Day Restrictions

Several documents ($n = 27$) recommended prohibiting, restricting, or implementing additional safety protocols for shifts starting ($n = 13$), ending ($n = 9$), or involving any work-related activities ($n = 14$) at specific times of day in a 24-hour period. A majority recommended some type of restrictive window between 12 AM and 6 AM (start $n = 12$, end $n = 8$, any $n = 7$), with all including 2 AM to 4 AM. No discernable trends by industry were observed.

3.1.5 Minimum Breaks

Beyond general suggestions that work breaks are one potential mechanism for mitigating work-related fatigue risk, less than a quarter ($n = 9$) of the documents had specific recommendations for the frequency and duration of breaks from work during a shift. The recommendations that were available were highly variable, but most suggested breaks of a 10 to 15-minute duration at least once every 1–3 h, dependent upon the nature of the task and the time of day. A few documents include recommendations for longer breaks of 30 min or more to be taken at 5 or more hours into a shift, presumably as lunch or meal breaks.

3.2 Shift Schedules: Block Components

3.2.1 Maximum Number of Consecutive Shifts

Less than half of documents had recommendations for a maximum number of consecutive shifts before a 'reset

Table 3 Number of work schedule documents with recommendations by work schedule category and industry

Category	Forestry	General	Mining	OGE	Rail	Utilities	Total
Daily Components							
Shift Duration	3	9	8	5	8	3	36
Any Shift Type	3	9	8	5	7	3	35
Night Shifts		2	4		4		10
Early Shifts					4		4
Monotonous		3	1	1			5
With Commute		2	4				6
Time Off Between Shifts	2	8	6	4	8	3	31
Any Shift Type	2	8	6	4	8	3	31
Night Shifts					4		4
Time of Day	3	8	7	3	5	1	27
Starting Shifts	1	6	4	1		1	13
Ending Shifts		2	5		1	1	9
Any Work	2	3	3	2	4		14
Work Breaks		1	2	1	3	2	9
Block Components							
Consecutive Shifts	1	9	4	3	7	2	26
Any Shift Type (any length)	1	4	1	3	7	1	17
8-Hour Shifts		4			1		5
12-Hour Shifts		2			1	2	5
Night Shifts (any length)		6		2	4	1	13
8-Hour Shifts			4		1		5
12-Hour Shifts		2	4				6
Early Shifts		2	1	1	4		8
Work Hours per Block	2	6	8	3	4	2	25
Hours per Week	2	6	8	2	2	2	24
Hours per 2–13 Weeks		1	6	2		2	11
Hours per Night Shift Block	1				1		2
Time Off Between Blocks	1	6	6	2	5	1	21
Any Shift Type	1	4	3	2	5	1	16
Night Shifts		3	3	1	2		9
Rotating Shifts		2			1		3
Per 7-Day Period		3	2	1	1	1	8
Sleep	2	6	6	3	2	2	21
Total Documents	3	10	9	5	8	3	38

Rail=Rail or Transit; OGE = Oil and Gas Extraction, including Pipeline

break' (i.e., at least 24 h off) ($n=17$). Of those that made such a recommendation, most recommended 7 sequential workdays or fewer ($n=10$) and were largely from general industry ($n=4$) and rail/transit ($n=5$). The remaining recommendations were split between 8 and 12 workdays ($n=4$), mostly from rail/transit ($n=2$), and 14–28 workdays ($n=3$), all of which came from OGE. Within these documents, there were additional recommendations for any shift type that varied with respect to shift length. For shifts at least 8 h in duration, all documents ($n=5$) recommended a limit of 6 or 7 consecutive shifts. Likewise, for 12-hour shifts, all documents recommended 4 or 5 consecutive shifts ($n=5$). For the documents that provided the respective information ($n=4$), 12-hour shifts had around 2–3 fewer consecutive workdays recommended than 8-hour shifts or those of any length.

Recommendations also varied with respect to night shifts (of any length) ($n=13$). Aside from two outliers, one each for rail/transit (6-night shifts) and OGE (21-night shifts), the remaining documents recommended a maximum of 3–4 consecutive night shifts ($n=11$), largely from general industry ($n=6$) and rail/transit ($n=3$). For the documents that included information on consecutive shift limits for night shifts and any shift type ($n=9$), most recommended a limit of 3–4 for night shifts and 7 for any shift type ($n=6$). Similar to the recommendations for any shift type, a few documents had specific recommendations for night shifts lasting 8 h ($n=5$) and 12 h ($n=6$). Specifically, a maximum of 6 consecutive shifts were more commonly recommended for 8-hour night shifts, and a maximum of 3–4 shifts were recommended for 12-hour night shifts. Finally, several documents ($n=8$) had specific recommendations for shifts with early start times (e.g., 5–7 AM or earlier), with most recommending a maximum of 4–5 consecutive early shifts.

3.2.2 Maximum Work Hours per Block

Twenty-two documents had recommendations for the maximum number of total work hours in a 7-day period. Of these, sixteen recommended either 48–50 h ($n=8$) or 55–56 h ($n=8$). These sixteen documents were mostly from general industry ($n=6$) or mining ($n=6$), with the remainder from forestry ($n=2$), utilities ($n=1$), and rail/transit ($n=1$). Six documents recommended a maximum between 60 and 84 h per week ($n=6$), representing all the OGE recommendations on this dimension ($n=2$), a quarter of the mining documents ($n=2$), and one document each from utilities ($n=1$) and rail/transit ($n=1$).

Some documents provided recommendations for maximum number of total work hours across longer time periods, ranging from 14 to 91 days (i.e., 2 weeks to 3 months) ($n=11$). Only two documents provided equivalent recommendations for total work hours for night shift blocks: 48 h every 10 days (rail/transit) and 24 h every 7 days (forestry).

3.2.3 Minimum Time off between Work Blocks

Some documents provided recommendations for the minimum amount of time off work between blocks (i.e., reset break) ($n=16$), which were mostly for 24 h ($n=7$; general industry=3, mining=2), 32–36 h ($n=4$; 1 each for forestry, mining, OGE, and rail/transit), and 48 h ($n=5$; rail/transit=3). For specific shift types, 46–48 h was recommended for night shifts ($n=9$; general industry=3, mining=3) and 48 h for rotating shifts ($n=3$).

3.3 Shift Schedules: Daily and Block Component Comparison

To compare and synthesize information across daily and block components, documents were identified which contained recommendations for both maximum shift duration and maximum work hours per block (i.e., total work hours in a 7-day period) (n = 19). Using these two data points, it was possible to estimate the number of consecutive shifts that could be worked at the recommended shift duration (daily) limit before the total weekly work hour (block) limit was reached. For instance, one mining document recommended a shift duration maximum of 12 h and also a maximum of 56 h of work per 7 days [48]. Following these recommendations, if an employee worked 12-hour shifts, they could only work 4 consecutive shifts (48 h total) before being required to take a reset break or work shorter shifts to stay under the block limit. While some documents still allowed for 5–7 consecutive shifts at their maximum shift duration limits (n = 5; OGE = 2), for most documents it would only be possible to work 3–4 shifts before the 7-day block hour limit was reached (n = 14; 6 = mining, 4 = general industry).

Conversely, it was also possible to compare the difference between the maximum shift duration recommendation and the ‘daily average’ work hours (i.e., calculated by dividing the block hour maximum recommendation by 7 days). Using the previous example, 7 consecutive shifts at an 8-hour daily average would reach the 56-hour weekly limit but still be 4 h per day less than the 12-hour shift duration maximum. Only 2 documents had an equivalent amount of work hours when comparing their maximum shift duration and daily average. In contrast, all 17 remaining documents had a daily average that was lower than its recommended shift duration maximum, with most suggesting an average that was 4 to 6 h shorter than the maximum shift duration ($n=13$; 6=mining, 4=general industry). This was largely due to most of these documents recommending both a 48–56 weekly work hour limit (i.e., 6–8 h per day on average) ($n=15$) and a shift duration maximum of 12 h ($n=14$).

To summarize, for most documents the two recommendations are inversely associated, such that working maximum shift durations would result in fewer consecutive shifts per week, and working the maximum weekly work hours would result in shorter average shift durations.

3.4 Minimum Sleep Hours

3.4.1 Work Schedule Guidance Documents

Beyond work schedule recommendations, several of the documents contained recommendations for minimum hours of sleep from a safety or work performance perspective ($n=21$), with recommendations ranging from at least 5 ($n=8$), 6 ($n=6$), or 7 h ($n=5$) of sleep per 24-hour period. Some documents also had recommendations for sleep in a 48-hour period ($n=7$), ranging from 10 ($n=1$), 12 ($n=5$), and 13 h ($n=1$) (approx. 5–7.5 h/day), and others had recommendations for sleep in a 7-day period ($n=4$), all of which recommended 50 h (approx. 7 h/day).

3.4.2 Supplemental Academic Documents

A total of 12 documents which contained specific sleep duration recommendations were identified from the academic and health agency literature search (Table 4) [65–76]. Most were published in peer-reviewed journals, and most were also authored by professional organizations or societies, including those based on sleep (American Academy of Sleep Medicine), health (American Thoracic Society), or occupational safety (Working Times Society). Three other

Table 4 Hours of sleep recommendation documents

Citation	Source	Type	Population*	Hours of Sleep
Watson et al., 2015	American Academy of Sleep Medicine and Sleep Research Society	Consensus / Panel	Public	≥7 h
Mukherjee et al., 2015	American Thoracic Society	Consensus / Panel	Public	7–9 h
Ross et al., 2020	Canadian Society for Exercise Physiology	Consensus / Panel	Public	7–9 h
ODPHP, n.d.	Healthy People 2030	National Health Goals	Public	≥7 h
Noda, 2015	Japanese Heath Service Bureau	Guidelines	Public	6–8 h
Czeisler et al., 2016	National Sleep Foundation	Consensus / Panel	Workers	>2 (all drivers); >5 (most healthy drivers)
Hirshkowitz et al., 2015	National Sleep Foundation	Consensus / Panel	Public	7–9 h
Dawson et al., 2021	Research Publication	Evidence Synthesis	Workers	≥4–5 h (in 24 h); ≥10–12 h (in 48 h)
Shriane et al., 2023	Research Publication	Consensus / Panel	Workers	7–9 h
Sprajcer et al., 2023	Research Publication	Evidence Synthesis	Workers	≥5 h
Alfawaz et al., 2021	Saudi Public Health Authority	Consensus / Panel	Public	7–9 h
Wong et al., 2019	Working Times Society	Consensus / Panel	Workers	≥7 h

*public=healthy adults in the general population, recommendations represent ideal sleep duration usually from a health-based perspective; workers=working population and/or motor vehicle drivers (including passenger and commercial)

documents came from independent research publications unaffiliated with a single entity. Approximately half (n = 7) of the academic documents contained recommendations focused on the health and wellbeing of the general public, the majority of which recommend at least 7 h of sleep in a 24-hour period for health-related purposes. The five other documents had recommendations focused on working populations or commercial and noncommercial drivers, primarily on the minimum number hours of sleep necessary from a safety or risk mitigation perspective. Two of these recommendations aligned with those for the general public of at least 7 h of sleep [74, 76], while the others recommended a minimum of approximately 5 h [66, 67, 75].

4 Discussion

The purpose of the grey literature review was to synthesize and compare guidance regarding recommendations for work schedules and sleep hours for industrial work common in mining. Work-schedule recommendations varied considerably (see Table 5 for a summary). The most common recommendations across documents were for shifts up to 12 h in duration with at least 10 h off between shifts, up to 7 consecutive shifts with a maximum of 56 working hours per week, and at least 24 h off between work sets. These same recommendations were also the most common among mining specific documents. With regards to sleep hours, the most common health-based recommendations were 7–9 h per 24-hour period, and at least 5 h for safety-based recommendations. In mining, the most common safety-based sleep recommendation was for at least 6 h of sleep in a 24-hour period. Despite these results, work schedule recommendations remained variable across and within industries.

A common pattern emerged across industries in recommendations addressing monotonous work and early or night shift arrangements. Specifically, less demands in the form of fewer daily or weekly work hours were recommended for all three, and more resources in the form of additional time off for recovery were recommended for night and early shifts. Beyond time needed for adequate sleep, workers who engage in leisure activities between shifts tend to have improved recovery, vigor, and engagement with their work the next day [77]. For these reasons, companies might choose to consider factors such as onsite sleeping arrangements, commute length, and the nonwork obligations of workers when implementing policies for work schedules. Similarly, there were often inverse associations between different recommendation maxima and minima, such that working at the maximum in one schedule aspect (e.g., maximum hours per week) would result in a schedule considerably below the maximum in another aspect (e.g., maximum hours per shift). Taken together, these observations support a degree of complexity, nuance, and consideration of multiple time- and task-based dimensions in shift schedule design.

While common recommendations are identified across the reviewed guidelines, providing a single prescriptive solution for designing work schedules is beyond the scope of this manuscript. Instead, our intent is to synthesize patterns within the existing guidelines and highlight how these patterns can support context-specific decision-making. The present analysis suggests that schedule parameters, such as

Table 5 Summary of work schedule results, most frequent recommendation by category

Category	Most Frequent Recommendation	N	Other recommendation(s)	Total N
Daily Components				
Shift Duration (Max.)	--	--	--	36
Any Shift Type	12 h	27	10 h (n=2) 14 h (n=5) 16 h (n=1)	35
Night Shifts	8–10 h	10	--	10
Early Shifts	8 h	4	--	4
Monotonous	8 h	5	--	5
With Commute	13 h	6	--	6
Time Off Between Shifts (Min.)	--	--	--	31
Any Shift Type	10–12 h	26	8 h (n=5)	31
Night Shifts	14 h	4	--	4
Time of Day (Restrict.)	2 AM to 4 AM	36*	12 AM to 6 AM (n=25)	36*
Starting Shifts	12 AM to 4 AM	13	12 AM to 6 AM (n=12)	13
Ending Shifts	1 AM to 6 AM	9	12 AM to 6 AM (n=8)	9
Any Work	2 AM to 4 AM	14	12 AM to 6 AM (n=9)	14
Work Breaks (Min.)	--	--	--	9
Block Components				
Consecutive Shifts (Max.)	--	--	--	26
Any Shift Type (any length)	6–7 shifts	10	8 shifts (n=2) 12 shifts (n=2) 14 shifts (n=2) 28 shifts (n=1)	17
8-Hour Shifts	6–7 shifts	5	--	5
12-Hour Shifts	4–5 shifts	5	--	5
Night Shifts (any length)	3–4 shifts	11	6 shifts (n=1) 21 shifts (n=1)	13
8-Hour Shifts	6 shifts	4	3 shifts (n=1)	5
12-Hour Shifts	3–4 shifts	6	--	6
Early Shifts	4–5 shifts	7	6 shifts (n=1)	8
Work Hours per Block (Max.)	--	--	--	25
Hours per 7-Day Period	48–56 h	16	60 h (n=2) 72 h (n=2) 84 h (n=2)	22
Time Off Between Blocks (Min.)	--	--	--	21
Any Shift Type	24–36 h	11	48 h (n=5)	16
Night Shifts	48 h	8	46 h (n=1)	9
Rotating Shifts	48 h	3	--	3
Per 7-Day Period	24 h	6	36 h (n=1) 48 h (n=1)	8
Sleep (Min.)				21
Total Documents				38
24-hour period	5–6 h	16	7 h (n=5)	21
48-hour period	10–12 h	6	13 h (n=1)	7
7-day period	50 h	4	--	4

*36 recommendations across 27 documents; 8 documents had a recommendation for 2 or more time-of-day categories (i.e., shift start, shift end, any work)

shift duration, time off between shifts, number of consecutive workdays, and weekly work hours, operate as an interdependent system in which changes in one element typically require compensatory adjustments in another to minimize fatigue risk. This perspective helps explain why similar schedules may pose different levels of risk depending on operational context, particularly when factors such as night work, early start times, monotony, or demanding tasks are present. Thus, the synthesis offered here can serve as a foundation for organizations seeking to incorporate fatigue considerations into schedule design by evaluating fatigue risks in their existing schedule structure, identifying contextual risk factors associated with work being done within their organization, and adjusting related schedule features accordingly. This approach acknowledges the uniqueness of each workplace while translating the aggregated insights of existing guidelines into actionable principles without prescribing any single schedule structure.

Along these lines, while the reviewed guidelines and recommendations were developed to help implement organizational policies that manage or mitigate risk at a broad level, it may be beneficial to incorporate other solutions for worker fatigue that account for specific risk contexts to complement these broad work schedule guidelines. Some clear benefits of implementing work schedule guidelines are increased opportunity for sleep, reduced continuous time on task, and increased opportunity for non-work activities that may compete with sleep if work hours are unrestrained [35, 78]. Conversely, inflexible one size fits all limits can be imprecise as there is a lack of consideration for specific risk contexts, such as the nature of work tasks being performed (e.g., operating machinery versus copying paper files), the work environment (e.g., hot/dim outside versus air-conditioned inside), and the circadian rhythms that create windows of low alertness during the day (2 PM to 4 PM) and at night (2 AM to 6 AM) [79]. Implementation of broad work schedule guidelines alone may also inaccurately convey that adherence equates to satisfactory risk mitigation, whereas comprehensive fatigue risk management may necessitate blending work schedule guidelines with nuanced, adaptable, and custom approaches [80].

Many of the documents referenced throughout the results and discussion illustrate how work schedule guidelines can be implemented in a nuanced manner, providing both broad risk mitigation and mitigation for specific risk contexts. For example, New South Wales Resources Regulator's mining document tangibly addresses the need for a multifaceted approach to fatigue risk management by recommending the implementation of *flexible* constraints, where the effects of certain risk factors are addressed by specifying stricter guidelines for workers engaging in high vigilance tasks (e.g., 8-hour shifts for monotonous/demanding work, 12-hour shifts otherwise) [48]. Similarly, the Department of Natural Resources and Mines guidance promotes flexibility via a lower limit for work hours during night shift (8 h) as well as recommending fewer consecutive night shifts as hours of work increase (e.g., 6 consecutive shifts for 8 h, 5 consecutive shifts for 10 h, 4 consecutive shifts for 12 h) [33]. These nuances serve to increase sleep opportunity for night-shift workers while also limiting the number of days that sleep debt can accrue when the opportunity for sleep decreases via increased work hours. Flexibility in this way may also provide exceptions that loosen guidelines when certain circumstances arise. The ANSI/API Recommended Practice 755 document contains a section that illustrates when and how exceptions to guidelines can be made [27]. For example, for an employee to exceed the work-hour guidelines, multiple managers must be notified and approve a documented risk assessment plan that describes where hazards are identified, the type of tasks to be performed, and individual characteristics (e.g., previous hours off, subjective fatigue levels). Work schedule policies with built-in contingencies that adjust guidelines based on changes in risk and reasonable needs to exceed guidelines provide a comprehensive approach to risk while also considering the need for an operation to remain flexible. To aid the reader, we provide our list of guidance documents (Supplementary Materials 1) as a resource repository for practitioners to review original sources, as they relate to their respective industry, for additional information and context that is useful for successfully implementing work schedule guidelines in a flexible and nuanced manner.

Fatigue risk management systems (FRMSs) are another method to complement work schedule guidelines. FRMSs utilize multiple strategies that can adapt as fatigue levels change [79]. At a minimum, an FRMS will adopt a risk-based approach to fatigue, incorporating multiple mechanisms to identify hazards and implement controls. These include predictive controls such as work schedule design and biomathematical modeling, reactive controls like fatigue incident investigation, and proactive controls such as fatigue assessment through prior sleep-wake data and self-reporting. Additionally, an FRMS will establish mechanisms for collecting data continuously to identify hazards and monitor the efficacy of controls [81]. The application of FRMSs does not nullify the benefits of work-schedule guidelines, rather they can serve to supplement each other. The FRMS approach can work in conjunction with work-schedule guidelines as the latter controls for fatigue by ensuring a shift structure provides adequate opportunity for sleep, while a comprehensive FRMS takes into consideration individual and contextual factors that may increase fatigue-related risk.

Like work schedules, recommendations for sleep are not one size fits all. As it pertains to maintaining good health, younger adults and adults (18–25 years and 26–64 years) may need more sleep (7–9 h) than older adults (≥ 65) (7–8 h) [68]. Excessive sleep can also be an indicator of illness or a medical problem [69]. While some recommendations indicate that 5 h of sleep is a sufficient minimum to maintain workplace safety, it is important to note that chronic sleep restriction has a cumulative negative effect on performance such that each night of additional restricted sleep reduces performance more over time [82]. This was mirrored in our results, in which the majority of documents that provided total sleep duration recommendations across a 48-hour period and a 7-day period suggest higher average daily sleep durations, i.e. in the 6–7 h range. While adequate sleep may be one of the most important factors for mitigating workplace fatigue risk, individual demographic factors and the effect of chronic sleep loss or potential undiagnosed or untreated sleep disorders are important considerations.

4.1 Limitations

There are several limitations of this review that should be considered. First, due to grey literature not typically being indexed in traditional databases, we were unable to conduct a systematic database search. Therefore, it is possible that some relevant literature may have unintentionally been omitted. Additionally, only English language documents were included, and guidance published in other languages may offer additional or differing recommendations that were not captured in this review. Our review also focused on industrial sectors, and the findings presented may not be applicable to other industries in different sectors. It is also important to note that this paper was primarily concerned with work schedule guidelines. Other potentially effective fatigue risk management strategies noted in the guidance documents (e.g., FRMSs) were not included in our review. Future work could expand upon our findings by comparing them against empirical studies specifically examining the effects that work schedule factors have on fatigue risk and sleepiness [9, 83], and by including biomathematical models [84]. Synthesizing this information could lead to future development of new or improved decision-making tools for practitioners to quickly assess either risk or 'guidance alignment' from a particular shift schedule system. Finally, it may also be of benefit to compare the guidelines and recommendations synthesized here with national and international legislative requirements currently in place across industries.

4.2 Conclusion

In conclusion, solutions to fatigue management are not simple or straightforward, but the information synthesized as part of this grey literature review provides a foundation to those seeking to explore recommendations that may inform workplace policies and practices to mitigate fatigue risk. This summary of existing recommendations on work schedules and sleep durations can be utilized to evaluate the alignment of existent workplace policies to industry recommendations. Moreover, the information presented herein can be paired with other work schedule evaluation tools such as fatigue risk matrices or biomathematical models in order to quantify different ranges of risk and implement controls accordingly. Many of the guidance documents included in our synthesis can serve as introductions to fatigue risk management across a breadth of contexts and the summarized information here can provide one additional reference tool as practitioners craft and apply fatigue management strategies with the specific circumstances and needs of their individual workplaces in mind.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42461-026-01502-6.

Declarations

Disclaimer The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC). Mention of any company or product does not constitute endorsement by NIOSH, CDC.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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