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The Prevalence of Risk Factors for Work-Related Fatigue in the U.S. Mining Industry: An Exploratory Analysis of Public Data Sets

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Abstract
Miner fatigue is widely recognized as a ubiquitous and significant risk, yet there is minimal published evidence detailing its burden within the industry. Given the complexities of direct fatigue measurement and the consequential scarcity of available primary data, this paper instead examines the prevalence of work-related fatigue risk factors among U.S. miners compared to the construction and oil and gas industries. We conducted exploratory analyses of fatigue risk factors across seven public data sets. Results indicate that workers in the U.S. mining industry—particularly in coal and metal—experience fatigue risk factors at a high rate, including weekly work hours, commute duration and time of day, shift work, work tasks, and sleep. The high burden of fatigue risk factors in mining highlights an opportunity to design and implement practical and effective controls that prevent the occurrence of fatigue and mitigate its risks. Further research is encouraged to validate these findings; incorporate fatigue-related questions in surveys of miners; and assess multiple risk factors concurrently across various mining commodities, types, and contexts.

Keywords Fatigue · Sleep · Work hours · Job demands · Shiftwork · Commute

1 Introduction

Defined as a biological drive for recuperative rest [1], fatigue is both a natural physiological state and a significant safety risk in workplace settings. It indiscriminately increases risk of harm to workers, equipment, and the work environment [2] while also negatively affecting productivity [3]. In mining, these risks may be particularly elevated due to common industry factors such as long working hours, shift work, physically demanding activities, monotonous or disengaging tasks, long commutes, extreme environmental conditions, loud noise exposure, and production pressures, all of which may synergistically amplify fatigue risk by reducing sleep opportunities and increasing time-on-task and cognitive/physical load [4, 5].

Characterizing the burden of fatigue in miners and the resultant impacts for both individual workers and industry are key to improving occupational safety and health in mines. Some limited research on fatigue risk factors has highlighted miners' exposures to long work hours and poor sleep quality. Compared to a national Australian average of 43.6 weekly hours, those in mining averaged 50 weekly hours, with 17% of miners working at least 60 h per week [6]. A large Canadian study found that miners averaged 6.2 h of sleep daily (5.5 h for night shift workers), with 79% indicating elevated fatigue and 84% exceeding poor sleep quality thresholds [7–9]. The potential impacts of fatigue are highlighted by Mine Safety and Health Administration (MSHA) injury data that demonstrated higher fatal risk for injuries occurring more than 8 h into a shift (odds ratio [OR] = 1.43) [10]. Other MSHA analyses indicated that 9.6% of all injuries occurred 9 or more hours into a shift [11] as compared to 3% occurring within the first shift hour [12]. Together, these studies provide critical evidence that suggest miners face elevated exposure to fatigue risk factors and potential safety outcomes. However, comparable

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U.S.-focused evidence that synthesizes patterns across multiple datasets and industries remains limited.

Furthermore, despite known risk factors, the burden of fatigue in U.S. mining—including prevalence, outcomes, and related costs—is largely unmeasured and poorly characterized [13]. One possible explanation is the lack of legal frameworks for work hours or fatigue risk management in the U.S. outside select industries (e.g., maritime, railroad, airline, trucking) [14]. Unlike these regulated sectors where varying mandates require minimum rest periods and limit continuous work periods, mining operations in the U.S. have comparatively little federal restrictions on shift length or scheduling practices, if any. This reduces incentives for systematic fatigue monitoring and management. Another is the limited documentation of fatigue-related factors on mandatory injury reporting forms, which typically only allow optional narrative notes or retrospective calculations of working hours at the time of injury [11, 15]. Currently, these forms do not systematically capture key fatigue indicators such as sleep duration, shift rotation patterns, or consecutive days worked, making it difficult to establish fatigue as a contributing factor in incident investigations. As a result, fatigue is rarely explicitly mentioned as a contributing factor in mining injury or fatality data, and evidence on the role of fatigue in incidents is typically limited to private company records or indirect references. Moreover, data from analyses of miners are often aggregated with that from oil and gas workers [16–19], potentially obscuring industry-specific patterns and preventing targeted intervention strategies for mining. Collectively, these limitations hinder benchmarking of fatigue risk factors in U.S. mining and constrain evidence-based fatigue risk management.

In the absence of reliable data on fatigue burden and resultant impacts, this exploratory descriptive analysis addresses this knowledge gap by synthesizing multiple public datasets to characterize work-related fatigue risk among U.S. mining workers. By bringing together diverse data sources with quantitative information on proxy indicators of fatigue risk (e.g., work hours, commute patterns, sleep duration), this study provides the first comprehensive, multi-dataset assessment of the existence of fatigue risk factors in U.S. mining workers and interprets these data within the context of other relevant industries (e.g., construction, oil and gas).

2 Method

Given the absence of systematic fatigue monitoring in U.S. mining and limited documentation of fatigue-related factors in injury reporting systems, we conducted an exploratory, descriptive synthesis of publicly available datasets, to better characterize fatigue risk factors (Table 1; Supplementary Material 1). Because fatigue is rarely measured directly in large-scale population surveys and no mining-specific fatigue surveillance system exists, we relied on established proxy measures [20], including the following: working hours, prevalence of extended or nonstandard shiftwork schedules (especially night shifts), sleep duration, sleep disorder symptoms, and commute time. The validity of these metrics as fatigue measurement proxies is well established through their reliable associations with fatigue symptomology and injury risk [21]. This approach allowed us to construct a more comprehensive profile of fatigue risk by synthesizing data from several complementary sources spanning multiple fatigue-related dimensions, providing breadth and triangulation not achievable through any single data source.

We identified publicly accessible U.S.-based data sets that met two essential criteria: (1) collection of variables broadly pertaining to risk factors for work-related fatigue

Table 1 Summary of data set descriptions

Dataset	Years	Industries*	Variables
Bureau of Labor Statistics (BLS): Current Employment Statistics (CES)	2014–2023	M, OSS, MIG	Work Hours
U.S. Census Bureau (USCB): American Community Survey (ACS)	2014–2022	M, OSS, MIG	Work Hours, Commute Duration, Commute Time of Departure & Arrival
U.S. Census Bureau (USCB): Current Population Survey (CPS)	2014–2023; May 2004 suppl.	M+OGE, OSS	Work Hours, Shift Type
National Institute for Occupational Safety and Health (NIOSH): 2012 National Survey of the Mining Population	2008	M, MIG	Work Hours, Shift Type
Mine Safety and Health Administration (MSHA): Mine Employment and Production Data	2014–2022	M, MIG	Work Hours
National Center for Health Statistics (CDC/NCHS): National Health Interview Survey	2004–2018**	M, OSS	Sleep Hours, Use of Sleep Medication
U.S. Department of Labor (DOL): Occupational Information Network (O*NET)	Feb 2024 (v. 28.2)	M, MIG, OSS	Work Abilities and Context

*M = Mining subsector *excluding* oil and gas extraction, M + OGE = Mining sector *including* oil and gas extraction, MIG = Mining industry groups (e.g., coal, metal, etc.), OSS = Other similar sectors (e.g., construction, manufacturing, transportation and warehousing, etc.)

**2004–2018 data used for hours of sleep variable, 2013–2018 data used for sleep medication variable (e.g., work schedule, work hours, sleep, etc.), and (2) inclusion of substantive numbers of mining workers that would afford the ability to group variables by mining subsector (excluding oil and gas) or, if necessary, mining sector (includes oil and gas).

Using a mixture of internal knowledge and expertise, professional contacts, and internet searches, a total of seven different data sources from six separate public (government) agencies or units were identified:

- Bureau of Labor Statistics (BLS): Current Employment Statistics (CES) - business-level reports from 670,000 worksites covering one-third of U.S. nonfarm employees.
- U.S. Census Bureau (USCB):
  - American Community Survey (ACS) − 3.5 million household addresses annually.
  - Current Population Survey (CPS) − 60,000 households monthly.
- National Institute for Occupational Safety and Health (NIOSH): 2012 National Survey of the Mining Population (based on 2008 data).
- Mine Safety and Health Administration (MSHA): Mine Employment and Production Data - quarterly industry reports required by federal law.
- National Center for Health Statistics (CDC/NCHS): National Health Interview Survey (NHIS) - comprehensive annual household survey monitoring health of civilian non-institutionalized population.
- U.S. Department of Labor (DOL): Occupational Information Network (O*NET) – subject matter expert ratings providing standardized occupation data for 800 + occupations.

These datasets were selected to provide extensiveness and alignment: large-scale employment surveys (e.g., BLS CES) offer nationally representative work hour and schedule data; health surveys (e.g., NHIS) provide sleep duration and quality measures unavailable in other work data; regulatory reporting (e.g., MSHA) captures industry-specific administrative records; and occupational databases (e.g., O*NET) enable characterization of fatigue-relevant job demands. In short, the selected sources collectively represent millions of workers annually and include both self-reported individual-level data, business-reported administrative data, and expert ratings data of standardized job attributes.

Across sources, work-hour estimates were taken from establishment-based (CES) and administrative reporting (MSHA) as well as self-reported survey measures (ACS/CPS). For CES, we summarized monthly seasonally adjusted estimates into annual means/standard deviations, and for MSHA we derived approximate annual weekly hours by dividing reported hours by employees. Commute time and timing were derived from pooled ACS microdata (e.g., distributions by departure/arrival time), sleep duration and sleep medication use were derived from pooled NHIS microdata, and fatigue-relevant work context/ability indicators were explored via O*NET and linked to industries using OEWS occupational employment distributions.

Some datasets produced weighted estimates. For population health surveys requiring nationally representative estimates (NHIS), we applied survey weights and variance adjustments following NCHS guidelines [22]. Employment survey estimates from CPS were obtained as published by BLS, which applies weights to match independent population controls [23]. CES data utilized seasonally adjusted estimates as published by BLS [24]. The NIOSH mining survey applied weights based on mine characteristics as described in the original study documentation [25] Annual data from 2014 onwards was extracted where available, though the most recent data varied by source (ACS and MSHA through 2022, CES and CPS 2023).

Where possible, we obtained data for workers in the North American Industry Classification System (NAICS) category 212 (Mining industry, excluding oil and gas extraction) to align with industry definitions. However, some datasets presented limitations. For example, the Current Population Survey only provides data at the mining sector level (NAICS 21), which includes oil and gas extraction and cannot be disaggregated. Within these constraints, we analyzed fatigue-related variables available across the datasets, including weekly work hours, commute duration and timing, shift work patterns, work task demands, and sleep duration and quality.

Table 1 contains a summary of relevant information associated with each data set. For full description of agency information, survey program, and data extraction and analysis for each of the seven data sources, refer to Supplementary Material 1.

3 Results

Results are organized within sections by variables across data sets. For simplicity, unless otherwise noted, the term "miners" is used henceforth to refer to workers in the mining *subsector* (i.e., *excluding* oil and gas workers), and "industry" or "industries" for comparisons across sectors (e.g., construction, manufacturing) and subsectors (e.g., miners, oil and gas extraction).

Table 2 Average weekly working hours by select industries across public data sources, means and standard deviations for annual estimates

	Dataset		
NAICS	CES	CPS	ACS
11: AFFH		42.2 (0.6)	43.8 (0.4)
1133: Logging	40.8 (2.2)		44.4 (0.4)
21: MQOGE	45.4 (1.0)	47.5 (1.3)	49.6 (0.9)
211: OGE	41.9 (0.9)		47.0 (0.7)
212: Mining (except OGE)	44.9 (0.8)		47.0 (0.4)
23: Construction	39.1 (0.3)	40.8 (0.4)	40.9 (0.2)
31–33: Manufacturing	40.5 (0.4)	41.9 (0.3)	42.3 (0.2)
Trade, Transportation, Utilities	34.3 (0.2)		37.6 (0.2)
42–45: Trade		37.2 (0.2)	36.1 (0.2)
42: Wholesale Trade	38.9 (0.2)		41.8 (0.3)
44–45: Retail Trade	30.8 (0.5)		34.8 (0.1)
48–49, 22: Transportation and Utilities		41.3 (0.4)	41.6 (0.6)
48–49: Transportation and Warehousing	38.6 (0.4)		41.4 (0.8)
22: Utilities	42.4 (0.3)		42.3 (0.2)
Total*	34.5 (0.2)	38.7 (0.2)	37.9 (0.2)

CES Current Employment Statistics, 2014–2023, *CPS* Current Population Survey, 2014–2023, *ACS* American Community Survey, 2014–2022, *NAICS* North American Industry Classification System, *AFFH* Agriculture, Forestry, Fishing, Hunting, *MQOGE* Mining, Quarrying, and Oil and Gas Extraction, *OGE* Oil and Gas Extraction

*Total estimates include all except military workers for CPS and ACS; CES total estimates (i.e., "All Private") exclude military and all workers in the public administration sector (NAICS 92)

3.1 Weekly Work Hours

Tables 2, 3 and 4 detail the results from the CES, CPS, ACS, MSHA, and NIOSH data regarding average weekly hours worked. Estimates varied, but average weekly working hours for miners ranged between 44.9 and 47.0, compared to estimates for agriculture, forestry, fishing, and hunting (AFFH) (42.2–43.8 h), construction (39.1–40.9 h), and utilities (42.3–42.4 h) (Table 2). Relative to all private industry workers (i.e., excluding military), miners worked on average between 9.1 and 10.4 more hours per week (based on ACS and CES estimates, respectively). In the CES data, miners worked 3.1 more hours per week on average than oil and gas. Although these averages were relatively equivalent in the ACS data, further exploring the data using frequency distributions (Table 3) revealed that 53.7% of miners worked at least 45 or more hours per week compared to 44.7% of oil and gas workers and 23.5% of all workers. Along these lines, 25.5% of coal miners worked at least 55 or more hours per week, compared to 19.6% of oil and gas workers and 7.9% of all workers.

Regarding mining industry groups, workers in coal mining tended to work slightly longer hours, with averages ranging between 1.0 and 1.9 more hours per week compared to all miners (CES, ACS, and MSHA) (Table 4). These differences were more pronounced for NIOSH survey results, with 5.7 and 7.7 more hours per week for coal workers depending on

Table 3 Percent distributions for average weekly working hours by industry in ACS 2014–2022 data

	Average Weekly Working Hours (% of survey participants)					
NAICS	1–34 h	35–44 h	45–54 h	55–64 h	65–74 h	75+h
11: AFFH	21.6	35.1	19.1	12.9	5.3	6.0
1133: Logging	16.2	38.3	21.9	15.8	4.9	2.9
21: MQOGE	5.4	41.5	24.9	13.1	4.4	10.8
211: OGE	5.2	50.1	25.1	9.1	2.5	8.0
212: Mining (except OGE)	4.2	42.1	32.0	15.3	3.7	2.7
2121: Coal Mining	3.4	37.7	33.5	18.5	4.6	2.4
2122–2123: Metal/Nonmetal	4.6	44.2	31.2	13.8	3.3	2.9
2122: Metal Ore	3.2	49.6	29.7	9.8	1.8	5.8
2123: NMMQ	5.2	41.8	31.9	15.6	3.9	1.6
23: Construction	15.3	56.3	18.6	7.1	1.7	1.0
31–33: Manufacturing	7.9	59.4	23.8	6.8	1.2	0.8
Trade, Transportation, Utilities	28.9	47.4	15.3	5.7	1.7	1.0
42–45: Trade	33.4	45.9	14.2	4.7	1.1	0.6
42: Wholesale Trade	12.4	52.9	24.1	8.0	1.6	0.9
44–45: Retail Trade	38.1	44.4	12.0	4.0	0.9	0.6
48–49, 22: Transportation and Utilities	17.2	51.1	18.2	8.2	3.5	1.8
48–49: Transportation and Warehousing	19.5	48.1	17.8	8.7	3.9	1.9
22: Utilities	5.3	66.7	20.1	5.6	1.2	1.0
Total*	25.2	51.5	15.5	5.4	1.4	1.0

NAICS North American Industry Classification System, *AFFH* Agriculture, Forestry, Fishing, Hunting, *MQOGE* Mining, Quarrying, and Oil and Gas Extraction, *OGE* Oil and Gas Extraction, *NMMQ* Nonmetallic Mineral Mining and Quarrying,

*Total estimates include all except military workers for ACS data

Table 4 Average weekly working hours by industry across public data sources, means and standard deviations for annual estimates

	Dataset					
	CES	ACS	MSHA	NIOSH*		
NAICS				P	PS	PPM
21: MQOGE	45.4 (1.0)	49.6 (0.9)				
211: OGE	41.9 (0.9)	47.0 (0.7)				
212: Mining (except OGE)	44.9 (0.8)	47.0 (0.4)	46.8 (1.0)	39.2	38.6	39.7
--All Underground Mines			45.6 (1.4)	42.9	41.8	42.7
--All Surface Mines			45.7 (0.9)	39.0	38.3	39.5
2121: Coal Mining	46.2 (1.4)	48.0 (0.9)	48.7 (1.6)	46.9	44.3	45.6
--Underground Coal			42.8 (1.5)	43.5	41.9	42.1
--Surface Coal			47.9 (1.7)	49.2	45.9	46.4
2122–2123: Metal/Nonmetal Mining		46.5 (0.6)	44.1 (0.6)			
--Underground MNM			38.7 (0.7)			
--Surface MNM			42.7 (0.6)			
2122: Metal Ore Mining	43.3 (1.1)	46.9 (1.2)		40.1	39.5	43.2
--Underground Metal				40.0	37.6	39.9
--Surface Metal				40.2	40.8	44.7
2123: NMMQ	45.0 (1.1)	46.4 (0.5)		36.3	37.8	40.3
--Underground Nonmetal				34.1	36.8	35.4
--Surface Nonmetal				36.5	37.9	40.9
21,231: Stone Mining	45.6 (1.2)			40.6	41.5	42.5
--Underground Stone				45.8	45.2	47.7
--Surface Stone				40.5	41.3	42.3
212,312: Limestone	46.2 (1.4)					
212311,3,9: Dimension/Granite	44.8 (1.4)					
21,232: Sand & Gravel				36.8	35.3	31.7
21,239: Other Nonmetal	43.6 (2.3)					
Total*	34.5 (0.2)	38.0 (0.2)				

CES Current Employment Statistics, 2014–2023, *ACS* American Community Survey, 2014–2022, *MSHA* Mine Safety and Health Administration, 2014–2022, *NIOSH* National Institute for Occupational Safety and Health, 2008,*P* Production Workers, *PS* Production Support Workers, *PPM* Preparation Plant and Mill Workers, *NAICS* North American Industry Classification System, *MQOGE* Mining, Quarrying, and Oil and Gas Extraction, *OGE* Oil and Gas Extraction, *MNM* Metal/Nonmetal (combined), *NMMQ* Nonmetallic Mineral Mining and Quarrying

*NIOSH estimates were only available for a single year (2008), therefore no standard deviations across multiple years were able to be calculated

the employee type. In general, surface operations overall had longer weekly working hours on average compared to their underground counterparts, particularly for coal (4.0–5.7 h), metal (0.2–4.8 h), and all nonmetal (1.1–5.5 h).

3.2 Commute

Table 5 details commuting information results from ACS data. Average one-way travel time to work was 31.3 min for miners, compared to 29.7 for oil and gas, 14.5 min for AFFH, 29.4 for logging, 27.0 for construction, and 25.5 for utilities. On average, miners reported traveling 10 min more to work compared to all workers combined. These differences were more pronounced for certain mining industry groups, particularly for coal (36.7 min) and metal (34.7 min).

For frequency distributions of commute duration, 51.9% of miners spent 30 min or longer traveling to work, which was similar to logging (51.0%), construction (50.4%), and OGE (48.5%). Additionally, 18.1% of miners spent 60 min or longer traveling to work, compared to 22.0% for logging, 16.1% for construction, and 14.9% for OGE. These percentages were more pronounced for some mining industry groups, with 24.5% of coal and 24.2% of metal mining workers traveling at least 60 min to work.

Finally, frequency distribution data was also available for the time of day that workers reported departing for work. We looked at the total percentage of workers that started their commute during the maximum period of sleepiness at physiological night (02:00 to 05:59), or Window of Circadian Low (WOCL) [26]. Results indicate that 41.7% of miners left for work in this window, compared to 42.6% in logging, 23.3% in OGE, 22.4% in construction, and 13.1% for all workers in private industry. Coal mining (41.1%) was roughly equivalent to miners as a whole, while metal mining was 52.0%. A summary of the ACS work hours and commute time results can be found in Fig. 1.

Table 5 Commute duration (minutes) and commute during WOCL by industry in ACS 2014–2022 data, means and percent distributions

NAICS	Commute Duration (% of survey participants)							WOCL (%)
	Mean	1–29 min	30–44 min	45–59 min	60–74 min	75–89 min	90+min	
11: AFFH	14.5	72.7	15.1	5.3	3.8	0.5	2.6	20.9
1133: Logging	29.4	48.8	19.8	9.2	11.2	1.5	9.3	42.6
21: MQOGE	31.7	50.1	20.6	10.7	8.4	1.5	8.7	30.7
211: OGE	29.7	51.4	22.3	11.3	7.5	1.1	6.3	23.3
212: Mining (except OGE)	31.3	48.1	21.4	12.4	9.3	2.1	6.7	41.7
2121: Coal Mining	36.7	36.5	23.0	16.1	13.0	3.0	8.5	41.1
2122–2123: Metal/Nonmetal	28.8	53.6	20.6	10.7	7.6	1.7	5.9	41.9
2122: Metal Ore	34.7	46.2	18.4	11.2	11.1	3.0	10.1	52.0
2123: NMMQ	26.2	56.7	21.5	10.5	6.1	1.2	4.0	37.5
23: Construction	27.0	49.7	23.8	10.5	9.0	1.4	5.7	22.4
31–33: Manufacturing	23.8	59.3	22.8	9.3	4.9	0.9	2.6	25.0
Trade, Transportation, Utilities	21.8	63.6	20.0	7.8	4.8	0.8	2.9	15.6
42–45: Trade	20.3	66.5	19.0	7.2	4.3	0.7	2.4	12.9
42: Wholesale Trade	24.4	56.6	22.8	9.8	6.3	1.1	3.4	15.9
44–45: Retail Trade	19.4	68.8	18.1	6.6	3.8	0.6	2.1	12.2
48–49, 22: Transportation & Utilities	25.6	56.5	22.5	9.5	6.1	1.1	4.3	22.2
48–49: Transportation & Warehousing	25.6	56.5	22.5	9.3	6.1	1.0	4.6	22.3
22: Utilities	25.5	56.7	22.4	10.2	6.2	1.2	3.4	21.5
Total*	21.4	62.1	20.6	8.3	5.2	0.9	2.9	13.2

NAICS North American Industry Classification System, *AFFH* Agriculture, Forestry, Fishing, Hunting, *MQOGE* Mining, Quarrying, and Oil and Gas Extraction, *OGE* Oil and Gas Extraction, *NMMQ* Nonmetallic Mineral Mining and Quarrying, *WOCL* Window of Circadian Low; percentage of workers that reported departing for work (i.e., leaving home to initiate commute) between 0200 and 0559

*Total estimates include all except military workers for ACS data

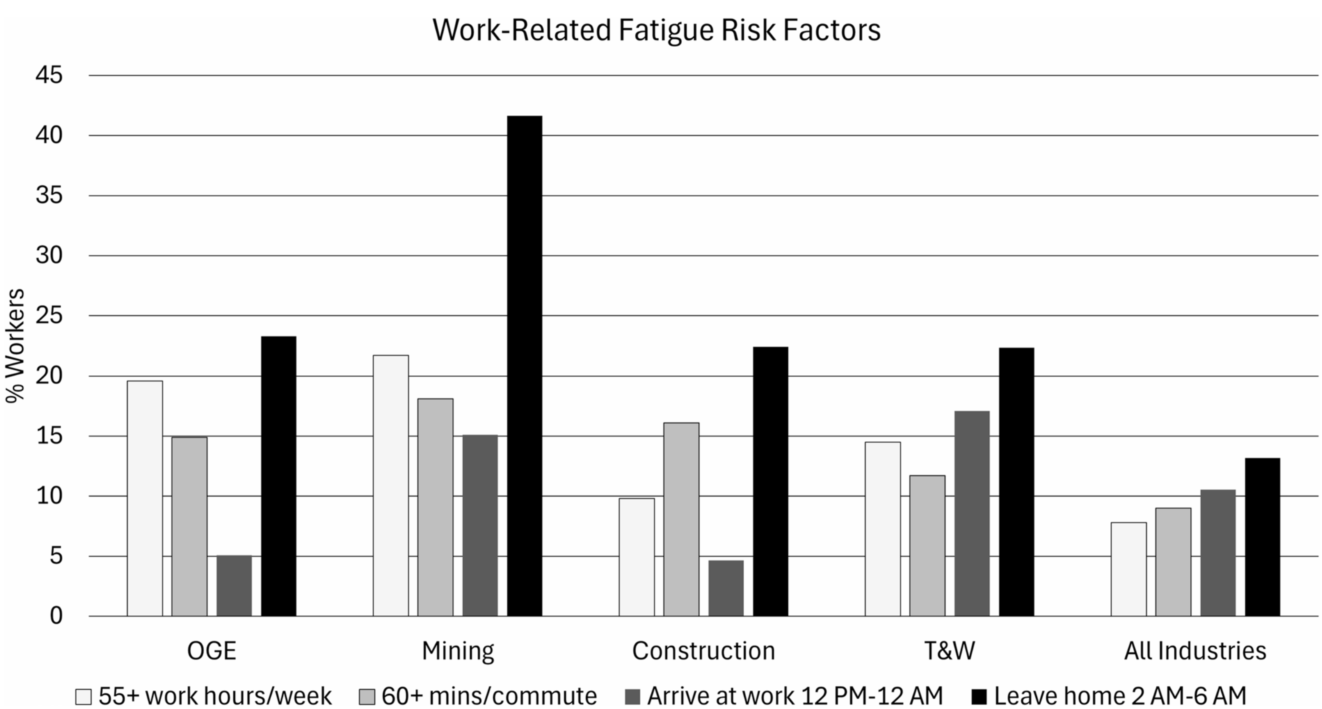

Fig. 1 Work-related fatigue risk factors by % of workers in select industries. American community survey, 2014–2022 OGE = Oil and gas extraction T&W = Transportation and warehousing

3.3 Shift Work

Table 6 summarizes shift work patterns using data from CPS (2004 supplement only), NIOSH, and ACS. According to CPS data, 31.9% of mining sector workers (i.e., including oil and gas) reported working a non-daytime schedule, compared to 9.9% in AFFH, 2.9% in construction, and 31.8% in transportation and warehousing. NIOSH data showed that 21.5% of all mining worksites used multiple daily shifts for production crews, with higher usage in underground mines (67.0%), coal mines (68.3%), and metal mines (64.7%).

Regarding shift timing, CPS data indicated that 3.6% of mining sector workers worked evening shifts (i.e., 2pm-midnight) and 4.9% worked night shifts (i.e., 9pm-8am). These percentages were larger than those for evening and night shifts in AFFH (1.4%; 2.3%) and construction (0.5%; 0.5%), but smaller than manufacturing (7.2%; 5.2%) and transportation and warehousing (5.6%; 5.6%). Work arrival time data from ACS indicated that a total of 9.4% of miners starting between noon and 6pm, and 5.7% between 6pm and midnight. These percentages were respectively higher compared to AFFH (4.7%, 1.7%), OGE (3.6%, 1.5%), and construction (3.2%, 1.4%), but were smaller compared to transportation and warehousing (11.3%, 5.8%). Regarding mining industry groups, coal mining had the largest proportion of workers arriving between noon and midnight (25.9%), followed by metal (11.6%) and nonmetal mining (9.4%).

Both CPS and NIOSH reported on rotating shifts. CPS data showed 15.1% of workers in the mining sector working under a rotating shift schedule compared to 4.4% of utilities and 3.9% of transportation and warehousing. NIOSH estimates varied by employee type and mine category, with rotating shifts reported for 7.7%−11.5% of miners, and considerably higher rates in underground mines (up to 42.2%) and metal mines (up to 72.4%).

3.4 Work Tasks

Tables 7 and 8 contain results from O*NET abilities and work context variables, respectively. For detailed O*NET item descriptions, see Supplementary Material 2.

Table 6 Percent shift work by industry across public data sources

Source	Shift Work (%)		Shift Type (%)		Arrival at Work (%)		Rotating Shift (%)		
	CPS	NIOSH	CPS	CPS	ACS	ACS	CPS	NIOSH	NIOSH
Description NAICS	Shift Work	≥2 Shifts/Day	Evening (2p-12a)	Night (9p-8a)	12p-6p	6p-12a	All	P	PPM
11: AFFH	9.9		1.4	2.3	4.7	1.7	1.1		
1133: Logging					3.2	1.4			
21: MQOGE	31.9		3.6	4.9	6.5	3.4	15.1		
211: OGE					3.6	1.5			
212: Mining (except OGE)		21.5			9.4	5.7		7.7	11.5
--All Underground Mines		67.0						42.2	22.9
--All Surface Mines		18.6						5.5	10.7
2121: Coal Mining		68.3			15.2	10.6		31.2	22.3
2122–2123: MNM					6.6	3.4			
2122: Metal Ore		64.7			7.4	4.3		59.3	72.4
2123: NMMQ		27.8			6.3	3.0		15.1	36.8
23: Construction	2.9		0.5	0.5	3.2	1.4	0.3		
31–33: Manufacturing	18.1		7.2	5.2	9.5	4.6	3.3		
Trade, transportation, utilities					12.3	4.0			
42–45: Trade	16.3		4.4	3.2	13.2	3.6	3.6		
42: Wholesale trade	8.0		2.7	1.8	5.6	2.2	0.7		
44–45: Retail trade	19.4		5.0	3.7	14.9	3.9	4.6		
48–49, 22: T & U	27.9		5.0	4.8	10.1	5.2	4.0		
48–49: T & W	31.8		5.6	5.6	11.3	5.8	3.9		
22: Utilities	9.5		1.9	0.8	4.2	2.0	4.4		
Total*	15.4		5.0	3.3	7.8	2.8	2.6		

CPS Current Population Survey, 2014–2023, *ACS* American Community Survey, 2014–2022, *NIOSH,* National Institute for Occupational Safety and Health, 2008,*P* Production Workers, *PPM* Preparation Plant and Mill Workers, *NAICS* North American Industry Classification System, *AFFH* Agriculture, Forestry, Fishing, Hunting, *MQOGE* Mining, Quarrying, and Oil and Gas Extraction, *OGE* Oil and Gas Extraction, *MNM* Metal/Nonmetal (combined), *NMMQ* Nonmetallic Mineral Mining and Quarrying, *T & U* Transportation and Utilities, *T & W* Transportation and Warehousing

*Total estimates include all except military workers for CPS and ACS

Table 7 Percent of workers by industry working in occupations at or above midpoint ratings (≥50) on select O*NET Ability variables

NAICS	Problem Sensitivity (%)	Perceptual Speed (%)	Visualization (%)	Selective Attention (%)	Time Sharing (%)	Response Orientation (%)	Rate Control (%)	Reaction Time (%)	Static Strength (%)	Auditory Attention (%)
11: AFFH	94.2	19.1	20.6	27.4	4.0	15.9	62.3	63.6	72.0	8.4
1133: Logging	91.7	59.7	78.1	76.4	18.7	69.9	71.0	71.7	32.4	29.5
21: MQOGE	91.3	57.7	66.7	78.4	32.1	29.1	43.7	50.2	50.8	46.9
211: OGE	89.4	55.0	49.8	66.1	16.5	15.4	19.1	34.2	29.8	24.4
212: Mining (except OGE)	92.0	66.6	73.8	83.4	44.9	47.7	51.5	53.8	58.2	53.0
2121: Coal Mining	90.4	72.6	79.0	85.0	49.0	44.7	51.7	52.7	55.1	55.1
2122: Metal Ore	85.7	70.3	71.9	81.8	37.2	42.8	44.8	48.1	50.5	48.7
2123: NMMQ	92.7	61.0	70.5	81.4	45.6	50.3	53.3	55.6	61.4	53.0
22: Utilities	89.6	61.0	52.1	73.0	9.4	14.0	14.3	17.5	21.8	15.9
23: Construction	90.0	48.6	62.1	77.5	17.8	8.7	22.1	21.7	52.5	10.0
31–33: Manufacturing	80.1	46.6	47.8	61.6	2.4	7.8	19.9	24.4	26.4	16.2
42: Wholesale Trade	84.7	23.0	21.4	41.3	5.6	11.8	9.3	14.1	29.9	10.9
44–45: Retail Trade	81.1	12.7	8.0	55.2	6.7	4.1	0.9	2.3	20.9	3.8
48–49: T & W	84.0	29.5	32.3	54.3	21.3	31.8	25.9	35.6	55.8	31.3
Total	77.7	24.5	22.5	54.2	13.8	5.4	5.8	8.3	22.2	7.3

O*NET=Occupational Information Network

Abilities=Enduring attributes of the individual that influence performance

Total estimates include percent of all occupations available in merged OEWS/O*NET data

See Supplementary Material 2 for detailed O*NET results

The Occupational Information Network (O*NET) is a free, publicly accessible online database containing hundreds of job titles, descriptions, and requirements that includes a variety of variables related to characteristics of both workers (e.g., abilities, knowledge, skills) and work itself (e.g., work activities, work context, tasks). For each of the 923 occupations in O*NET, data (ratings) are provided by surveys administered to job incumbents, job experts, and job analysts, which are converted to standardized scores ranging from 0 to 100 to aid in comparisons between different jobs and variables, where 50 represents the "average" or midpoint. For our analyses, we focused on identifying occupations at or above the midpoint (50 to 100) on fatigue-relevant characteristics, corresponding to *important* or *frequent* characteristics of the job.

The percentage of miners whose occupations rated at or above the midpoint (i.e., 50 to 100) on key O*NET Ability variables (i.e., were important to the occupation) was generally higher than in other industries (Table 7). For example, time sharing (i.e., the ability to switch between tasks) was important for 44.9% of miners, compared to 21.3% in T&W, 17.8% in construction, and 18.7% in logging. Rate control (timing movements to match changes in speed/direction) (51.5%) and reaction time (53.8%) were also more prominent among miners. The most striking contrast appeared in auditory attention, rated important for 53.0% of miners compared to 3.8–31.3% in other industries. Coal mining showed slightly higher importance on perceptual speed, visualization, and time sharing, while only perceptual speed was slightly more important for metal ore mining. For nonmetal mining, static strength was most notable (64.4%), exceeding construction (52.5%) and T&W (55.8%) but not AFFH (72.0%).

Select fatigue-relevant O*NET Work Context variables were also more frequent for miners (Table 8). Over half (51.9%) frequently worked in non-environmentally controlled indoor settings. While 57.1% frequently worked outdoors exposed to weather, less than AFFH (77.0%) and construction (71.7%), miners experienced some of the most frequent rates of exposure to excessive noise (79.5%), extreme temperatures (63.6%), poor light (36.5%), and whole-body vibration (39.2%). Metal ore mining had the highest frequency of working in hazardous conditions (43.5%), while coal mining had the highest frequency of working with hazardous equipment (76.4%). Except for logging (78.3%), miners as a whole (72.7%) and coal mining (73.0%) were the most likely to have a serious perceived consequence of error (i.e., *how serious would the result usually be if the worker made a mistake that was not readily correctable?*). Finally, machine-paced work was more common for miners (51.8%), particularly coal (52.0%) and nonmetal (53.7%).

3.5 Sleep

Table 9 details sleep results from NHIS. Approximately 36.6% of miners reported sleeping six or less usual hours of

Table 8 Percent of workers by industry working in occupations at or above midpoint ratings (≥50) on select O*NET Work Context variables

NAICS	Indoors (%)	Outdoors (%)	Noise (%)	Temp (%)	Light (%)	Vibration (%)	Hazardous Conditions (%)	Hazardous Equipment (%)	Consequence of Error (%)	Pace Equip Speed (%)
11: AFFH	24.2	77.0	34.2	74.9	8.5	5.6	4.9	22.4	27.4	22.1
1133: Logging	15.7	79.6	80.7	40.1	21.5	51.6	4.1	61.0	78.3	45.0
21: MQOGE	50.8	60.0	72.6	63.8	47.1	19.2	39.9	61.7	64.6	37.3
211: OGE	42.2	48.3	56.6	45.3	37.6	3.5	38.2	47.0	53.4	21.7
212: Mining (except OGE)	51.9	57.1	79.5	63.6	36.5	39.2	30.0	69.1	72.7	51.8
2121: Coal Mining	60.4	58.4	81.7	65.9	44.3	44.3	37.9	76.4	73.0	52.0
2122: Metal Ore	62.4	43.7	74.6	47.4	42.7	38.4	43.5	67.3	66.8	45.2
2123: NMMQ	42.5	60.8	78.8	68.1	29.7	37.0	19.8	65.1	73.1	53.7
22: Utilities	48.9	47.1	59.1	49.0	32.5	11.6	38.8	48.7	57.2	15.0
23: Construction	50.1	71.7	76.7	72.9	51.9	8.8	23.9	68.2	68.7	21.5
31–33: Manufacturing	38.6	12.9	55.4	35.7	7.4	0.3	21.1	43.9	44.6	43.3
42: Wholesale Trade	22.3	23.8	28.3	27.6	10.6	0.9	7.7	13.1	24.1	11.5
44–45: Retail Trade	11.5	8.7	16.3	13.5	2.6	0.0	5.2	7.7	13.8	5.0
48–49: T & W	31.7	57.9	49.0	59.2	26.5	3.9	8.6	17.4	45.8	14.1
Total*	15.4	18.2	34.7	21.6	8.7	1.1	8.0	14.7	31.7	9.9

O*NET=Occupational Information Network

Work Context=Physical and social factors that influence the nature of work

Indoors=Indoors, Not Environmentally Controlled (separate from "Indoors, Environmentally Controlled")

Outdoors=Outdoors, Exposed to Weather

Noise=Sounds, Noise Levels Are Distracting or Uncomfortable

Temp=Very Hot or Cold Temperatures

Light=Extremely Bright or Inadequate Lighting

Vibration=Exposed to Whole Body Vibration

Pace Equip Speed=Pace Determined by Speed of Equipment

Total estimates include percent of all occupations available in merged OEWS/O*NET data

See Supplementary Material 2 for detailed O*NET results

sleep per day, compared to 24.7% in AFFH, 32.3% in OGE, 30.5% in construction, and 36.9% in Transportation and Warehousing (T&W). Likewise, 58.3% of miners as well as T&W workers reported sleeping seven to eight hours, compared to 68.9% in AFFH, 63.4% in OGE, and 64.8% in construction. No similarly discernible industry-related pattern was observed for percent of workers reporting sleeping nine or more hours. Although several other sleep variables were considered (e.g., trouble falling/staying asleep), we report on percent of workers indicating any usage of sleep medication in the past week. Results indicate an elevated usage of sleep medication by miners (14.0%), compared to AFFH (7.7%), OGE (9.9%), construction (7.5%), and T&W (9.6%).

4 Discussion

This exploratory analysis summarizes publicly available evidence on patterns of proxy indicators of risk factors for work-related fatigue among workers in the U.S. mining industry by synthesizing multiple data sources. It also contextualizes findings through direct comparison with other similar industries. Our results indicate that miners experience a higher rate of several established fatigue risk factors, including extended work hours, longer and earlier commutes, prevalent shift work schedules, greater exposure to physically and cognitively demanding work tasks and environments, and shorter sleep durations.

Data from CES, CPS, ACS, MSHA, and NIOSH indicated that U.S. miners generally work more average weekly hours compared to other similar industries. Specifically, miners reported substantially greater hours compared to all private industry workers, moderately greater than logging and construction, and slightly greater than oil and gas extraction. Within mining, coal and surface workers (except stone) had the highest average weekly working hours, exceeding the overall average for miners. Long working hours have been consistently associated with increased fatigue and safety risks [27, 28], particularly when shifts exceed 12 h [21]. Joint guidelines from the American Academy of Sleep Medicine (AASM) and Sleep Research Society (SRS) emphasize

Table 9 Usual hours of sleep per day and any usage of sleep medication in past week by percent of industry workers, NHIS 2004–2018 and 2013–2018 data

NAICS	Sleep Duration %†			% Sleep Med Used‡
	≤6 h	7–8 h	≥9 h	
11: AFFH	24.7%	68.9%	6.4%	7.7%
211: OGE	32.3%	63.4%	4.4%	9.9%
212: Mining (except OGE)	36.6%	58.3%	5.0%	14.0%
22: Utilities	34.3%	63.4%	2.4%	8.8%
23: Construction	30.5%	64.8%	4.7%	7.5%
31–33: Manufacturing	35.8%	60.1%	4.1%	9.5%
42: Wholesale Trade	30.3%	65.1%	4.6%	9.7%
44–45: Retail Trade	31.1%	62.1%	6.8%	10.2%
48–49: T&W	36.9%	58.3%	4.9%	9.6%
Total*	31.7%	63.2%	5.2%	10.9%

NHIS National Health Interview Survey, *NAICS* North American Industry Classification System, *AFFH* Agriculture, Forestry, Fishing, Hunting, *OGE* Oil and Gas Extraction, *T & W* Transportation and Warehousing

*Total estimates include all except military workers

†2004–2018 NHIS data

‡2013–2018 NHIS data

that extended shifts intensify fatigue by prolonging wakefulness and reducing recovery time [29]. Notably, approximately 22% of miners in our analyses, including 26% of coal, exceeded weekly working hours limits (55+hours) recommended by several mining governing bodies [30, 31], potentially placing them at heightened fatigue-related risk of injury or long-term illness. The observed pattern of extended hours aligns with common fatigue controls centered on roster design, situational limits on or conditional approval mechanisms for consecutive long shifts, and protection of adequate recovery time between shifts.

Commuting time further compounds fatigue risk among miners. ACS data demonstrated that miners have longer average commutes compared to workers in construction and oil and gas extraction, amounting to nearly 99 additional minutes commuting per week under a standard five-day schedule. Weekly commute times were even longer for workers in metal ore mining (132.1 additional minutes) and coal mining (152.6 additional minutes). For approximately 24% of metal and coal, weekly commuting exceeded 10 h or more. Nearly 42% of miners (52% of metal) commuted during times of peak physiological sleepiness (WOCL). Indeed, driving during WOCL has been associated with higher-risk for sleep-related vehicle crashes [32], especially those involving fatigue, speeding, and younger male drivers [33]. Extended commutes in general have been associated with sleep disturbances, physical inactivity, and elevated fatigue-related risks, including increased likelihood of drowsy driving incidents, particularly among shift workers [34–37].

Compared to other industries, miners were more frequently engaged in shift work schedules, particularly those involving night, rotating, or nonstandard shifts. Shift work schedules are widely documented to negatively impact health, safety, and sleep quality through disruptions in circadian rhythms, sleep duration, and social misalignment [21, 38–40]. Rotating shifts especially can induce circadian disturbances and heightened fatigue [41, 42].

Many mining occupations are characterized by high exposure to fatigue risk factors. These same occupations also ranked consistently higher in fatigue-sensitive cognitive demands, including response orientation, rate control, and time sharing, compared to other similar industries. Though previous reviews have suggested that work environment and task-related factors can increase work-related fatigue risk for miners [4, 5], the present analyses of O*NET data are among the first to use standardized data to compare risk factor prevalence across occupational categories and industries. Occupations in mining are among the most frequently exposed to distracting sounds, extreme temperatures, inadequate lighting, and whole-body vibration. These factors exacerbate fatigue risk by increasing cognitive work demands, reducing vigilance, and negatively affecting physiological recovery [43–45]. In particular, the effects of work-related exposure to light [46], noise [47], temperature [48], and whole-body vibration [49] on fatigue risk have been consistently documented.

Consistent with prior studies, our findings showed miners had shorter sleep duration, were less likely to achieve recommended sleep duration (7–8 h), and reported higher use of sleep medication. Use of sleeping medication is a core component on the Pittsburgh Sleep Quality Index PSQI [50]—often considered the gold standard for self-reported sleep quality—and can be a strong albeit less consistent predictor of global PSQI scores, poorer sleep quality, fatigue, and physical and mental health outcomes [51, 52]. While the sleep health of miners has been investigated on a smaller scale with individual studies [4], more comprehensive research would benefit the development of practical interventions [7–9, 17–19, 53]. For example, clarifying sleep-related fatigue risks in workers with temporary living arrangements, such as drive-in-drive-out (DIDO), would promote understanding and mitigation of fatigue risk [54, 55].

Our results show a consistent pattern of elevated fatigue risk in mining relative to other similar industries. The multiplicative nature of risk factors—including long hours, extensive commuting, and prevalent shift work—combined with the fatigue-sensitive and high-consequence nature of their work, suggest that miners are at significant risk of experiencing a level of fatigue that has implications for safety and health. The findings also suggest opportunities for targeted interventions, highlighting patterns which point toward several potential areas for industry and regulatory attention: fatigue risk management systems that incorporate fatigue monitoring and science-based scheduling practices, sleep health programs including education about sleep hygiene for shift workers, access to sleep disorder screening, and workplace environmental controls targeting the specific exposures miners face (noise, vibration, temperature extremes, lighting) that compound fatigue risk beyond scheduling factors alone.

Future research building on these exploratory findings could strengthen evidence for specific interventions by determining industry-specific burden through direct assessment rather than proxy measures. Other efforts might include determining the industry-specific burden of fatigue; assessing fatigue risk factors across mine types, commodities, and geography; and working with industry partners to pilot and evaluate practical interventions and control measures. This work would be strengthened by examining other health determinants that may influence fatigue and sleep health, such as age, education, and rurality. Particular attention to workers with temporary living arrangements such as in drive-in-drive-out (DIDO) operations would clarify population-specific fatigue risks and inform tailored mitigation approaches.

Because these analyses are exploratory and descriptive, findings should be interpreted with caution. Direct measures of fatigue were largely unavailable, necessitating reliance on proxy indicators such as hours worked or sleep duration, which may not fully capture the multifaceted nature of fatigue [56, 57]. Also, certain estimates of central tendency may not be stable because miners represent a small fraction (<0.2%) of workers in national public data sets [58]. In addition, restricted access to raw data precluded statistical significance testing, and shared industry coding complicated distinctions between mining and oil gas workers. Broad classification of mining industry groups can mask operational diversity within each commodity type (e.g., coal, gold, molybdenum), restricting detailed interpretations of specific industry characteristics. Despite these limitations, the convergence of evidence across multiple datasets suggests that fatigue risk is a salient and persistent concern with the U.S. mining industry.

5 Conclusion

Compared with workers in similar industries, U.S. miners are exposed to fatigue risk factors at a higher rate. These include demanding work schedules such as long working hours and shift work, challenging work environments characterized by heat, noise, and high cognitive demands), and non-work influences such as extended commuting times, and compromised sleep health. The elevated burden of fatigue risk factors in mining highlights an opportunity to design and implement practical and effective strategies to better prevent the occurrence of fatigue and mitigate its risks.

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Declarations

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