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Women in Mining—Acute Injuries Among Women in the United States Mining Workforce 1979 –2023

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Abstract
Mining has long been recognized as a hazardous occupation, and historically, it has been dominated by men. However, there is limited understanding of the specific injuries experienced by women mine workers. Previous studies have either excluded women from the analysis or aggregated the data without considering sex. Mine Accident, Injury, and Illness reports published by MSHA were analyzed from 1979–2023. Fatal and non-fatal injuries among women were analyzed by age at the time of injury, mining commodity, work activity performed at the time of the injury, job description, and part of body affected. Of the 17,848 injuries among women miners, 37.5% in coal miners and 62.5% occurred in metal/nonmetal (MNM). The majority of injuries occurred among miners aged 19–34 years (coal: 38.4%; MNM: 42.0%), with coal miners having the most injuries with 1–5 years of total tenure (32.8%) and MNM miners with less than one year of total tenure (39.8%). For both sectors, the highest number of injuries occurred among general laborers (coal: 43.8%; MNM: 27.2%) and during material handling (coal: 26.5%; MNM: 30.2%). Back (coal: 21.9%; MNM: 18.9%) and hands (coal: 14.5%; MNM: 15.3%) were the most commonly affected body parts. This study points to the importance of safety measures and research to address acute injuries women miners face, particularly younger and less experienced workers.

Keywords Acute injuries · Women miners · Mining sectors · Safety culture

1 Introduction

Mining has long been recognized as one of the most hazardous occupations in the United States [1]. It is also an historically male-dominated industry. While over 314,400 miners were employed in the United States as of 2022 [2], it is estimated that only 10–17% of these miners were women [3].

Historical records specifically documenting injuries and fatalities in women miners can be challenging to find, as early accounts often focused more on the broader experiences of miners rather than sex-specific details. It is likely that even the number of fatalities related to mining and mine work among women is historically undercounted as women were often not included on official mine company rosters, despite working in and around the mines. In addition, some of the activities (for example hauling and bearing coal) that women performed at mines in the early history of mining was not considered "work" by mine owners, government overseers and even family members [4]. During World War II, women temporarily took on jobs that were vacated by men, including within the mining industry [5], and by the

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mid-twentieth century, the landscape for women's employment opened up considerably as a consequence of the 1964 Civil Rights Act [6] and the inclusion of sex as a basis for nondiscrimination in hiring in the 1967 amendment of Title VII [7].

By the 1980s, there was broad acknowledgement that women miners, like their male counterparts, encountered occupational hazards and experienced injuries in the coal mining industry. A 1984 analysis of injury reports among women coal miners based on data collected by the Mine Safety and Health Administration (MSHA) under 30 Code of Federal Regulations (CFR) Part 50 [8] for the period 1978–1980 found increased injuries recorded in underground locations compared to surface locations, with sprain injuries being the major cause of lost time [9]. There is limited understanding of occupational injuries among women mine workers because other studies using MSHA data often either exclude women from the analysis due to limited data [10] or are aggregated with no mention of sex [11–15]. The few injury reports that have disaggregated their findings by sex focused on injuries occurring during the first hour of work and working long hours in mining [10, 16]. However, there has not been an overall descriptive analysis of acute injuries experienced by women miners in the last 40 years.

To address this knowledge gap, we used data from the MSHA Part 50 program submitted to the agency from 1979 through 2023 [8]. This analysis focuses on fatal and non-fatal injuries among coal and metal/non-metal (MNM) women miners by activity, job, and body part affected and describes the impact of these injuries on women miners. Comparisons to men in mining is avoided to concentrate exclusively on the experiences of women mine workers.

2 Methods

Mine operators are required to notify MSHA of any acute occupational reportable injuries "requiring medical treatment or resulted in death or loss of consciousness or inability to perform all job duties on any workday after the injury or temporary assignment to other duties or transfer to another job" that occurred on mine property within 24 h. This reporting is done using the MSHA 30 CFR Part 50, Mine Accident, Injury, and Illness Report, Form 7000–1 under the Federal Mine Safety and Health Act of 1977 [8]. The accident, injury, and illness reports for all miners were extracted from the MSHA website for the period 1983–2023 [17]. Reports from 1979–1982 were compiled from deidentified data previously shared by MSHA with the National Institute for Occupational Safety and Health (NIOSH). This activity was reviewed by CDC, deemed research not involving human subjects, and was conducted consistent with applicable federal law and CDC policy.

Sex is recorded as male or female on this form. Only reports where female sex was recorded were considered for this analysis. Both operator contractors and employees were included. Injuries due to natural causes, non-employees on mine property, or reports with no injury recorded were excluded. Illnesses, both acute and chronic (such as pneumoconiosis, COPD, diabetes, and silicosis), were excluded from this paper as it focused on acute injuries and fatalities. Reports with identical identification numbers were reviewed and included if the reports were found to be distinct (i.e., by year, location and commodity of mine). For duplicates, the duplicate with more complete information was retained. After applying these exclusion criteria, the data consisted of 17,848 incidents reported from January 2, 1979 to June 27, 2023.

Incidents were assigned into coal and MNM sectors based on the commodity of mine where the incident occurred. Coal sector included both bituminous and anthracite coal commodities. MNM sector included metal, stone, non-metal, sand and gravel commodities [11, 18]. Demographic characteristics of women miners who sustained an injury included age at the time of incident, total mining tenure, and tenure at the mine where the incident was reported. Incidents were examined by region, location (surface, underground), commodity of the mine, and time of the incident.

Specific activities performed by the miners at the time of the incident were examined using modified groupings presented by Alessa et al. [19]. Three hundred and thirty occupations listed by MSHA were condensed into 30 occupation groupings using the NIOSH occupation crosswalk for mining [20]. Injured body parts had been recorded using 46 MSHA codes. These codes were then condensed into 26 2-digit Occupational Injury and Illness Classification System (OIICS v2.01) groupings under the category 'part of body.' Injuries due to personal protection equipment (PPE) was determined using the category 'source.' Frequencies of injuries by sector for other categories such as nature of injury and outcome of the incident, incident type and classification by fatal and non-fatal injuries are included in Supplementary Information.

3 Results

MSHA received reports of 18,803 injuries among women miners from 1979–2023. After applying exclusion criteria, a total of 17,848 acute injuries were analyzed: 6,687 (37.5%) injuries among women coal miners and 11,161 (62.5%) injuries among women MNM miners (Table 1). For both sectors, majority of injuries occurred among miners aged 19–34 years (coal: 2,570 injuries, 38.4%; MNM: 4,693 injuries, 42.0%). By total tenure, majority of injuries occurred among coal miners with 1–5 years of total tenure (2,192

Table 1 Characteristics of work-related incidents among U.S. women miners at the time of the injury, 1979–2023

Characteristics	Coal		Metal/Nonmetal		Total	
	# of injuries	Percent[1]	# of injuries	Percent[1]	# of injuries	Percent[1]
Total[2]	*6,687*	*37.5*	*11,161*	*62.5*	*17,848*	
Miner age at the time of injury						
< 18 years	13	0.2	98	0.9	111	0.6
19–34 years	2,570	38.4	4,693	42.0	7,263	40.7
35–44 years	2,193	32.8	3,231	28.9	5,424	30.4
45–54 years	1,386	20.7	2,024	18.1	3,410	19.1
55–64 years	366	5.5	838	7.5	1,204	6.7
More than 65 years	28	0.4	59	0.5	87	0.5
Missing	131	2.0	218	2.0	349	2.0
Mine Region[3]						
Western	1,359	20.3	6,417	57.5	7,776	43.6
Interior	1,433	21.4	2,879	25.8	4,312	24.2
Eastern	1,690	25.3	1,415	12.7	3,105	17.4
Central Appalachia	2,205	33.0	236	2.1	2,441	13.7
Northeastern	0	0.0	166	1.5	166	0.9
US islands	0	0.0	48	0.4	48	0.3
Commodity[4]						
Bituminous Coal	6,649	99.4	-	-	6,649	37.3
Anthracite Coal	38	0.6	-	-	38	0.2
Metal	-	-	5,463	48.9	5,463	30.6
Stone	-	-	2,835	25.4	2,835	15.9
Nonmetal	-	-	2,190	19.6	2,190	12.3
Sand and Gravel	-	-	673	6.0	673	3.8
Mine location						
Surface	2,011	30.1	10,183	91.2	12,194	68.3
Underground	4,676	69.9	978	8.8	5,654	31.7
Accident time						
Morning hours (0700–1500)	2,437	36.4	6,113	54.8	8,550	47.9
Afternoon hours (1500–2300)	2,378	35.6	2,800	25.1	5,178	29.0
Night hours (2300–0700)	1,690	25.3	1,722	15.4	3,412	19.1
Missing	182	2.7	526	4.7	708	4.0
Total tenure						
Less than 1 year	1,387	20.7	4,442	39.8	5,829	32.7
1–5 years	2,192	32.8	3,389	30.4	5,581	31.3
5.1–10 years	1,378	20.6	1,581	14.2	2,959	16.6
10.1–15 years	978	14.6	861	7.7	1,839	10.3
More than 15 years	751	11.2	888	8.0	1,639	9.2
Tenure at mine where incident occurred[5]						
Less than 1 year	1,679	25.1	4,337	38.9	6,016	33.7
1–5 years	2,403	35.9	3,665	32.8	6,068	34.0
5.1–10 years	1,319	19.7	1,543	13.8	2,862	16.0
10.1–15 years	792	11.8	802	7.2	1,594	8.9
More than 15 years	493	7.4	814	7.3	1,307	7.3

[1]Total percentage may not sum up to 100% due to rounding

[2]There were no unique identifiers for individual miners, so it is possible that multiple injuries occurred throughout a given miner's career but were represented as distinct reports in this dataset

[3]Western region includes Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, Wyoming. Interior region includes Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Oklahoma,

Table 1 (continued)

Texas, Wisconsin. Eastern region includes Alabama, Florida, Georgia, Maryland, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee. Central Appalachian region includes Kentucky, Virginia, West Virginia. Northeastern region includes Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, and Vermont. US islands include Hawaii, Puerto Rico, and Virgin Islands

[4]Coal commodity sector includes bituminous and anthracite coal mines. Metal/Nonmetal (MNM) commodity sector includes metal, stone, non-metal, sand and gravel mines

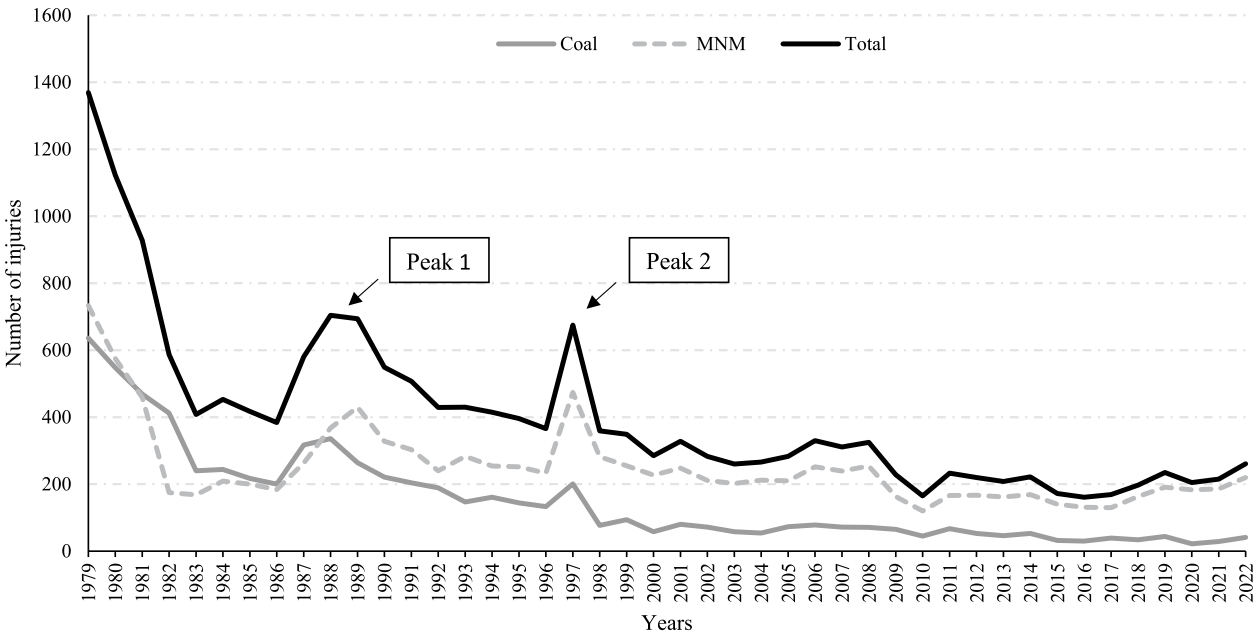
[5]Tenure at mine where incident occurred was missing for one coal miner associated with an incident

injuries, 32.8%) and among MNM miners with less than 1 year of total tenure (4,442 injuries, 39.8%). The tenure at the mine where the injury occurred followed a similar pattern as total tenure for both sectors.

Injuries were most reported in the Appalachian (2,205 injuries, 33.0%) and Eastern US regions (1,690 injuries, 25.3%) for coal miners and in the Western US region (6,417 injuries, 57.5%) for MNM miners (Table 1). Infrequently, injuries were reported in the Northeastern US (166 injuries, 1.5%) and US islands (Hawaii, Puerto Rico, and Virgin Islands; 48 injuries, 0.4%) for MNM miners only. Among coal miners, the majority of reported injuries were associated with bituminous coal (6,649 injuries, 99.4%) and underground (4,676 injuries, 69.9%) mines. Among MNM miners, the majority of injuries were associated with metal (5,463 injuries, 48.9%) and surface (10,183 injuries, 91.2%) mines. Incidents most often occurred between 0700 and 1500 h at MNM mines (54.8%), though no clear peak hours were identified for incidents occurring at coal mines.

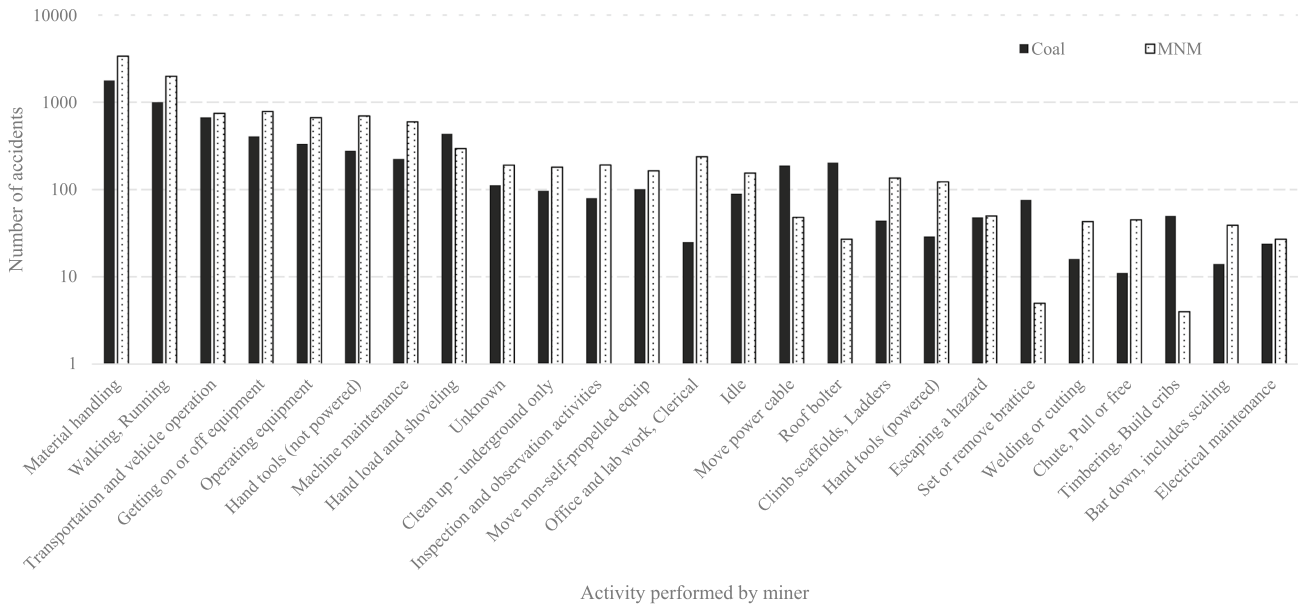
The highest number of incidents were reported in 1979 for both coal (636 injuries, 9.5%) and MNM (733 injuries, 6.6%) miners (Fig. 1). After excluding year 2023, as it was not a full calendar year, the lowest numbers of incidents were reported in 2020 for coal miners (22 injuries, 0.3%) and in 2010 for MNM miners (120 injuries, 1.1%). There were two periods with an increased number of incidents following 1979: the first one was in 1988–1989, followed by a second peak in 1997.

Among the top 25 activities that constituted 96.3% of the reported activities and had over 50 injuries when combining both sectors, material handling had the highest injury frequency (Fig. 2: coal: 1,775 injuries, 26.5%; MNM: 3,376 injuries, 30.2%). Within most of these 25 activities, MNM miners had a higher number of injuries reported than coal miners. The exceptions were activities that more commonly occur in coal mines: hand load and shoveling (437 injuries, 6.5%), moving power cable (189 injuries, 2.8%), roof bolter (205 injuries, 3.1%), set or remove brattice (76 injuries, 1.1%), and timbering, build cribs (50 injuries, 0.7%).



The two peaks could be partly explained by efforts of Mine Safety and Health Administration (MSHA) to clarify reporting processes and increase enforcement of regulations

Fig. 1 Number of work-related injury incidents among U.S. women miners, 1979–2022. Data shown here is for Jan 1979–Dec 2022 since investigations in 2023 were recorded only through June 27th, 2023



Mine Safety and Health Administration (MSHA) codes for activities can be found at https://www.cdc.gov/niosh/mining/UserFiles/data/guide_2016.pdf . Codes 44–73 (except 55, 62, and 69) were grouped into 'operating equipment.' Codes 55 (haulage or dump truck), 62 (mantrip), 69 (shuttle car, ram car, buggy), and 76 (ride equipment) were grouped together as 'transportation and vehicle operation.' Roof bolter codes 77–80 were grouped together as 'roof bolter.' Codes 21 (environmental tests or checks), 36 (inspect equipment or mine), and 42 (observe operations) were grouped together as 'inspection and observation activities.' Codes 26 (handling coal, rock, ore), 27 (handling explosives), 28 (handling supplies or material), and 29 (handling timber) were grouped together as 'material handling

Fig. 2 Top 25 activities that resulted in work-related incidents for U.S. women miners, 1979–2023

For both sectors, majority of injuries occurred among general laborers (coal: 2,932 injuries, 43.8%; MNM: 3,032 injuries, 27.2%) (Table 2). This job category included occupations such as parts runner, pick-up person, blacksmith, and roof trimmer. In addition to general laborers, materials handling equipment operator (727 injuries, 10.9%) and belt/conveyor crew (533 injuries, 8.0%) also had high proportion of injuries recorded among coal miners. Material processing (2,374 injuries, 21.3%) and truck drivers (1,239 injuries, 11.1%) sustained the highest proportion of injuries recorded among MNM miners. Different body parts were affected by these injuries (Table 3). Back injuries were commonly reported for both sectors (coal: 1,467 injuries, 21.9%; MNM: 2,108 injuries, 18.9%) followed by hand(s) injuries (coal: 966 injuries, 14.5%; MNM: 1,705 injuries, 15.3%). However, the common use of PPE, including harness and gloves to potentially prevent these back and hand injuries, were not included in the reports.

Information on the nature and the severity (i.e., outcome) of the incident are shown in SI Tables 1 and 2. Musculoskeletal and connective tissue injuries (coal: 3,924 injuries, 58.7%; MNM: 6,480 injuries, 58.1%), and injuries that led to days away from work with no change in work activity were most frequently reported (coal: 5,012 injuries, 75%; MNM: 3,949 injuries, 35.4%) for both industry sectors. For nonfatal injuries, overexertion (coal: 874 injuries, 13.1%; MNM: 1,806 injuries, 16.2%) and handling of materials (coal: 2,343 injuries, 35.1%; MNM: 3,990 injuries, 35.8%) were most frequently reported (SI Tables 3a and 3b).

Thirty-three fatalities were reported among women miners in both sectors, with 'caught between a moving and a stationary object' (n = 10) as the most common incident type. By incident classification, powered haulage was the most frequently reported (n = 22). Incident types and classifications are detailed in SI Tables 4a and 4b, respectively.

4 Discussion

This study describes injuries among women miners and identified 17,848 incidents from January 2, 1979, to June 27, 2023. These findings highlight that most injuries were reported among miners aged less than 35 years and those with less than 5 years of mining tenure. A recent study of women coal miners participating in medical surveillance showed that women miners had relatively short tenures, with a median tenure of 5 years [21]. Though that study only included women in coal mining, the shorter tenures of women who may have less experience in the industry could potentially contribute to the higher number of injuries observed in the lowest tenure groups.

This analysis also shows that back injuries were the most common type of injury and most injuries were reported

Table 2 Job descriptions for U.S. women miners at the time of the work-related incidents, 1979–2023

Job descriptions	Coal		Metal/Nonmetal		Total	
	N	Percent (%)[1]	N	Percent (%)[1]	N	Percent (%)[1]
General labor	2,932	43.8	3,032	27.2	5,964	33.4
Material processing worker	143	2.1	2,374	21.3	2,517	14.1
Truck driver	326	4.9	1,239	11.1	1,565	8.8
Office worker	265	4.0	897	8.0	1,162	6.5
Technician / sampler	104	1.6	808	7.2	912	5.1
Mechanic / repairman	216	3.2	640	5.7	856	4.8
Materials handling equipment operator	727	10.9	65	0.6	792	4.4
Heavy equipment operator	194	2.9	537	4.8	731	4.1
Belt / Conveyor crew	533	8.0	41	0.4	574	3.2
Roof bolter / roof support	390	5.8	26	0.2	416	2.3
Miner	4	0.1	375	3.4	379	2.1
Rail / motorman	121	1.8	118	1.1	239	1.3
Foreman / supervisor / management	61	0.9	165	1.5	226	1.3
Drilling operator	68	1.0	106	0.9	174	1.0
Electrician	80	1.2	94	0.8	174	1.0
Engineer	27	0.4	128	1.1	155	0.9
Continuous mine operator	135	2.0	14	0.1	149	0.8
Examiner / dispatcher / safety officer	57	0.9	84	0.8	141	0.8
Explosives worker	83	1.2	52	0.5	135	0.8
Longwall operator	122	1.8	5	< 0.1	127	0.7
Dragline / crane / rotary bucket operator	21	0.3	73	0.7	94	0.5
Welder	22	0.3	68	0.6	90	0.5
Hoisting operator	0	0.0	81	0.7	81	0.5
Others [2]	56	0.8	139	1.2	195	1.1
Total	**6,687**		**11,161**		**17,848**	

[1]Total percentage may not sum up to 100% due to rounding

[2]Regular job descriptions for women miners with less than 0.5% of total injuries were grouped into "others". It included loading/unloading, light equipment, road grader operator, dredge/barge/boat operator, auger, dragline/crane/rotary bucket, shopman/machinist, and not elsewhere classified

among women working as general laborers across both coal and MNM sectors. Material handling was the most frequently reported activity at the time of injury for both sectors. For forty-four years, thirty-three women miners were reported as dying from workplace injuries due to severe injuries caused by crushing and powered machinery. These hazards have been well documented due to the potential for significant physical harm [22, 23]. NIOSH is undertaking various initiatives to enhance powered haulage safety. These efforts include analyzing failures in the human–machine interface, conducting technology assessments, and creating training materials along with virtual reality resources [24].

Two peaks in the number of injuries were identified during 1979–2023. This could be explained, in part, by efforts of MSHA to clarify reporting processes and increase enforcement of regulations in 1987, along with a grace period from October 15, 1997 through April 17, 1998 which allowed mine operators to file any unreported occupational illness without penalty that occurred from the previous 5 years for inactive or retired miners [11, 25, 26].

This report intentionally avoids comparisons to men in mining to focus solely on the experiences of women mine workers [21]. Women have been active participants in the mining workforce for over a century, though the actual employment of women in mining is largely unknown as both historical and contemporary accounting of workforce numbers have not been systematically documented over time, especially with respect to sex. Therefore, the total number of women employed in mining in the US can only be estimated, as no entity publishes accurate data on mining employment by sex. Literature on this topic has estimated that in recent years, women comprise 10%–17% of the mining workforce [3, 27]. These estimates likely fluctuate by commodity, mine size, and geographical locale. The lack of a denominator limits our ability to compare differences between groups and calculate

Table 3 Frequency of body parts commonly affected by work-related injury for U.S. women miners using categories from CDC Occupational Injury and Illness Classification System (OIICS) cross walked from the Mine Safety and Health Administration (MSHA) codes

Body part [1]	Coal		Metal/Nonmetal		Total	
	N	Percent (%)[2]	N	Percent (%)[2]	N	Percent (%)[2]
Back, including spine, spinal cord	1,467	21.9	2,108	18.9	3,575	20.0
Hand(s)	966	14.4	1,705	15.3	2,671	15.0
Leg(s)	822	12.3	1,327	11.9	2,149	12.0
Multiple body parts	592	8.9	896	8.0	1,488	8.3
Ankle(s)	405	6.1	742	6.6	1,147	6.4
Shoulder(s), including clavicle(s), scapula(e)	325	4.9	675	6.0	1,000	5.6
Face	261	3.9	668	6.0	929	5.2
Arm(s)	281	4.2	614	5.5	895	5.0
Foot (feet)	359	5.4	412	3.7	771	4.3
Wrist(s)	210	3.1	508	4.6	718	4.0
Neck	288	4.3	331	3.0	619	3.5
Pelvic region	132	2.0	183	1.6	315	1.8
Chest, including ribs, internal organs	128	1.9	148	1.3	276	1.5
Head	111	1.7	163	1.5	274	1.5
Body Systems	39	0.6	177	1.6	216	1.2
Multiple trunk locations	73	1.1	137	1.2	210	1.2
Upper extremities, multiple locations	45	0.7	94	0.8	139	0.8
Lower extremities, multiple locations	54	0.8	55	0.5	109	0.6
Cranial region, including skull	40	0.6	65	0.6	105	0.6
Abdomen	38	0.6	53	0.5	91	0.5
Trunk, unspecified or NEC	20	0.3	32	0.3	52	0.3
Ear(s)	10	0.1	21	0.2	31	0.2
Multiple head locations	10	0.1	19	0.2	29	0.2
Lower extremities, unspecified or NEC	1	< 0.1	4	< 0.1	5	< 0.1
Unspecified [3]	10	0.1	21	0.2	31	0.2
Total	**6,687**		**11,161**		**17,848**	

Abbrevaitions: *NEC* not elsewhere classified

[1]OIICS 2-digit codes for part of body affected can be found at https://wwwn.cdc.gov/wisards/oiics/Trees/MultiTree.aspx?TreeType=BodyPart

[2]Total percentage may not sum up to 100% due to rounding

[3]Unspecified included MSHA codes 800 (Body parts, NEC) and 900 (unclassified)

rates. Thus, it is critical to collect disaggregated employment data to evaluate and support a more diversified workforce.

There are limitations from using the MSHA Part 50 program to capture all mining-related injuries. First, it may lead to an underestimation of injuries. The Part 50 program is intended to capture all mining related injuries and to enforce incident reporting to MSHA. However, publications linking MSHA Part 50 data with workers' compensation data have shown underreporting within this system by 23–66% [28–30]. Moreover, while most research using the MSHA dataset has not included sex of the miner during analysis, one study that did include sex suggests that underreporting of injury in mining is higher for females than males [28]. Secondly, it is possible that miners could have sustained multiple injuries throughout their careers but because there were no unique identifiers for individual miners, incidents were represented as distinct reports in this dataset. Thirdly, reports that may have been misclassified as acute and chronic illnesses would have been excluded from this analysis. Lastly, since identifiers were unavailable, it was not possible to validate the cause of hospitalizations and deaths using hospital discharge data and coroner reports, respectively.

Recent reports indicate the mining industry recognizes the need to increase diversity in its workforce – including initiatives targeted specifically at increasing participation of women in the workforce [31, 32]. Though the employment landscape for women in the US has shifted since the 1970s, the decade in which this dataset begins, women continue to face challenges in mining similar to those in other male-dominated industries. Women are often not offered the same training in injury prevention and opportunities for career advancement as their male colleagues in traditionally

male-dominated industries [33–36]. The work culture environment, safety equipment, and PPE have long been designed for a "standard" size or the body type of men [37, 38] and typically do not account for the physical differences of women [39–44]. The scope of this analysis was limited to summarizing the frequency of injuries experienced by women mine workers and not identifying potential causes or contributing factors for injuries, such as potential availability or access to properly fitting PPE for women miners. Further research is needed in this area. NIOSH continues to address these inequities through the development of more inclusive PPE solutions [45]. Other barriers such as organizational structures, work cultures, and practices for women in mining should also be explored [3, 46].

5 Conclusions

This study describes workplace injuries faced by women miners, particularly younger and less experienced workers. The findings point to the importance of safety measures, inclusive trainings in injury prevention, and more focused research on women in mining with different tenures. Increased attention to the experiences of women in mining can contribute to building a safe work environment for all miners. Collection of sex-specific employment data could support future research to investigate potential sex differences in injury rates among men and women. Ongoing efforts at NIOSH, including focus groups and interviews with women miners across various mining sectors, aim to deepen our understanding of their experiences, injury reporting practices, and the overall safety culture in mining. Further research is needed to elucidate the causes of these injuries and to prioritize targeted interventions.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42461-025-01236-x.

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Data Availability Supporting data for this study are freely accessible on the Mine Safety and Health Administration (MSHA) website.

Declarations

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

Competing Interest The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Donoghue AM (2004) "Occupational health hazards in mining: an overview," (in eng). Occup Med (Lond) 54(5):283–289. https://doi.org/10.1093/occmed/kqh072
2. Centers for Disease Control and Prevention. "Mine operator and independent contractor employees by sector, 1983 - 2022." https://wwwn.cdc.gov/NIOSH-Mining/MMWC/Employee/Count?StartYear=1983&EndYear=2022&SelectedMineType=. Accessed 17 May 2024.
3. Eiter BM, Dugdale ZJ, Robinson T, Nixon CT, Lawson H, Halldin CN, Stazick C (2023) "Occupational Safety and Health of Women in Mining," (in eng). J Womens Health (Larchmt) 32(4):388–395. https://doi.org/10.1089/jwh.2023.0034
4. Moore M (199) Women in the Mines: Stories of Life and Work. Twayne Pub; First Edition pp. 1–337.
5. Social Security Board. "Employment of Women in War Production." https://www.ssa.gov/policy/docs/ssb/v5n7/v5n7p4.pdf. Accessed 17 May 2024.
6. Back CJ (2020) "The Civil Rights Act of 1964: An Overview," (ed) Congressional Research Service, pp. 1–104.
7. Fisher A (2022) "Women's Rights and the Civil Rights Act of 1964," ed. National Archives: The U.S. National Archives and Records Administration.
8. Department of Labor (1977) "PART 50—Notification, investigation, reports and records of accidents, injuries, illnesses, employment, and coal production in mines," In 30 CFR 50 vol. 30 CFR 50, Mine Safety and Health Administration Ed, (ed). Washington DC: Department of Labor.
9. Watson AP, White CL (1984) Workplace injury experience of female coal miners in the United States. Arch Environ Health 39(4):284–93. https://doi.org/10.1080/00039896.1984.10545851
10. De S, Almberg KS, Cohen RA, Friedman LS (2020) Injuries during the first hour at work in the U.S. mining industry. Am J Ind Med 63(12):1124–1133. https://doi.org/10.1002/ajim.23186
11. Coleman PJ, Kerkering JC (2007) Measuring mining safety with injury statistics: lost workdays as indicators of risk. J Safety Res 38(5):523–533. https://doi.org/10.1016/j.jsr.2007.06.005
12. Asfaw A, Mark C, Pana-Cryan R (2013) Profitability and occupational injuries in U.S. underground coal mines. Accid Anal Prev 50:778–786. https://doi.org/10.1016/j.aap.2012.07.002
13. Friedman LS, Shannon B, Go LHT, Shao Y, Almberg KS, Cohen RA (2023) Poor adherence to dust, noise and safety regulations predict injury rates in underground coal mines. Occup Environ Med 80(5):254–259. https://doi.org/10.1136/oemed-2022-108650
14. Yorio PL, Laney AS, Halldin CN, Blackley DJ, Moore SM, Wizner K, Radonovich LJ, Greenawald LA (2018) Interstitial Lung Diseases in the U.S. Mining Industry: Using MSHA Data to Examine Trends and the Prevention Effects of Compliance with Health Regulations, 1996–2015. Risk Anal 38(9):1962–1971. https://doi.org/10.1111/risa.13000
15. Groves WA, Kecojevic VJ, Komljenovic D (2007) Analysis of fatalities and injuries involving mining equipment. J Safety Res 38(4):461–470. https://doi.org/10.1016/j.jsr.2007.03.011
16. Friedman LS, Almberg KS, Cohen RA (2019) Injuries associated with long working hours among employees in the US mining industry: risk factors and adverse outcomes. Occup Environ Med 76(6):389–395. https://doi.org/10.1136/oemed-2018-105558
17. Mine Safety and Health Administration (MSHA). "Mining Industry Accident, Injuries, Employment, and Production Data Accident / Injury Self-Extracting Files." https://arlweb.msha.gov/STATS/PART50/p50y2k/AITABLE.HTM. Accessed 17 May 2024.
18. Mine Safety and Health Administration (MSHA). "Metal/Nonmetal Fatalities for 1900 through 2022." https://arlweb.msha.gov/stats/centurystats/mnmstats.asp. Accessed 17 May 2024.

19. Alessa FM, Nimbarte AD, Sosa EM (2020) Incidences and severity of wrist, hand, and finger injuries in the U.S. mining industry. Saf Sci 129:104792. https://doi.org/10.1016/j.ssci.2020.104792
20. National Institute of Occupational Safety and Health (NIOSH). "NIOSH MIning Occupational Crosswalk." https://wwwn.cdc.gov/niosh-mining/CostCalcsFatal. Accessed 29 May 2024.
21. Hall NB, Myers NT, Reynolds LE, Blackley DJ, Laney AS (2024) "Women in Coal Mining-Radiographic Findings of Women Participants in the Coal Workers' Health Surveillance Program 1970–2022," (in eng). J Womens Health (Larchmt). https://doi.org/10.1089/jwh.2024.0140.
22. Moniri-Morad A, Shishvan MS, Aguilar M, Goli M, Sattarvand J (2024) Powered haulage safety, challenges, analysis, and solutions in the mining industry; a comprehensive review. Results Eng 21:101684. https://doi.org/10.1016/j.rineng.2023.101684
23. Myers NT, Hall NB, Saif NT, Laney AS (2025) "Powered Haulage Fatalities in Appalachian Coal Mines," (in eng). J Appalach Health 6(4):4–9. https://doi.org/10.13023/jah.0604.02
24. National Institute for Occupational Safety and Health (NIOSH). "Haul Truck Research Roadmap Report 2020." https://www.cdc.gov/niosh/mining/researchprogram/strategicplan/HaulTruckRoadmap2020.html. Accessed 17 Sept 2024.
25. Department of Labor (1997) "Federal Register - 60674," in 30 CFR 50 vol. FR Doc. 97–29635, Mine Safety and Health Administration (ed) 62(218). Washington DC.
26. Randolph RF (1993) "Human factors and safety issues in new mining technologies," In Sweden G, Almgren U, Kumar, Vagenas N (eds) Proceedings of the second international symposium on mine mechanization and automation, in Mine Mechanization and Automation.
27. Ellix H, Farmer K, Little KLR, Moonsamy T, Ruban P, Zapata G (2021) "Why women are leaving the mining industry and what mining companies can do about it," McKinsey & Company. [Online]. Available: https://www.mckinsey.com/industries/metals-and-mining/our-insights/why-women-are-leaving-the-mining-industry-and-what-mining-companies-can-do-about-it.
28. Almberg KS, Friedman LS, Swedler D, Cohen RA (2018) Mine Safety and Health Administration's Part 50 program does not fully capture chronic disease and injury in the Illinois mining industry. Am J Ind Med 61(5):436–443. https://doi.org/10.1002/ajim.22826
29. Heberger JR, Wurzelbacher SJ (2024) "Mining Injuries 2012–2019: Using Workers' Compensation Claims Data From 35 States to Identify Rates and Costs Associated by Nature of Injury, Event/Exposure, and Body Part Affected," (in eng). J Occup Environ Med 66(5):e160–e175. https://doi.org/10.1097/jom.0000000000003067
30. Eastern Research Group Inc., "Evaluation of Accuracy and Completeness of Nonfatal Injury and Illness Reporting in the Mining Industry," Department of Labor, Lexington, MA, 2013. [Online]. Available: https://www.dol.gov/sites/dolgov/files/OASP/legacy/files/FINAL_REPORT_evaluation_accuracy_completeness_nonfatal_injury_illness_reporting_mining.pdf. Accessed 21 Aug 2024.
31. EY Global, "Women in mining 2022: You can't be what you can't see." [Online]. Available: https://assets.ey.com/content/dam/ey-sites/ey-com/en_au/topics/corporate-social-responsibility/ey-you-cant-be-what-you-cant-see-20220923.pdf
32. Cummins Inc. "From building careers to lasting impact: recognizing vast opportunities for women in mining." https://www.cummins.com/news/2023/02/28/budding-careers-lasting-impact-recognizing-vast-opportunities-women-mining#:~:text=The%20mining%20industry%20also%20has,demand%20within%20the%20mining%20industry. Accessed 4 June 2024.
33. Tessier-Sherman B, Cantley LF, Galusha D, Slade MD, Taiwo OA, Cullen MR (2014) Occupational injury risk by sex in a manufacturing cohort. Occup Environ Med 71(9):605–610. https://doi.org/10.1136/oemed-2014-102083
34. Kelsh MA, Sahl JD (1996) Sex differences in work-related injury rates among electric utility workers. Am J Epidemiol 143(10):1050–1058. https://doi.org/10.1093/oxfordjournals.aje.a008669
35. Hannah Ellix KF, Kowalik L, Little R, Moonsamy T, Mussacaleca M, Ruban P, Zapata G "Why women are leaving the mining industry and what mining companies can do about it." [Online]. Available: https://www.mckinsey.com/industries/metals-and-mining/our-insights/why-women-are-leaving-the-mining-industry-and-what-mining-companies-can-do-about-it
36. Goldenhar LM, Sweeney MH (1996) Tradeswomen's perspectives on occupational health and safety: a qualitative investigation. Am J Ind Med 29(5):516–520. https://doi.org/10.1002/(SICI)1097-0274(199605)29:5%3c516::AID-AJIM11%3e3.0.CO;2-3
37. Occupational Safety and Health Administration (OSHA) (2023) "National Archives, Federal Register, PPE in Construction, Proposed Rule," In 29 CFR 1926 vol. 88 FR 46706 (ed) Department of Labor pp. 46706–46720.
38. National Institute for Occupational Safety and Health (NIOSH). "Women's Safety and Health Issues At Work." DHHS (NIOSH) publication number 2001–123. https://www.cdc.gov/niosh/docs/2001-123/default.html. Accessed 28 May 2024.
39. Janson D, Newman ST, Dhokia V (2021) Safety footwear: A survey of end-users. Appl Ergon 92:103333. https://doi.org/10.1016/j.apergo.2020.103333
40. Janson DJ, Clift BC, Dhokia V (2022) PPE fit of healthcare workers during the COVID-19 pandemic. Appl Ergon 99:103610. https://doi.org/10.1016/j.apergo.2021.103610
41. Dobson JA, Riddiford-Harland DL, Bell AF, Steele JR (2017) Effect of work boot type on work footwear habits, lower limb pain and perceptions of work boot fit and comfort in underground coal miners. Appl Ergon 60:146–153. https://doi.org/10.1016/j.apergo.2016.11.008
42. Yoo IG, Lee J, Jung MY, Lee JH (2011) Effects of wearing the wrong glove size on shoulder and forearm muscle activities during simulated assembly work. Ind Health 49(5):575–581. https://doi.org/10.2486/indhealth.ms1235
43. Heberger JR, Nasarwanji MF, Pollard JP, Kocher LM (2022) "The Necessity for Improved Hand and Finger Protection in Mining," (in eng). Min Metall Explor 39(2):507–520. https://doi.org/10.1007/s42461-022-00557-5
44. Women in Global Health. " Fit for women? Safe and decent PPE for women health and care workers." https://womeningh.org/wp-content/uploads/2022/11/WGH-Fit-for-Women-report-2021.pdf. Accessed 25 Feb 2025.
45. Pena M, Kiederer M, Dempsey PG, Yoon NK, Garza CE, Earnest S, Trout D (2023) "Personal Protective Equipment Fit in the Construction Sector," ed: National Institute for Occupational Safety and Health (NIOSH).
46 Valadares SS, De CarvalhoNeto AM, Mota-Santos CM, Diniz DM (2024) Women in mining: from subtle barriers to open prejudice. Revista de Gestão 31(3):262–274. https://doi.org/10.1108/REGE-10-2021-0193