Published in final edited form as:
J Occup Environ Hyg. 2024 January ; 21(1): 58–67. doi:10.1080/15459624.2023.2268142.

Risk factors for heat-related illness resulting in death or hospitalization in the oil and gas extraction industry

Nancy W. Lin[a], **Alejandra Ramirez-Cardenas**[b], **Kaitlin C. Wingate**[b], **Bradley S. King**[b], **Kenneth Scott**[b], **Kyla Hagan-Haynes**[b]

[a]Department of Environmental and Occupational Health, Colorado School of Public Health, University of Colorado, CU Anschutz, Aurora, Colorado;

[b]National Institute for Occupational Safety and Health (NIOSH) Western States Division, Denver, Colorado

Abstract

Many oil and gas extraction (OGE) activities occur in high-heat environments, resulting in a significant risk of heat-related illness among outdoor workers in this industry. This report highlights cases of occupational heat-related illness that resulted in death and identifies common risk factors for heat-related fatalities and hospitalizations among OGE workers. Two databases maintained by the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) were reviewed to identify heat-related fatalities, hospitalizations, and associated risk factors among OGE workers. Nine fatalities and associated risk factors were identified during 2014–2019 from NIOSH's Fatalities in Oil and Gas Extraction (FOG) Database. Risk factors identified included those commonly associated with heat-related fatalities: new workers not acclimatized to heat, inadequate heat stress training, and underlying hypertension or cardiovascular disease. Of particular note, substance use was identified as a significant risk factor as more than half of the fatalities included a positive postmortem test for amphetamines or methamphetamines. Fifty heat-related hospitalizations were identified from OSHA's Severe Injury Report Database during January 2015-May 2021. Heat stress has been and will continue to be an important cause of fatality and adverse health effects in OGE as hot outdoor working conditions become more common and extreme. More emphasis on heat stress training, acclimatization regimens, medical screening, and implementation of workplace-supportive recovery programs may reduce heat-related fatalities and injuries in this industry.

✉**CONTACT** Bradley S. King Bradley.King@cdc.hhs.gov NIOSH Western States Division, PO Box 25226, Denver, CO 80225, USA.

Disclaimer
The findings and conclusions in this report are those of the authors and do not necessarily represent the official views of NIOSH or the University of Colorado Anschutz Medical Campus.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Keywords

Heat stress; heatstroke; OGE; outdoor workers

Introduction

The U.S. oil and gas extraction (OGE) industry employed 353,487 workers in 2020 (BLS 2022). Increasing global temperatures make it more likely that outdoor workers, including OGE workers, may work in increasingly extreme heat conditions. The Permian Basin, located in western Texas, is where nearly 40% of U.S. oil production occurs (RRC 2022). Summer temperatures in this region routinely surpass 37.7 degrees Celsius (°C) (100 degrees Fahrenheit (°F)). Many OGE activities are performed outside and work shifts surpassing 12hr are normal on onshore well sites (Siddique et al. 2019; Hagan-Haynes et al. 2022).

Between 2011 and 2019, 344 U.S. workers died on the job due to environmental heat exposure; this is likely under-reported since this count only accounts for fatal injuries where heat exposure was a direct cause and not a contributing factor (BLS 2021). The true incidence of heat-related occupational injuries is unknown (Gubernot et al. 2014). There is a strong link between environmental heat exposure and occupational injuries. Heat exposure can lead to a physiological response in workers manifesting as fatigue, reduced psychomotor performance, loss of concentration, and reduced alertness or as a psycho-behavioral response displaying as discomfort, altered behavior, and reduced use or improper wearing of personal protective equipment (PPE) (Schulte and Chun 2009; Varghese et al. 2018). Both responses contribute to increased workplace hazards, physical injury risks, and heat-related illness (HRI) (Varghese et al. 2018).

The human body seeks to maintain a core temperature of 37 °C (98.6 °F) regardless of external conditions (McDonald et al. 2008). However, the body's ability to maintain homeostasis can be affected by high external temperatures and other factors, which can lead to a spectrum of HRI (McDonald et al. 2008) including heatstroke, heat syncope, dehydration or loss of electrolytes, and heat exhaustion (ACGIH 2017). Individual risk factors that increase the likelihood of HRI include advanced age, comorbidities (such as cardiovascular disease and diabetes), obesity, pregnancy, poor hydration, certain medications, recreational drug/alcohol usage, having had a previous HRI, use of certain PPE and clothing and the lack of heat acclimatization (Jacklitsch et al. 2016). Additional indications that may place workers at greater risk of HRI include lack of sleep, fatigue, or lack of recovery from the previous day, not having eaten recently, gastrointestinal discomfort, and psychological stress (Morrissey et al. 2021).

While heat stress is a commonly recognized hazard for outdoor oil and gas workers, peer-reviewed heat stress exposure and health effects studies on this population are limited. A comprehensive review and meta-analysis of occupational heat strain in outdoor workers published in 2022 by Ioannou et al. included studies that involved monitoring workplace heat exposures among outdoor workers carrying out their duties in warm-to-hot environments. Of the studies included, only 0.5% of the outdoor workers worked in oil and gas production and were from a single study of heavy-oil power plant workers in a subtropical country (Yang et al. 2017). McDonald et al. (2008) described conditions and recommendations for improving heat stress safety in the Arabian Gulf oil and gas industry, while Girard et al. (2021) investigated the effects of seasonal heat stress on cognitive function in workers in the oil and gas industry in the Middle East. Our search of the peer-reviewed literature yielded few, if any, studies focused on HRI among the U.S. oil and gas worker population.

The U.S. OGE industry must understand the risks of heat stress and the steps to be taken to protect workers. This report summarizes heat-related fatal and severe illnesses in the OGE industry from 2014 to 2021 and recommends appropriate prevention controls.

Methods

NIOSH Fatalities in Oil and Gas Database

The fatalities reviewed were identified from the National Institute for Occupational Safety and Health (NIOSH) Fatalities in Oil and Gas Extraction (FOG) database (NIOSH 2021). This database collects detailed information about fatalities that have occurred among OGE workers from 2014–2019, representing all available years of data in the database. Information on the fatal incidents is collected from Occupational Safety and Health Administration (OSHA) reports, Bureau of Safety and Environmental Enforcement (BSEE) reports, media coverage, autopsy, medical reports (if available), and other industry sources (Ridl et al. 2017).

The FOG database was screened for all incidents involving heat or environmental exposures by filtering for incidents with an event type of “Exposure: environmental.” The resulting records were reviewed to determine if heat or high temperatures were mentioned. The database was also filtered for incidents that were weather-related, with high temperatures noted as an environmental factor. A keyword search was also performed for “heat,” “hot,” and “temperature” in the incident descriptions.

After this initial screen, the resulting fatality records were individually reviewed by an occupational medicine fellow for evidence that the fatalities were caused by heat. In the review, data extracted from descriptions contained in the fatality records of each case were compiled in a spreadsheet including worker demographics, recorded environmental and core body temperatures (if available), physical activities characterized as “moderate,” “heavy,” or “very heavy” preceding the fatality (ACGIH 2017), reported heat-related symptoms, new employee status, evidence of inadequate training, and occupational risk factors such as positive drug results from a toxicology screen. Extracted data was also reviewed by research team members for completeness and validation, as needed.

A core temperature of 40.5 °C (105 °F) and brain dysfunction are typically used for a medical diagnosis of heatstroke (Bouchama and Knochel 2002). However, core temperature and symptoms before death were often missing from the FOG incident files. Because of instances of such missing data, the criteria outlined in Table 1 were developed to identify cases meeting epidemiological case definitions intended to apply to this review of FOG record data for definite or possible heatstroke-related fatality or where HRI was a contributing factor in fatalities.

OSHA severe injury report database

Heat-related incidents in the OGE industry that required hospitalization from January 2015 to May 2021 were collected from the OSHA severe injury reports database, which is a compilation of OSHA-mandated reports on all severe work-related injuries, as required by OSHA Standard 1904.39 (OSHA 2014). The database includes an incident description including the location, date, North American Industry Classification System (NAICS) codes, and Occupational Injury and Illness Classification System (OIICS) codes that describe the event or exposure, part of the body affected, and source and nature of the injury or illness (OSHA 2015). To identify heat-related incidents, the OSHA severe injury report was filtered by the OIICS codes “530 Exposure to temperature extremes, unspecified” and “531 Exposure to environmental heat.” These results were then filtered to include only those company types that operate in the OGE industry as defined by NAICS. These included oil and gas operators (211), drilling contractors (21311), and well-servicing companies (213112). The resulting data including the date and location of the event, the nature of the illness, and a brief narrative of the event was compiled in a spreadsheet and analyzed. Detailed information available in the NIOSH FOG fatality reports such as worker demographics, core body and environmental temperatures, or associated occupational risk factors were unavailable in the OSHA Severe Injury Report database.

Results

Heat-related fatalities from the FOG database

Ten fatalities in the FOG database during the years 2014–2019 were identified as potential heat-related fatalities after the initial screening. These 10 were then individually reviewed using the criteria in Table 1. From this review, nine met the criteria for a heat-related fatality. A summary of the fatalities is found in Table 2. Six met the criteria for definite heatstroke-related fatality, while three were classified as possible. All nine occurred between June and September and all nine workers were engaged in well servicing activities (NAICS code 213112). Eight fatalities occurred in Texas, and one occurred in Kansas. The following presents summaries and occupational risk factors in common among a selection of the fatal incidents:

Worker #1

Summary.—This was a male in his 40s working in a confined space to remove an obstruction. In late afternoon, the worker called management personnel reporting he was cramping and feeling nauseous. He was instructed to continue working. After a 12–13-hr shift in direct sun, he went to his residence where he suffered a seizure, hitting his head on a windowsill and causing a head laceration. He later died at the hospital. The OSHA inspection report listed heat exhaustion as a cause of death.

Occupational risk factors.—The worker was doing moderate-to-heavy work outside in June where the temperature was 35.5 °C (96 °F) and in an enclosed space, possibly impairing sweat evaporation due to reduced airflow. He was employed by the company for 2 days and did not have significant time to acclimatize to the hot work environment. Although the worker notified management of his symptoms, he was instructed to continue working, suggesting management personnel were not adequately trained or knowledgeable on heat stress and HRI prevention.

Worker #2

Summary.—This was a male in his 20s checking a pipeline. Throughout his shift, he walked 7 miles, took several breaks, and drank seven to eight bottles of water. He was later found unconscious and unresponsive by a coworker. His internal body temperature registered 42.8 °C (109 °F) and subsequently died of heatstroke. The medical examiner reported hyperthermia as a contributing factor to his death.

Occupational risk factors.—The worker performed at least moderate physical activity in August where the temperature ranged from 23.9 to 33.3 °C (75–92 °F) with 36% humidity. The OSHA report indicated employees of the company were not adequately trained to recognize signs and symptoms of heat stress and a period of acclimatization was not implemented for new hires.

Worker #3

Summary.—This was a man in his 50s pumping rainwater out of a containment area. His colleague stepped away for an undetermined amount of time and found the worker unresponsive upon his return. The colleague began first aid, but the worker died in the hospital. The medical examiner reported hyperthermia as a contributing factor to his death.

Occupational risk factors.—The worker was performing at least moderate physical activity outside in June where the temperature was approximately 37.2 °C (99 °F) with 39% humidity.

Worker #4

Summary.—This was a male in his 50s moving heavy hoses while wearing heavy coveralls and a half-face-piece respirator with P100 filters for about an hour in direct sunlight. After finishing, he called the dispatcher and said he was very hot and needed water. He also called his wife, stating he was going to a truck stop to cool off. An hour later, a coworker saw the worker’s truck at the truck stop, finding the driver dead in the driver’s seat; drinking water was found in his vehicle. The medical examiner listed hyperthermia as a contributing factor to his death.

Occupational risk factors.—This was a lone worker performing heavy physical activity in August when the temperature was 37.2 °C (99 °F) and humidity up to 40%, with a heat index of 43.3 °C (110 °F). The worker was wearing heavy coveralls and a half-face respirator, which contributed to increased heat and workload.

Worker #5

Summary.—This was a male in his 60s welding at a remote oilfield site and found unconscious by other workers. Upon regaining consciousness, the worker stated he may have overheated. He was able to drive to his office where coworkers drove him home. His condition deteriorated and he was taken to the hospital where he died from a fractured skull, ribs, and contusions, likely sustained when he lost consciousness and fell in the field. The OSHA inspection report listed heat exhaustion as a cause of death.

Occupational risk factors.—This was a worker performing moderate-to-heavy activity in a remote oilfield in September where the temperature was 35.5 °C (96 °F) and the heat index registered 40.5 °C (105 °F). The worker was also welding which generates heat. The employer didn’t have a heat stress management program so the worker likely did not have appropriate heat stress training. He experienced an unwitnessed fall and lost consciousness, which may have been a result of heat exhaustion; the coroner listed blunt force trauma of the head as the primary cause of death.

Personal risk factors for heat-related fatalities

Of the nine fatalities identified, five had positive postmortem drug screens for amphetamines and/or methamphetamines; it is unknown if these were prescribed medications. Two of these five workers also had positive drug screens for cocaine. All the fatalities were male, reflecting a significant majority of the industry’s workforce. Most were under 50 years of age, reflective of exertional heatstroke which typically impacts those aged 15–45 (Jacklitsch et al. 2016). Of the nine fatalities, eight were performing at least moderate work activity, with several noted as heavy work activity, a contributing factor to exertional heatstroke. Height/weight or body mass index (BMI) was identified in the records of seven workers who suffered fatalities. Of these, five had a BMI above 30.0 (obese) and one had a BMI between 25.0 and 29.9 (overweight). A history of hypertension or atherosclerotic cardiovascular disease was noted in the records of four of the nine fatalities.

Heat-related illnesses from the OSHA severe injury report database

From the severe injury database between January 2015–May 2021, 50 OGE workers reported experiencing serious HRI requiring hospitalizations. A summary of the adverse health effects and hospitalizations is found in Table 3. The states with the highest numbers of incidents were Texas (30), Oklahoma (5), and North Dakota (5). (While these are known to be large oil and gas producing states, other states with heat stress hospitalizations may be missing due to limitations in the data source; see “Limitations” section below.) Most were performing at least some moderate physical activity. All incidents occurred between May and September, with the highest number of incidents in July (21). Many of the reports had missing information about symptoms, but the most frequently mentioned symptoms, when present, were body aches/cramps/pain, feeling ill or sick, and nausea/vomiting.

Discussion

Four main risk factors associated with HRI arose in the analysis of OGE fatalities: lack of acclimatization, inadequate training, underlying cardiovascular disease, and a positive drug screen for sympathomimetic drugs, particularly amphetamines. In at least four fatalities, fluids and/or air-conditioning were provided suggesting that preventing heatstroke requires more than access to fluids and a cool environment, or that fluids and cool environment were provided too late or inefficiently.

This study demonstrates a lack of appropriate acclimatization and heat stress training programs available to some OGE workers, especially new employees. The absence of acclimatization protocols for new workers in heat illness prevention programs has previously been identified as a factor among cases of occupational HRI resulting in death (Arbury et al. 2014). In this review, five of nine worker fatalities were individuals working at their company for less than two weeks; three died on their first day of work, suggesting a lack of acclimatization may be a factor in such cases. It is unknown if or to what extent self-pacing, a protective behavior in which a worker adjusts their work rate in severe thermal conditions to avoid physiological strain (Miller et al. 2011), may have been compromised in these cases. New or inexperienced workers may have overridden the instinct to reduce work rate in response to perceived heat stress, also contributing to the HRI. Additionally, there was evidence of inadequate heat stress training in five fatalities, which could fail to recognize or appropriately respond to the signs and symptoms of heat stress.

Four of nine fatalities involved workers with underlying cardiovascular disease or hypertension. Hot conditions cause an increase in cardiac demand as heart rate and cardiac output increase (ACGIH 2017). This increased demand on the cardiovascular system can be especially dangerous for individuals with underlying cardiovascular disease. In a systematic review and meta-analysis of published epidemiologic evidence linking heat exposures and cardiovascular disease outcomes, Liu et al. reported a 1.6% increased risk of morbidity due to arrhythmias and cardiac arrest associated with high temperatures (Liu et al. 2022). Additionally, they found that there is an associated 2.1% increase in cardiovascular diseaserelated mortality for every 1 °C (1.8 °F) increase in temperature above reference temperatures (Liu et al. 2022).

Amphetamines, methamphetamines, and cocaine can induce hyperthermia independent of external temperatures, especially in the brain, which is responsible for the neurotoxicity associated with the drugs (Bowyer and Hanig 2014). Hyperthermia occurs in a dose-dependent manner and produces a breakdown of the blood-brain barrier, which alters neurochemical brain metabolism (Sharma et al. 2009). External temperature greatly amplifies the hyperthermic effects of these drugs; in animal models of methamphetamine intoxication, warm external temperatures cause a higher and more rapid rise in brain temperature and subsequently death (Kiyatkin and Sharma 2009). In a report of OSHA medical records and investigation materials between 2010 and 2019, a high prevalence of amphetamine use (>25%) among 34 U.S. workers with severe hyperthermia was identified (Karasick et al. 2020). In this review, greater than 50% of workers tested positive postmortem for amphetamines and/or methamphetamines. It is uncertain if the amphetamines were prescribed by a medical practitioner or if they were taken for recreational use.

Most of the HRI reported in the severe injury database were from Texas in the months between May and September, peaking in July and August during which environmental temperatures are often the highest. While Texas is hot in the summertime, this also reflects that a majority of OGE work is done in this state. Seventy percent of recorded injuries were amongst workers employed by well-servicing companies (NAICS 213112), which constituted 53.5% of employment in 2020 of the three NAICS codes identified (BLS 2022). This suggests well-servicing workers may be at greater risk for HRI, particularly given 100% of the heatstroke fatalities identified in this review were well-servicing workers. Activities performed by well-servicing workers to maintain and repair a well's equipment and components are often demanding and performed outdoors. Employers in this sector particularly should be aware of and responsive to the significant potential for exertional HRI from the combination of heavy activity load and high temperatures. Many reports in the OSHA database had no information on reported symptoms. However, the three most commonly reported symptoms included body aches/cramps/pain; feeling ill or sick; and nausea/vomiting; these are unsurprising as heat cramps may be the initial manifestations of HRI resulting from dehydration and loss of electrolytes and nausea/vomiting is a noted sign of heat exhaustion which can progress to heatstroke if left untreated (Gubernot et al. 2014; Jacklitsch et al. 2016). Such symptoms suggest workers may not have been properly hydrating throughout their work shifts or taking sufficient rest breaks from what was likely to be high-exertion work activities. While these injuries didn't progress to more serious heatstroke or fatality, the incidents should be recognized by employers as sentinel health events indicating inadequate heat control measures and the need to improve heat stress management programs (Jacklitsch et al. 2016).

Recommended controls

OGE work inevitably requires work outside in high heat conditions. It is impossible to eliminate or substitute this heat exposure since the heat is a consequence of the natural climate. However, several other control measures can be taken to mitigate the dangers of heat stress by addressing risk factors identified in this report including inadequate heat stress training, lack of acclimatization programs, and the elevated risk of HRI with underlying cardiovascular disease and amphetamine use. From the fatalities identified, adequate and comprehensive HRI-prevention training and management programs are essential and should be developed or strengthened in the following areas:

- Emphasize heat stress training to new hires and reinforce such training to all field workers regularly, including how to:
  - recognize early signs and symptoms of HRI,
  - notify supervisors immediately if workers suspect they or a colleague may be suffering from an HRI,
  - provide basic first aid for workers experiencing HRI including cooling the individual with whatever means possible,
  - seek immediate medical help,
  - understand the importance and indicators of hydration status, and

- understand the risk of amphetamine use (including amphetamines prescribed by a physician) in hot working conditions.

- Provide easy access to adequate hydration and electrolyte replacement to maintain electrolyte balances.
- Train and permit workers to self-pace during work activities under high thermal stress as part of a holistic approach to managing heat stress and work/rest schedule, but it is important to recognize that relying on self-pacing alone may not be sufficient (NIOSH 2017).
- Implement buddy systems in which each worker and supervisor is assigned to observe one or more fellow workers for early signs of HRI (Jacklitsch et al. 2016).
- Follow NIOSH recommendations for acclimatizing new and returning workers to working conditions in the heat. It is recognized that many OGE workers' shifts include 14 consecutive workdays followed by 14 days off work. Absence from work in the heat for a week or more results in a loss of acclimatization; most individuals' heat tolerance returns to baseline after one month away from work in the heat (Jacklitsch et al. 2016).
- Utilize a medical monitoring program that includes:
  - Assessing workers' health before and during work in hot environments, particularly work that is physically demanding (Jacklitsch et al. 2016),
  - A preplacement medical evaluation for workers in hot jobs that includes a comprehensive work and medical history (including the cardiac, vascular, respiratory, neurologic, and renal systems), physical examination and blood pressure evaluation, obesity assessment, and assessment of a worker's ability to wear and use protective clothing and equipment (Jacklitsch et al. 2016).
  - Identifying workers who may have low physical work capacity due to medical illness (especially cardiovascular disease, high blood pressure, or diabetes) as a component of medical screening as they may be more susceptible to heat stress.
  - Documenting what medications workers take with attention to medications that can exacerbate dehydration (e.g., diuretics) or hyperthermia (e.g., amphetamines). Amphetamine use can be screened for using a urine toxicology screen. Employers must recognize that if workers are prescribed amphetamines for conditions such as attention deficit hyperactivity disorder (ADHD) or narcolepsy, these medications may result in a positive urine toxicology screen.
  - Recognizing that workers taking amphetamines are at higher risk of HRI and need extra precautions when working in hot environments including longer and more conservative acclimatization regimens. If the

option is available, these workers may be better suited for alternative work activities having more limited heat exposures.

Limitations

Limitations to the NIOSH FOG database include incomplete information in the available materials. The FOG database leverages secondary data from a variety of sources. Data for a given characteristic may be missing in the FOG records for several reasons including lack of standardized data collection by a source, differential data collection practices across sources, or logistical difficulty obtaining data for a given fatality. Extensive meteorological details were often not included in the source material reviewed for the fatalities. While ambient temperature and relative humidity were often found to be recorded in the source materials (and included in this review when available), additional climate parameters that could provide more details on the thermal conditions leading to the fatalities such as cloud cover, air velocity, and solar exposure were not included in the fatality records. Additional fatalities in the FOG database may have been heat-related but lacked information required to identify the role heat played. The NIOSH FOG database excludes fatalities that may have been triggered by or associated with work activities but occurred outside of work. Given these limitations, this study likely underestimated the number of heat-related fatalities.

Limitations to the OSHA database include inconsistencies in information on worker activities or symptoms before hospitalization. Reports to the database are submitted by health and safety professionals from individual companies, resulting in non-standardized reporting. Hospitalizations, amputations, or loss of an eye are included in the database; however, workers with injuries that don't require hospitalization aren't included. The OSHA severe injury reports database includes severe injuries required to be reported to federal OSHA from 24 states and the District of Columbia under federal OSHA jurisdiction (OSHA 2022). This database doesn't include information from OSHA state plans which maintain their own requirements for reporting to their individual state agencies (OSHA 2018). Lastly, mandatory reporting began in January 2015; incidents before that are not included in the review.

Conclusion

Among oil and gas workers, this study identified 9 heat-related fatalities and 50 hospitalizations. Risk factors for fatalities included new hires who weren't acclimatized to heat and inadequate training on heat stress and HRI. This review also identified personal risk factors including underlying hypertension or arteriosclerotic cardiovascular disease and substance use that have the potential to increase the risk for HRI as major co-factors in heat-related fatalities among oil and gas workers. Particularly regarding the issue of amphetamine/methamphetamine use, these data present an opportunity to highlight the importance for OGE occupational safety and health managers to introduce or improve the implementation of medical screening for and training about the use of substances that may exacerbate hyperthermia as well as workplace supportive recovery programs (Ramirez-Cardenas et al. 2023). Such programs may not only prevent substance misuse and encourage recovery amongst workers but may also play a role in preventing heat-related fatalities.

In addition to better understanding the effectiveness of interventions related to substance use, an area for future study to better understand, respond to, and prevent HRI in the OGE industry is the use of improving and emerging technologies. Because so many workers in the OGE industry work alone and/or in remote locations, a better understanding of how lone worker technologies can help identify workers experiencing a heat-related event, such as a fall or losing consciousness, would be highly valuable. When experiencing an HRI, the ability to quickly respond with emergency services may prove critical to saving lives; the use of such lone-worker technology to improve response time for heat stress incidents deserves additional investigation as a tool for OGE health and safety managers.

In addition to lone worker technology, other technologies being developed can measure in real-time workers' physiological parameters related to heat stress as well as hydration status. These technologies are developing rapidly and include smart textiles, patches, and wearable accessories such as watches, belts, or bracelets (Saidi and Gauvin 2023). Testing and validating the use of these technologies by workers in the OGE industry specifically to identify conditions in real-time before a potentially fatal heat-related event is an area in need of further research.

The development of the FOG database was supported by a National Occupational Research Agenda (NORA) grant. While FOG data is not currently being collected due to the end of funding, future funding and access to OSHA data systems could allow for additional surveillance of fatal heat incidents. This data collection and analysis could provide important insights and directions on how the OGE industry can best address heat-related illness resulting in death or hospitalization as hot outdoor working conditions become more common and extreme.

Acknowledgments

The authors would like to thank Marie De Perio, Brenda Jacklitsch, Thomas Hales, and Ryan Hill who provided reviews of the manuscript.

Funding

Authors supported by CDC/NIOSH T32 OH009229 Mountain and Plains Education and Research Center and through programmatic funds of the NIOSH Western States Division.

Data availability

For more information about requesting FOG data, please contact the NIOSH Oil and Gas Program at ✉ nioshoilandgas@cdc.gov. Data from the OSHA Severe Injury Report Database is available at https://www.osha.gov/severeinjury.

References

American Conference of Governmental Industrial Hygienists (ACGIH). 2017. 2017 TLVs and BEIs: threshold limit values for chemical substances and physical agents and biological exposure indices. Heat stress and strain Cincinnati (OH): ACGIH Worldwide.

Arbury S, Jacklitsch B, Farquah O, Hodgson M, Lamson G, Martin H, Profitt A. 2014. Heat illness and death among workers-United States, 2012–2013. MMWR. 63(31):661–665. [PubMed: 25102413]

BLS. 2021. The Economics Daily, 43 work-related deaths due to environmental heat exposure in 2019. Washington (DC): Bureau of Labor Statistics; [accessed 2022 Aug 05]. https://www.bls.gov/opub/ted/2021/43-work-related-deaths-due-to-environmental-heat-exposure-in-2019.htm.

BLS. 2022. Quarterly census of employment and wages. Washington (DC): Bureau of Labor Statistics; [accessed 2022 Aug 19]. https://www.bls.gov/cew/.

Bouchama A, Knochel JP. 2002. Heat stroke. N Engl J Med. 346(25):1978–1988. doi: 10.1056/NEJMra011089. [PubMed: 12075060]

Bowyer JF, Hanig JP. 2014. Amphetamine- and methamphetamine-induced hyperthermia: implications of the effects produced in brain vasculature and peripheral organs to forebrain neurotoxicity. Temperature (Austin). 1(3):172–182. doi: 10.4161/23328940.2014.982049. [PubMed: 27626044]

Girard O, Gaoua N, Grantham J, Knez W, Walsh A, Racinais S. 2021. Effects of living and working in a hot environment on cognitive function in a quiet and temperature-controlled room: an oil and gas industry study. Temperature (Austin). 8(4):372–380. doi: 10.1080/23328940.2021.1959289. [PubMed: 34901319]

Gubernot DM, Anderson GB, Hunting KL. 2014. The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. Int J Biometeorol. 58(8):1779–1788. doi: 10.1007/s00484-013-0752-x. [PubMed: 24326903]

Hagan-Haynes K, Ramirez-Cardenas A, Wingate KC, Pratt S, Ridl S, Schmick E, Snawder J, Dalsey E, Hale C. 2022. On the road again: a cross-sectional survey examining work schedules, commuting time, and driving-related outcomes among U.S. oil and gas extraction workers. Am J Ind Med. 65(9):749–761. doi: 10.1002/ajim.23405. [PubMed: 35735247]

Ioannou LG, Foster J, Morris NB, Piil JF, Havenith G, Mekjavic IB, Kenny GP, Nybo L, Flouris AD. 2022. Occupational heat strain in outdoor workers: a comprehensive review and meta-analysis. Temperature (Austin). 9(1):67–102. doi: 10.1080/23328940.2022.2030634. [PubMed: 35655665]

Jacklitsch B, Williams WJ, Musolin K, Coca A, Kim J-H, Turner N. 2016. NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments. Cincinnati (OH): U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No.: 2016-106. https://www.cdc.gov/niosh/docs/2016-106/pdfs/2016-106.pdf

Karasick AS, Thomas RJ, Cannon DL, Fagan KM, Bray PA, Hodgson MJ, Tustin A. 2020. Notes from the field: amphetamine use among workers with severe hyperthermia–eight states, 2010–2019. MMWR. 69(30):1004–1005. [PubMed: 32730241]

Kiyatkin EA, Sharma HS. 2009. Acute methamphetamine intoxication. Brain hyperthermia, blood-brain barrier, brain edema, and morphological cell abnormalities. Int Rev Neurobiol. 88:65–100. doi: 10.1016/S0074-7742(09)88004-5. [PubMed: 19897075]

Liu B, Varghese BM, Hansen A, Zhang Y, Driscoll T, Morgan G, Dear K, Gourley M, Capon A, Bi P. 2022. Heat exposure and cardiovascular health outcomes: a systematic review and meta-analysis. Lancet Planet Health. 6(6):e484–e495. doi: 10.1016/S2542-5196(22)00117-6. [PubMed: 35709806]

McDonald O, Shanks N, Fragu L. 2008. Heat stress: improving safety in the Arabian Gulf oil and gas industry. Prof Safety. 53(8):31–36.

Miller V, Bates G, Schneider JD, Thomsen J. 2011. Self-pacing as a protective mechanism against the effects of heat stress. Ann Occup Hyg. 55(5):548–555. doi: 10.1093/annhyg/mer012. [PubMed: 21474543]

Morrissey MC, Casa DJ, Brewer GJ, Adams WM, Hosokawa Y, Benjamin CL, Grundstein AJ, Hostler D, McDermott BP, McQuerry ML, et al. 2021. Heat safety in the workplace: modified Delphi consensus to establish strategies and resources to protect the US workers. Geohealth. 5(8):e2021GH000443. doi: 10.1029/2021GH000443.

NIOSH. 2017. Heat stress: work/rest schedules. Spokane (WA): U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2017–127; [accessed 2023 Aug 15]. https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2017-127.pdf

NIOSH. 2021. Fatalities in the oil and gas extraction industry. Washington (DC): National Institute for Occupational Safety and Health; [accessed 2022 Jul 22]. https://www.cdc.gov/niosh/topics/fog/default.html

OSHA. 2014. Occupational safety and health standards: reporting fatalities, hospitalizations, amputations, and losses of an eye as a result of work-related incidents to OSHA. Washington (DC): Occupational Safety and Health Administration; [accessed 2022 Jul 22]. https://www.osha.gov/laws-regs/regulations/standardnumber/1904/1904.39

OSHA. 2015. Severe injury reports. Washington (DC): Occupational Safety and Health Administration; [accessed 2022 Jul 22]. https://www.osha.gov/severeinjury

OSHA. 2018. State plan adoption of OSHA's revised reporting requirements. Washington (DC): Occupational Safety and Health Administration; [accessed 2022 Jul 22]. https://www.osha.gov/recordkeeping/2014/state-adoption-table

OSHA. 2022. Report a fatality or severe injury. Washington (DC): Occupational Safety and Health Administration; [accessed 2022Jul22]. https://www.osha.gov/report

Ramirez-Cardenas A, Wingate K, Pompei R, King B, Scott K, Hagan-Haynes K, Chosewood LC. 2023. Fatalities involving substance use among US oil and gas extraction workers identified through an industry specific surveillance system (2014–2019). J Occup Environ Med. 65(6): 488–494. doi: 10.1097/JOM.0000000000002856. [PubMed: 36998177]

Ridl S, Retzer K, Hill R. 2017. Oil and gas extraction worker fatalities 2014: NIOSH fatalities in Oil and Gas Extraction (FOG) database. Denver (CO): U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No.: 2017–193. https://Www.cdc.gov/niosh/docs/2017-193/2017-193.pdf

RRC. 2022. Permian basin information and statistics. Austin (TX): Railroad Commission of Texas; [accessed 2022 Aug 8]. https://www.rrc.texas.gov/oil-and-gas/major-oil-and-gas-formations/permian-basin/

Saidi A, Gauvin C. 2023. Toward real-time thermal stress prediction systems for workers. J Therm Biol. 113: 103405. doi: 10.1016/j.jtherbio.2022.103405. [PubMed: 37055098]

Schulte PA, Chun HK. 2009. Climate change and occupational safety and health: establishing a preliminary framework. J Occup Environ Hyg. 6(9):542–554. doi: 10.1080/15459620903066008. [PubMed: 19551548]

Sharma HS, Muresanu D, Sharma A, Patnaik R. 2009. Cocaine-induced breakdown of the blood-brain barrier and neurotoxicity. Int Rev Neurobiol. 88:297–334. [PubMed: 19897082]

Siddique A, Rodrigues C, Simmons R. 2019. The impact of PV shades in reducing heat stress in the ONG drilling industry in the western region of the United Arab Emirates. Paper Presented at: The Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE. doi: 10.2118/197462-MS.

Varghese BM, Hansen A, Bi P, Pisaniello D. 2018. Are workers at risk of occupational injuries due to heat exposure? A comprehensive literature review. Saf Sci. 110(Part A):380–392. doi: 10.1016/j.ssci.2018.04.027.

Yang YC, Wei MC, Hong SJ. 2017. Evaluation of occupation hot exposure in industrial workplaces in a subtropical country. Int J Occup Med Environ Health. 30(3): 379–395. doi: 10.13075/ijomeh.1896.00761. [PubMed: 28481372]

Table 1.

Criteria for epidemiological case definitions of heat-related fatalities.

Criterion 1:	The worker had a measured core temperature of 40.5 °C (105 °F) or greater
Criterion 2:	The worker had symptoms of brain dysfunction consistent with heat stress including loss of consciousness, mental status changes, seizures, and delirium/agitation
Criterion 3:	The worker was performing moderate, heavy, or very heavy physical activities[a] in an environment with a temperature that was measured or assumed to be greater than 32.2 °C (90 °F). A temperature less than 32.2 °C can be accepted if the worker was wearing heat-insulating clothing.
Criterion 4:	"Hyperthermia," "heat stress," "heat exhaustion," or "heatstroke" were mentioned as potential contributing causes of death on the final OSHA inspection or medical examiner's report
• Incidents that met at least three of the above criteria were defined as definite epidemiological cases of heatstroke.	
• Incidents that met two of the above criteria were defined as possible epidemiologic cases of heatstroke or where HRI was a contributing factor in fatalities.	

[a] Per the 2017 ACGIH® TLV® manual, moderate activity is defined as normal walking, sustained moderate upper or lower extremity work, such as light pushing and pulling. Heavy activity is defined as intense upper or lower extremity work, such as carrying, shoveling, sawing, pushing, or pulling heavy loads, or fast-paced walking. Very heavy activity is defined as very intense activity at a fast to maximum pace (ACGIH 2017).

Table 2.

Characteristics of heat-related fatalities among OGE workers, fatalities in oil and gas extraction (FOG) database, 2014–2019 (*n*=9).

	Count	% of Total
Age		
Median (Range)	35 (19–67)	
Sex		
Male	9	100
NAICS		
213112—Well Servicing	9	100
States		
Kansas	1	11.1
Texas	8	88.9
Months of fatality		
June	3	33.3
July	3	33.3
August	2	22.2
September	1	11.1
Heat-related conditions identified		
Measured core temperature of 40.5 °C (105 °F) or greater	3	33.3
Symptoms of brain dysfunction including loss of consciousness, mental status changes, seizures, and delirium/agitation	9	100
Moderate, heavy, or very heavy physical activity in an environment with temperature greater than 32.2 °C (90°F)	8	88.9
Additional risk factors		
Lack of acclimatization	4	44.4
Inadequate training	5	55.6
Use of PPE that may have contributed to heat load	2	22.2
Underlying hypertension or arteriosclerotic cardiovascular disease	4	44.4
Body mass index (BMI) above 30.0 (obese)	5	55.6
Positive drug screen	5	55.6
First day of work	3	33.3
Worked at the company for less than 2 weeks	5	55.6

Table 3.

Characteristics of heat-related adverse health effects resulting in hospitalizations among OGE workers, OSHA Severe injury database, January 2014–May 2021 (*n*=50).

	Count	% of Total
NAICS		
211—Operators	2	4
213111—Drilling Contractors	13	26
213112—Well Servicing Contractors	35	70
State[a]		
Arkansas	1	2
Illinois	2	4
Louisiana	3	6
Mississippi	1	2
North Dakota	5	10
Ohio	3	6
Oklahoma	5	10
Texas	30	60
Month of recorded incident		
May	4	8
June	7	14
July	21	42
August	12	24
September	6	12
Heat exhaustion symptoms[b]		
Body aches/cramps/pain	14	28
Feeling ill or sick	8	16
Nausea/vomiting	6	12
Lightheadedness or dizziness	4	8
Fatigue or weakness	2	4
Loss of consciousness or collapse	2	4
Shortness of breath	2	4
High Creatinine Kinase	1	2
Sweating heavily	1	2
Undefined	20	40

[a]The OSHA severe injury reports database does not include information from OSHA state plans which maintain their own requirements for reporting to their individual state agencies.

[b]Multiple symptoms may be reported for each individual.