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Risk Analysis of Occupational Heat-Related Illness

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Heat-related illness (HRI) has become a particular concern in recent years. Many industry workers are affected by HRI due to prolonged exposure to heat and humidity. HRI is a well-known health threat that can lead to serious morbidity and mortality. This study aimed to recognize HRIs characteristics and risk factors by reviewing the HRI incident report between 1984 and 2020. Data cleaning and text mining methods were used to derive incident features and relevant risk factors. The results showed that trucks and roofs are the highest incidence locations and the main symptoms of HRI are collapse, dehydration, dizziness, and vomit. In the 1,406 incident cases, 43.8% of HRIs were fatal. The findings revealed that 89.7% of HRI patients were male with an average age of 41.4. Besides, HRIs were highly influenced by season and time of day, with 77% of incidents in the summer months and 64.1% between 11 am and 5 pm. Furthermore, between 1984 and 2020, HRI demonstrated a considerable upward tendency. The findings will assist employers and safety professionals to take appropriate actions to eliminate or reduce the identified risk factors.

Key Words: Heat-related Illness, Risk Factors, Workers, Text Mining

Introduction

Among all weather-related mishaps, heat is the leading cause of mortality. Due to climate change, extreme heat events become more frequent with an increased number of HRI cases in recent years (Coates et al., 2014; Jones et al., 2015). Working in hot environments can increase mortality and morbidity. Physical activity in a hot environment increases the risk of HRI, some of which can be fatal, such as heat exhaustion and heat stroke (Xiang et al., 2014). Occupations such as workers are more susceptible to HRI because of their frequent exposure to heat. In 2021, the United States is seeing record-breaking hot weather, putting millions of employees at risk of heat sickness or injury in both indoor and outdoor work situations (OSHA, 2021a). Thousands of employees suffer from HRI each year as a result of occupational heat exposure, even when underreported (EPA, 2021; OSHA, 2021b). Between 1992 and 2019, 907 employees died from heat stress, according to the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (BLS, 2021). HRI not only creates substantial health difficulties to employees but also leads to considerable productivity and financial losses (Flouris et al., 2018; Takakura et al., 2017).

However, HRIs are preventable and can be readily reduced by low-cost interventions (Casa et al., 2015; Lundgren et al., 2013; Payel et al., 2018). The Occupational Safety and Health Administration

(OSHA) has suggested a few measurements to prevent repeat accidents, such as monitoring heat conditions, training supervisors and workers to control and recognize heat hazards, and providing sufficient shade, fluids, and breaks (OSHA, 2021c). However, the increasing number of HRI cases in recent years indicates that reducing the occurrence of heat illnesses is still challenging. Nowadays, OSHA is seeking additional efforts or measures to improve workplace safety and protect indoor and outdoor workers from hazardous heat (OSHA, 2021d). OSHA does not have a specific regulation related to heat, and it is looking for additional information and interventions on HRI and initiating rulemaking to protect workers from harmful heat (OSHA, 2021d).

In order to prevent repeat accidents and promote workplace safety, it is essential to understand the causes of HRI accidents. OSHA gathered the accidents inspection reports from the local federal or state office and provided as a complete description as possible of how the accident occurred. The reports are crucial materials for the incidents factors analysis. The purpose of this study is to investigate the essential factors influencing HRI and other key elements by analyzing OSHA HRI accidents data from 1984 to 2020. Based on the results of the characteristics and risk factors of HRI accidents analysis, safety professionals can take appropriate actions to eliminate or reduce the identified risk factors.

Literature review

Risk Factors and Prevention of HRI

HRI is a syndrome that occurs when people are exposed to an extreme heat environment when their thermoregulatory functions are disrupted. HRI symptoms include heat rashes, heat cramps, heat exhaustion, and heat stroke (Lugo-Amador et al., 2004; Gauer et al., 2019). Risk factors of HRI include both environmental and human factors. These factors vary greatly with the workplace, occupation, and human factors (Zhang et al., 2014). The environmental factors include high temperature, high humidity, and direct sunlight (Wang et al., 2021). The human factors include age, physical exertion, mental illness, drugs, and pregnancy (Becker et al., 2011). Physicians and authorities can give preventive interventions by identifying high-risk populations and workplaces (Becker, et al., 2011). OSHA has taken a variety of approaches to address dangerous heat for both indoor and outdoor workers (OSHA, 2021c). These include requiring employers to provide workers with readily accessible drinking water, adequate rest, and shade (OSHA, 2021c). Employers in the construction industry are recommended to provide heat safety training to their employees (NIOSH, 2016). First aid actions will be taken when workers experience heat-related illnesses, such as hydration, taking rest, and accessing to an air-conditional area (Becker, 2011; Lugo-Amador et al., 2004).

A study concluded that HRI was associated with workers' age, maximum skin temperature, post-warm-up heart rate, and work area (Kakamu, et al., 2021). The study also found that simple actions can help to prevent HRIs, such as knowing the physical fatigue of workers in the morning was effective in preventing the occurrence of HRI. (Kakamu, et al., 2021). Researchers also found that workers with insufficient rest are less productive and have a higher risk of getting HRIs (Ebi et al., 2021). Many studies have shown that the HRI prevention measures being implemented by OSHA are effective. Studies found that taking extra precautions to protect new workers is essential. For example, an assessment of workplace deaths indicates that about 70% of deaths occurred during the first few days of work, and upwards of 50% occur on the first day of work (Arbury et al., 2014; Tustin et al., 2018). Additionally, it is also found that training supervisors and workers are an effective method to reduce HRIs. A study conducted training for farmworker crew leaders on OSHA's Heat Safety Tool application and evaluated the training effectiveness (Luque et al., 2020). The results showed that conducting heat safety training reduced the risk of HRI, especially among less experienced farmworkers (Luque et al., 2020). Another effective HRI prevention method is to introduce an HRI prevention program, which includes training, acclimatization, and medical care (McCarthy et al., 2019). In this program, the rate of HRI experienced by Texas outdoor workers declined each year from 2009 to 2017, and no HRI case was reported to occur over the hot season during the last two years (McCarthy et al., 2019). However, more HRI accidents still occurred because many companies or employers fail to effectively implement these preventive methods (Arbury et al., 2014). According to a questionnaire survey of military personnel, it is suggested that establishing educational programs and improving systematic educational materials are critical to raising awareness of HRI (Wang et al., 2021). Knowledge, attitude, and practice were recognized as the three most significant strategies for avoiding HRIs (Wang et al., 2021).

Occupational Safety and Health Data Collection and Analysis

The OSHA Integrated Management Information System (IMIS) provides a list of enforcement cases, including HRI cases. This database is updated daily from over 120 OSHA Area and State 18b plan offices (OSHA, n.d.). Additionally, many companies have developed incident reporting systems to identify hazards and actively prevent repeat incidents (Song et al., 2020). According to a steel manufacturing company, all incidents are required to be reported by the employees and workers and then organized by safety managers into company-specific categories (Song et al., 2018). Moreover, an electricity generation company documents accidents and incidents using different IT systems, and existing data gathering approaches are being continuously improved, such as the usage of risk registers (Leva et al., 2017). After an accident occurs, an inspection summary with a complete description of the accident process is significantly important for risk analysis. It is crucial to classify and analyze the risk factors and causes of accidents, as prevention strategies should be developed accordingly to different causes. However, natural language narratives are ambiguous and vague, unstructured textual data that require a lot of time and effort to retrieve and analyze (Soleimani et al., 2019). Currently, techniques such as Natural Language Processing (NLP), text mining, and machine learning are applied to text analysis.

Text mining is the process of extracting previously unseen and non-obvious information from textual data (Miner et al., 2012). The current researches mainly focus on optimizing text mining models and identifying and classifying risk factors (Zhang et al., 2019; Song et al., 2020). According to Song et al. (2020), to prevent the recurrence of similar accidents, an energy source recognition approach was applied to identify and evaluate hazards, and text mining was used to analyze the causal factors of past accidents. Before performing the classification process, NLP techniques were used by the researchers to pre-process the text data, then a hybrid supervised machine learning model was proposed for construction site accident classification (Cheng et al., 2020). For the classification of large injury accidents dataset, the Human-machine learning method was implemented to improve the accuracy of text mining (Marucci-Wellman et al., 2017). For example, a study combined techniques including machine learning to implement automatic coding and aid in extracting the causes of workers' injuries and compensation (Bertke et al., 2012).

Methodology

In this study, data collection, data cleaning, and text mining were used to identify the risk factors and features of HRI. The first step was to pre-process the unstructured narrative data from OSHA inspection summaries to extract the main elements of HRI such as demographic characteristics, time trending, location distribution, accident summary, etc. Then the study contributed the text mining technique to extract keywords of each HRI incident.

Data Collection

OSHA gathers occupational enforcement cases data and makes them publicly available on its website. This study obtained the HRI incident reports from the inspection summary of IMIS (OSHA, 2021e) between 1984 and 2020. Each report provides a complete description of each incident including the demographic characteristics and occupations of the workers, the event degree, the course of the accident, etc. A total of 2,418 relevant event records were identified under all heat-related keywords. The dataset was made up with a short one-sentence incident description. The detailed incident description text data were then acquired from the Summary ID of each incident. A complete dataset was finalized in an excel spreadsheet.

Data Cleaning

Due to the ambiguity and vagueness of natural language description, a few data cleaning methods were used to correct and remove inaccurate information. As a result, 1,406 valid data were identified by the HRI keyword search such as "heat-related illness", "heat stroke", and "heat exhaustion". The most significant and independent columns in the excel file were designated using feature selection analysis, including Date, Time, City, State, Accident degree, Age, Sex, Occupation and Incident description, while the less important ones were removed (Table 1).

This study used a TM package in R-language to discover the characteristics and key factors of HRI from investigation summaries (Feinerer, 2008). Before starting to mine the text data, several spelling problems and unnecessary characters had to be fixed or eliminated. For example, removing all punctuations, stop words, and numbers, and converting uppercase letters to lowercase letters. Furthermore, the number of possible keywords was reduced by combining words with different tenses and similar meanings. For example, the combination of "fall" and "fell" is classified as "fall", and the combination of "roofing" and "roof" is classified as "roof".

Table 1

A sample dataset of the collected HRI incident data

Event number	1	2	3
Summary number	129395.01	129284.01	128851.01
Age	23	39	45
Sex	M	M	M
Date	9/4/20	9/3/20	8/20/20
Time	5:00 PM	2:15 PM	11:00 AM
City	Oklahoma City	Hampton	Englewood
State	OK	VA	CO
Accident Degree	Fatality	Fatality	Fatality
Occupation	Construction Laborers	Carpenter	Construction Laborers

Investigation Summary	At 5:00 p.m. on September 4, 2020, an employee was working to break concrete and separate rebar. At some point, the employee requested a break and upon returning from the break showed signs of disorientation and was stumbling. The employee was taken to a local hospital, where the employee died of suspected heat stroke.	At 2:15 p.m. on September 3, 2020, an employee worked outdoors performing various labor tasks such as site cleanup and demolition of roof materials. After approximately six to seven hours of working in the heat, the employee went to the work vehicle to take a break. The employee was later discovered unresponsive in the driver's seat of the vehicle. Coworkers called for emergency services and at tempted first aid. The employee was transported, by ambulance, to a local hospital, where the employee was pronounced dead of heat stroke.	At 11:00 a.m. on August 20, 2020, Employee #1, employed by a specialty construct ion company, was setting rebar for a new commercial building, a multi-employer construction project. He was placing and tying the rebar when he showed signs of heat-related illness. Employee #1 walked to a shaded area, collapse, and died. His death was attributed to an apparent heat stroke.

Results

Demographics and HRI Characteristics

Of these 1406 HRI incidents, 616 were fatalities, 535 were hospitalized and 256 were non-hospitalized. The average age (standard deviation) was 41.4 with a maximum of 25% of young workers aged 25-34 (Figure 1). Besides, the majorities were males 89.7% and females were 10.3%.

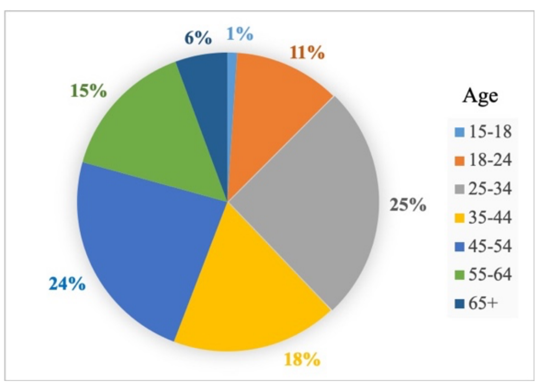

Figure 1. The age distribution of HRI workers

HRI accidents were unevenly distributed by month and time of day, with the majority of HRIs (77%) occurring in the summer months: June, July, and August. The largest proportion (36%) occurred in July. During the day, the most HRI occurred between 11 am and 5 pm, making up 64.1% of the total accidents during the day (Figure 2). In Figure 3, HRI has shown an increasing trend over the past thirty years. Especially in the last five years, the number of HRI accidents has a significant and rapid increase. The most significant increase is in hospitalized accidents, where the number of HRI accidents has increased by 257% over the last five years.

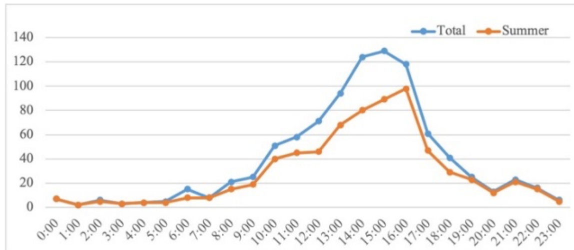

Figure 2. The whole year and summer time distribution of HRI accidents

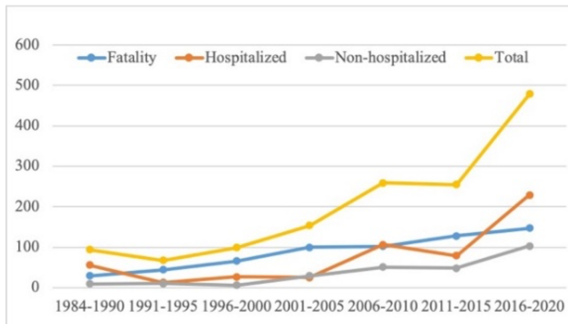

Figure 3. Trends of the number HRI incidents in 1984-2020

The US Census Bureau divides the US into four regions, including Northeast, Midwest, South, and West. According to Figure 4, the West region had the highest number of HRI cases at 47%, with California accounting for 42% of all regions and 90% of the West. Then followed by the South region, which accounted for 33% of all HRI accidents in the US. The Northeast and Midwest had fewer HRI cases, with 9% and 11% respectively.

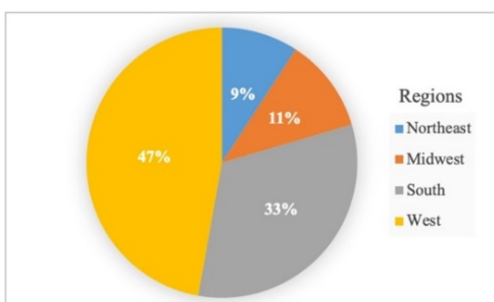

Figure 4. The geographic distribution of HRI accidents

Key Risk Factors

According to the text mining results, several keywords showed up as the most significant factors of the HRI accidents (Figure 5). The top twenty were "July", "August", "June", "Collapse", "Truck", " Dehydration", "Training", "Roof", "Humidity", "Fall", "Dizzy", "Lunch", "Weather", "Concrete", "September", " Vomit", "Firefighters", "Cramp", and "Vehicle". These factors also indicated that the

HRI accidents occurred mainly in the summer, and that trucks, roofs, etc. were the main locations of accidents. It can also be seen that the main symptoms of HRI are collapse, dehydration, dizziness, vomit, etc.

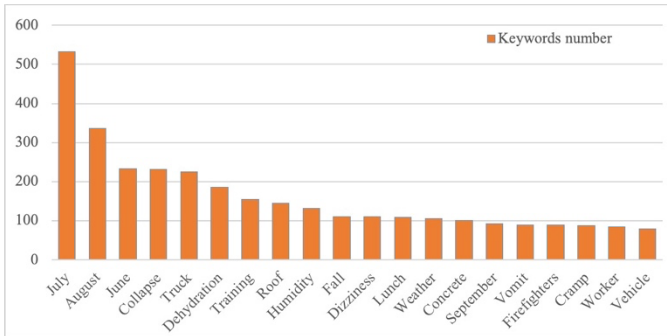

Figure 5. The keywords of the HRI accidents description text data

Conclusion

This study analyzed 1,406 HRI incident reports between 1984 and 2020. Through the methods of data cleaning and text mining, descriptive text data were used to identify characteristics and key risk factors of HRI accidents. The demographic characteristics indicated that middle-aged male workers were more frequently injured by heat stress. The temporal and spatial distribution revealed that time and location have a strong influence on HRI. In addition, “roof” is a location-based keyword with a high number of occurrences. Workers should minimize long-time work on the roof during hot seasons and periods. It is also suggested that more protective and effective measurements should be implemented when working on the roof. The results of the study can help with developing more explicit risk control plans for specific populations and dangerous workplaces.

This study analyzed the spatial and temporal characteristics of the number of HRI in recent years, and the next step will analyze the ratio of HRI to total workers to derive a more comprehensive understanding of the spatial and temporal variation of HRI. Future research also can explore the potential correlations between HRI factors and provide more effective HRI prevention strategies. In addition, root cause analysis can be conducted on HRI accidents, such as global warming, to seek more effective hazard control measures.

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