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Snow or ice-related injury claims in cold months during 2016–2021

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ABSTRACT

Introduction: Falls, a preventable worker-related injury, are major contributors to worker's disability and death. In spite of this, there is relatively little analysis on snow or ice- related slips, trips and falls among workers in the workers' compensation system. This analysis aimed to describe the frequency, characteristics, and occupational burden of snow or ice-related slip, trip, or fall (STF) claims in Wisconsin. *Methods:* This study is a descriptive analysis of working age adults' snow or ice-related STF lost time claims during the months of October through April for the years 2016–2022. *Results:* A total of 7,385 claims were reported, which represented 33.1% of all STF injuries. The overall claim rate during the study period was 2.65 claims per 1,000 workers (95% CI: 2.60 – 2.71). Workers aged 45 years or more had the highest risk. Fracture of lower leg, including ankle (20.3%), intracranial injury (10.7%), and fracture of the forearm (7.3%) were the most frequent primary diagnoses among hospitalized cases or seen in the emergency room. The mean lost time was 11.8 weeks (range: 0.5 – 210.3 weeks). Transportation and Warehousing, Public Administration and Wholesale Trade industries had the highest burden. Occupations with the highest burden were Transportation and Material Moving, Building and Grounds Cleaning and Maintenance, Installation, Maintenance, and Repair. Conclusions: Snow or ice-related STFs remain a common cause of injuries in cold weather and are particularly relevant for an aging workforce. *Practical Applications:* This analysis informs on the occupational burden of the snow or ice-related events on workers. It is important for preparedness and prevention efforts because of the frequency of unpredictable snow or ice events particularly in regions that are not used to it.

1. Introduction

Falls are the second leading cause of unintentional injury-related deaths among adult workers (National Safety Council, 2021; U. S. Bureau of Labor Statistics, 2023) and contribute significantly to disabilities subsequent to fractures, head injuries and other traumatic injuries. Slips, trips and falls (STF) had the third highest cases of days away from work, job restriction, or transfer (U. S. Bureau of Labor Statistics, 2023). Despite an overall downward trend in injuries, ice and snow injuries remain the predominant secondary cause of weather-related occupational deaths across years (U. S. Bureau of Labor Statistics, 2022). In 2021, among U.S. working adults, falls accounted for 2.28 million emergency department (ED) visits and amounted to $248.61 billion in total costs, including medical, work loss and quality of life costs (National Center for Injury Prevention Control & Centers for Disease Control and Prevention, 2021). The overall burden is much greater if we factor in the impact on family, cost of work accommodations and productivity (Quintana, 1999).

Several occupational and general injury studies have determined that the risk of STF increased significantly with cold weather such as snow or ice events (Bell et al., 2013; Bentley & Haslam, 1998; Hippi & Kangas, 2022; Lewis & Lasater, 1994; Lipscomb et al., 2006; Smith & Nelson, 1998). Colder regions have higher STF rates than other regions and the highest cold-weather STF rates are experienced by the working-age population during weekday morning commutes (Unguryanu et al., 2020). In Wisconsin, a northern U.S. state known for cold weather, falls or slips were a major leading cause of workplace injury in 2022 and snow or ice-related injuries amounted to 5% of all lost time payment and 6% of permanent partial disability payment (Wisconsin Occupational and Health Safety Program & Department of Health Services, 2024).

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In spite of this, there are few efforts to systematically track the incidence of occupational snow or ice-related STF injuries over time, by region, or by industry and occupation. Little has been done in the U.S. in the past thirty years, since Leamon and Murphy's comprehensive STF analysis of Worker's Compensation data and Sink et al's evaluation of winter-related occupational injury claims (Leamon & Murphy, 1995; Sinks et al., 1987). Even studies outside the U.S. are dated and generally limited to a particular sector (Bentley & Haslam, 1998; Frost et al., 2022; Hauschild et al., 2016; Lipscomb et al., 2006) or focused on interventions such as proper footwear (Bagheri et al., 2019; Cockayne et al., 2021; Gao & Abeysekera, 2004). Given the dearth of recent literature in this area, the burden of snow or ice-related occupational slips, trips and falls and the potential variation in trends with climate change, more current and systematic examinations of this type of occupational injury are warranted.

This paper focuses on these injuries in Wisconsin, a state known for its winter conditions. The present analysis aims to describe the frequency and characteristics of Wisconsin's snow or ice-related STF claims and examine the occupational burden using worker's compensation claim data.

2. Methods

2.1. Study design

This was a descriptive analysis to characterize snow or ice-related STF injury claims (claim counts, denials, proportion of STF claims relative to all claims, demographics, injury types) among Wisconsin working age adults (18–64 years) and their occupational burden (lost time, claim counts and rates by industry and occupation, and prevention indices) during October 1, 2016–April 30, 2022. For the purpose of this analysis, we defined winter-season as the period between October 1 and April 30, which means May to September was excluded from each year. This covers the full season of likely ice and snow events in Wisconsin in recent years. This analysis adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (SDC1 STROBE checklist).

2.2. Operational definitions

We defined a snow or ice-related STF injury as any injury for which detailed claim information cause of injury code was coded as "*ice or snow*" according to the worker's compensation insurance organization (WCIO) codes (Worker Compensation Insurance Organization, 2023). To account for miscoded claims, we included any other claims where the injury description contained the words "*ice"* or "*snow*" and "*fall*," "*slip*," "*trip*," "*iced*," "*icy*," "*icey*," "*snowy*," "*snowed*," "*snowey*," or "*fell*." These additional claims were reviewed for accuracy and the claims related to "*ice machine*" or "*ice rink*" incidents were excluded.

2.3. Data sources

The primary data source was workers compensation claims extracted from the Wisconsin workers compensation claims database. Occupational injury claims in the database were reported to the Wisconsin Department of Workforce Development by insurance carriers and some self-insured employers. Claims data included claimant occupation, nature of injuries, body parts injured, payment status, the amount of lost work time and associated lost time payments.

Unemployment insurance (UI) data were used to identify the claimant's industry. Employers listed in the claims data were linked to UI, which served as the source of the employer's industry code according to the North American Industry Classification System (NAICS).

Hospital discharge data were linked to the claim data by name, date of birth and sex to identify cases who sought care in the Emergency Department or were admitted after the injury. We included hospitalization records that happened within three days from the injury date. Primary and secondary diagnoses were also obtained for hospitalized cases, using the International Classification of Diseases Clinical Modification (ICD10-CM) codes in the discharge data.

Finally, to obtain the number of workers to serve as the denominator for demographics and industry and occupation rate calculations, we used the 5-year (2017–2021) American Community Survey (ACS) extracted from Integrated Public Use Microdata Series (IPUMS) (Ruggles et al., 2022). Unstable denominators (i.e., relative standard error $>$ 30%) were excluded from this analysis. Following the stability criteria established by the Washington State Department of Labor & Industries, Safety and Health Assessment and Research for Prevention (SHARP) Program, industries or occupations with fewer than 45 claims during the study period were also considered unstable and therefore excluded (Anderson et al., 2014).

2.4. Industry and occupation identification

We linked the worker's compensation claims data to the UI data by the federal employer identification number (FEIN). In cases where the previous linkage was not conclusive, we conducted a second linkage by employer name and manually reviewed them for accuracy. We derived the occupation from both the occupation and injury description fields. To obtain the standard occupation codes (SOC), we run the free-text occupation description through the National Institute for Occupational Safety and Health (NIOSH) Industry and Occupation Computerized Coding System (NIOCCS) (U.S. National Institute for Occupational Safety and Health, 2021).

2.5. Statistical analyses

We conducted descriptive analyses by computing the annual claim counts, percent of claims denied, and the proportion of snow or ice-related STF claims relative to all claims. We determined snow or ice-related STF claim rates and rate ratios by age using the youngest age category (18–24 years) as reference. Lost time and lost time payments were described as mean and range (minimum and maximum) and total lost time payment. We determined claim counts and rates by industry sector (2-digit NAICS), major occupation (2-digit SOC) and minor occupation (3-digit SOC). Rates were expressed as claims per 1,000 workers and their 95% confidence interval was computed.

We ranked the industry sectors and occupations (major and minor) by using the prevention index (Anderson et al., 2014). The prevention index (see formula below) ranks industries and/or occupations equally by claim count and claim rate, and it is used in occupational health to determine the burden of an injury as well as the industries or occupations where prevention strategies could have the most impact (Anderson et al., 2014; Meyers et al., 2018). We also computed the prevention index (PI) by minor occupations.$Prevention\ index = (Frequency\ rank + Rate\ rank)/2$.

The data were cleaned, visualized and analyzed by using the statistical software R interfaced with Posit (formerly called RStudio).

3. Results

During the study period, a total of 7,385 snow or ice-related STF claims were reported to the Department of Workforce Development in Wisconsin, averaging 1,231 claims (range: 868–1,748) per winter-season. No upward or downwad trend was detected during the study period (Mann-Kendall trend test, $p = 0.13$). Out of the total claims, 10.4% ($n = 772$ claims) were denied. The snow or ice-related STF claims represented 33.1% (7,385/22,257) of slip, trip and fall SFT claims and 8.3% (7,385/89,411) of all claims during the study period. Close to two-thirds (62.9%) of the injuries occurred among workers who were at least 45 years old. Such workers were more than four times more likely to be injured compared to the youngest workers (18–24 years) (Table 1).

Table 1
Snow or ice-related claim count, percentage, rate with 95% confidence interval (CI) and rate ratio by age category from October 1, 2016 – April 30, 2022.

Age (years)	Number of claims (N = 7,385)	Percentage of all claims (%)	Rate	Rate ratio (95% CI)
18–24	333	4.5	0.88	—
25–35	992	13.4	1.62	1.84 (1.63–2.09)
35–44	1,414	19.1	2.3	2.6 (2.31–2.94)
45–54	2,162	29.3	3.55	4.03 (3.59–4.53)
55–64	2,484	33.6	4.38	4.97 (4.44–5.59)

Abbreviations: CI: Confidence interval.

Using the Worker Compensation Insurance Organization nature of injury classification – which is distinct from a clinical classification – most injuries were coded as strain or tear (28.5%), fracture (20.1%), contusion (16.6%) and sprain or tear (12.9%). Workers reported the following injured body parts: knee (15.6%), shoulders (14.4%) and multiple body parts (14.2%). In our dataset, 21.8% (1,718 workers) were documented in the hospital discharge data. Fracture of lower leg, including ankle (20.3%), intracranial injury (10.7%) and fracture of the forearm (7.3%) were the most predominant primary diagnoses among hospitalized or ED cases. Two other types of traumatic head injuries, "other and unspecified injuries of head" (4.7%) and "superficial injury of head" (1.8%), were found among the most predominant clinical diagnoses. The mean lost time in our dataset was 11.8 weeks (range: 0.5–210.3 weeks). However, 30% of workers were out of work for at least 10.7 weeks and 10% were out of work for at least 22.2 weeks (Fig. 1). The mean lost time payment was U.S. $6,311 (range: $14.3 – $198,859.2) and amounted to U.S. $33,222,097.

Linking the snow or ice-related STF claims data to UI data allowed identification of 92.1% of industry codes and 89.2% of occupation codes, leaving 587 claims (7.9%) without standard industry codes and 799 claims (10.8%) without standard occupation codes.

The overall snow or ice-related STF claim rate during the study period was 2.65 claims per 1,000 workers (95% CI: 2.60–2.71). The industry sectors with the highest prevention index for snow or ice-related claim rates were Transportation and Warehousing, Public Administration and Wholesale Trade (Table 2). Healthcare and Social Assistance (PI: 5) and Manufacturing (PI: 10) were two sectors with high claim counts (respectively, n: 854 and n: 764) and low claim rates (respectively, rate: 2.0; 95% CI: 1.9–2.2 and rate: 1.5, 95% CI: 1.4–1.6).

Table 2
Snow or ice-related claim count, percentage, rate and prevention index (PI) by industry sector from October 1, 2016 – April 30, 2022.

Sector	Count (N = 7,385)	Percentage	Rate (95% CI)	PI
Transportation and Warehousing	884	13.0	7.7 (7.1–8.2)	1
Public Administration	828	12.2	8.4 (7.8–9)	2
Wholesale Trade	431	6.3	5.9 (5.4–6.5)	3
Construction	498	7.3	2.8 (2.6–3.1)	4
Health Care and Social Assistance	854	12.6	2 (1.9–2.2)	5
Administrative and Support and Waste Management and Remediation Services	395	5.8	4.3 (3.9–4.8)	6
Educational Services	473	7.0	2 (1.8–2.2)	7
Real Estate and Rental and Leasing	123	1.8	3.7 (3.1–4.4)	8
Retail Trade	488	7.2	1.7 (1.5–1.8)	9
Manufacturing	764	11.2	1.5 (1.4–1.6)	10
Information	98	1.4	2.2 (1.8–2.7)	12
Accommodation and Food Services	250	3.7	1.6 (1.4–1.8)	13
Agriculture, Forestry, Fishing and Hunting	101	1.5	2 (1.6–2.3)	14
Other Services (except Public Administration)	126	1.9	1.1 (0.9–1.3)	16
Professional, Scientific, and Technical Services	130	1.9	0.9 (0.7–1)	17
Finance and Insurance	118	1.7	0.8 (0.7–1)	18

Abbreviations: CI: confidence interval; PI: Prevention index.

The top major occupations by prevention index were Transportation and Material Moving; Building and Grounds Cleaning and Maintenance; Installation, Maintenance, and Repair; Office and Administrative Support and Protective Service (Table 3). All these top major occupation groups except Office and Administrative Support had a snow or ice-

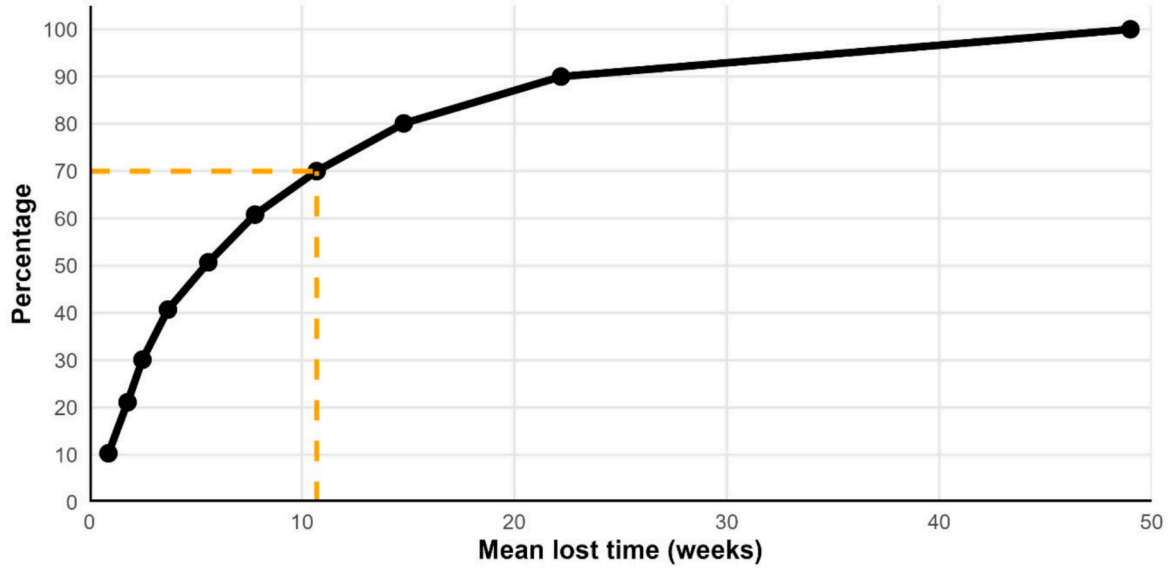

Fig. 1. Snow or ice-related SFT percentage of workers by mean lost time from October 1, 2016 – April 30, 2022.

Table 3
Snow or ice-related claim count, percentage, rate and prevention index (PI) by major occupation from October 1, 2016 – April 30, 2022.

Major occupation	Count (N = 7,385)	Percentage	Rate (95% CI)	PI
Transportation and Material Moving	1,808	27.5	8.3 (7.9–8.7)	1
Building and Grounds Cleaning and Maintenance	436	6.6	5.1 (4.6–5.5)	2
Installation, Maintenance, and Repair	412	6.3	4.4 (4–4.8)	3
Office and Administrative Support	593	9.0	2 (1.8–2.1)	4
Protective Service	289	4.4	6.8 (6–7.6)	5
Healthcare Support	323	4.9	3.1 (2.7–3.4)	6
Construction and Extraction	359	5.5	2.8 (2.5–3.1)	7
Production	496	7.5	1.8 (1.6–2)	8
Healthcare Practitioners and Technical	302	4.6	1.7 (1.5–1.9)	9
Farming, Fishing, and Forestry	72	1.1	3.3 (2.5–4.1)	10
Sales and Related	316	4.8	1.3 (1.2–1.5)	11
Community and Social Service	96	1.5	2 (1.6–2.4)	12
Food Preparation and Serving Related	218	3.3	1.7 (1.5–2)	13
Educational Instruction and Library	242	3.7	1.5 (1.3–1.7)	14
Management	299	4.5	1 (0.9–1.1)	15
Personal Care and Service	62	0.9	1.1 (0.8–1.3)	16
Business and Financial Operations	96	1.5	0.6 (0.5–0.8)	17
Arts, Design, Entertainment, Sports, and Media	47	0.7	1 (0.7–1.3)	18
Architecture and Engineering	49	0.7	0.8 (0.6–1)	19

Abbreviations: CI: confidence interval; PI: Prevention index.

related claim rate higher than that of the remaining major occupations. Production workers had the third highest snow or ice-related claim count (PI: 8; n: 496) and relatively low claim rate (rate: 1.8; 95% CI: 1.6–2.0) similar to that of Office and Administrative Support (Table 3).

At the more detailed level (Table 4), the top five minor occupations by prevention index were Motor Vehicle Operators (n:1,262; rate: 15.4; 95% CI: 14.5–16.2), Building Cleaning and Pest Control Workers (n: 366; rate: 5.8; 95% CI: 5.2–6.4), Material Moving Workers (n: 519; rate: 4.2; 95% CI: 3.8–4.6), Other Installation, Maintenance, and Repair Occupations (n: 275; rate: 5.8; 95%CI: 5.1–6.5) and Material Recording, Scheduling, Dispatching, and Distributing Workers (n:233; rate: 5; 95% CI: 5,1–6.5).

4. Discussion

Our analysis showed the high occupational burden of snow or ice-related STF injuries in terms of injuries, lost time, industry and occupation distribution. The likelihood of incurring these injuries increased significantly with workers 45 years old or more. The predominant injuries among hospitalized cases were fractures of the lower leg including ankle, followed by head injuries. Almost one third of injured workers were out of work for 10 weeks or more.

The percentage of snow or ice-related STF claims (33.1%) in our analysis was similar to that of a worker's compensation insurance carrier's analysis in 2013–2014. The latter showed that winter STF represented 29% of all worker's compensation claims and specifically 33% in Wisconsin (Accident Fund Holding Inc, 2014). All these findings denote the need for prevention strategies to ensure a healthy workforce across seasons.

Our analysis identified high-burden industries and occupations. Industries with the highest occupational burden were Transportation and Warehousing, Public Administration and Wholesale Trade. Occupations with the highest burden were Transportation and Material Moving, Building and Grounds Cleaning and Maintenance, Installation, Maintenance, and Repair. Looking at both minor occupation and industry, motor vehicle operators had the highest rates and were concentrated in Wholesale Trade, Transportation and Warehousing, Retail Trade and Manufacturing. This points towards a high risk for delivery drivers in particular.

Table 4
Snow or ice-related claim count, rate and prevention index (PI) by minor occupation from October 1, 2016 – April 30, 2022.

Description	Count	Rate (95% CI)	PI
Motor Vehicle Operators	1,262	15.4 (14.5–16.2)	1
Building Cleaning and Pest Control Workers	366	5.8 (5.2–6.4)	2
Material Moving Workers	519	4.2 (3.8–4.6)	3
Other Installation, Maintenance, and Repair Occupations	275	5.8 (5.1–6.5)	4
Material Recording, Scheduling, Dispatching, and Distributing Workers	233	5 (4.4–5.7)	5
Law Enforcement Workers	175	8.6 (7.3–9.8)	6
Home Health and Personal Care Aides; and Nursing Assistants, Orderlies, and Psychiatric Aides	267	3.8 (3.3–4.2)	7
Construction Trades Workers	297	2.6 (2.3–2.9)	8
Health Technologists and Technicians	115	2.2 (1.8–2.6)	9
Other Production Occupations	178	1.8 (1.5–2.1)	10
Assemblers and Fabricators	97	2.2 (1.8–2.6)	11
Other Office and Administrative Support Workers	110	2.1 (1.7–2.6)	12
Healthcare Diagnosing or Treating Practitioners	184	1.5 (1.2–1.7)	13
Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	84	2.4 (1.9–2.9)	14
Agricultural Workers	62	3.3 (2.5–4.1)	15
Other Educational Instruction and Library Occupations	65	2.8 (2.1–3.5)	16
Information and Record Clerks	158	1.6 (1.4–1.9)	17
Other Sales and Related Workers	62	3.1 (2.3–3.8)	18
Other Management Occupations	190	1.1 (1–1.3)	19
Other Protective Service Workers	51	3.8 (2.8–4.8)	20
Cooks and Food Preparation Workers	92	1.9 (1.5–2.3)	21
Counselors, Social Workers, and Other Community and Social Service Specialists	81	2.1 (1.6–2.6)	22
Preschool, Elementary, Middle, Secondary, and Special Education Teachers	118	1.2 (1–1.5)	23
Retail Sales Workers	109	1.2 (1–1.4)	24
Grounds Maintenance Workers	46	2.7 (1.9–3.5)	25
Metal Workers and Plastic Workers	89	1.4 (1.1–1.7)	26
Sales Representatives, Wholesale and Manufacturing	57	1.9 (1.4–2.4)	27
Food and Beverage Serving Workers	72	1.5 (1.1–1.8)	28
Other Healthcare Support Occupations	54	1.8 (1.3–2.2)	29
Business Operations Specialists	72	0.8 (0.6–0.9)	30
Operations Specialties Managers	54	0.9 (0.6–1.1)	31
Supervisors of Sales Workers	48	0.7 (0.5–0.8)	32

Abbreviations: CI: confidence interval; PI: Prevention index.

A similar analysis in Maine, a state in the northeast U.S., showed the same distribution of industries and occupations (Dawson & Maine Department of Labor Research and Statistics Division, 2013). The workers in these industries and occupations are mostly outdoors and their work requires them to be exposed to snow and ice hazards while performing their tasks (Council of States Territorial Epidemiologists, 2023).

The literature identifies other risk factors that contribute to these injuries. There are human bio-mechanic factors, underfoot conditions, built-in environmental hazards (e.g., inadequate lighting, steps, uneven sidewalks or pavement), poor quality footwear, unsafe working practices or work behaviors, and workplace policies (Bentley & Haslam, 2001; Gao & Abeysekera, 2004). The hierarchy of controls can be applied to mitigate such risks as they relate to winter conditions. Prompt and thorough snow removal (clearing or de-icing) from parking lots,

sidewalks, roads and outdoor work surfaces is an effective way to reduce STF injuries. Addressing other outdoor surface hazards (e.g., uneven surfaces, debris), keeping indoor surfaces clear, dry, and slip-resistant (e.g., through use of anti-slip entryway mats), and providing proper signage are also important. Administrative control recommendations include scheduling changes (e.g., allowing for remote work or delayed starts; rerouting or rescheduling operations as needed) and providing worker winter weather training (e.g., on topics such as proper winter PPE use and driving and walking speeds). Slip-resistant footwear and protective clothing have proven to significantly reduce the incidence of snow or ice-related incidents (Hsu et al., 2016; U.S. Occupational Safety and Health Administration, 2024). In Canada, a study among home care workers showed the workers who wore new calf-length casual winter boots with the highest maximum achievable angle (KITE Research Institute, 2024) were significantly less likely (68%) to incur snow or ice-related falls compared to other workers who wore any other winter footwear of their choice (Bagheri et al., 2021). Thus, although snowy and icy weather conditions cannot be eliminated, related STF hazards can be effectively addressed through various engineering controls, administrative controls, and PPE.

At the same time, the results of our study beg the question of whether such control strategies are being used to protect the most at-risk workers. For instance, there is no legal obligation for employers to provide their employees with winter boots. Purchasing the type of state-of-the-art winter footwear described in the Canadian study of home health care workers, places a significant economic burden on low-wage workers. Such workers could include many of the groups highlighted in our analysis–such as warehouse workers, building cleaners, some transportation and production workers, and healthcare and social assistance workers like home health workers.

In a similar vein, many of these and other workers noted in our analysis may operate off-site or at multiple sites. In addition to home health care workers, arguably all five of the minor occupation groups highlighted in our analysis—Motor Vehicle Operators; Building Cleaning and Pest Operators; Material Moving Workers and Other Installation; Maintenance and Repair Operations; Material Recording, Scheduling, Dispatching, and Distributing Workers—could be routinely dispatched to multiple sites, including other businesses or private homes. Since management cannot directly mitigate the potential STF hazards in such situations, it is imperative to provide workers with PPE and empower them through administrative controls to assess risks in their immediate environment and make decisions to ensure their safety—even if such decisions entail delays, route changes or scheduling adjustments. Whether there are any employers who adhere to such best practices, and how they chose to implement them, would be a fruitful area for future research.

Lastly, immigrant workers may be at particular risks of winter STF. Lack of familiarity with winter conditions, language barriers and lack of adequate training from the employer can all contribute to such risks. Future work that focuses on effective interventions for immigrant or other workers unaccustomed to winter conditions, would also be promising.

There are a few limitations to our analysis. First, our data only reflected STF injuries that resulted in three or more days of lost work time. Less severe injuries or those that were promptly and effectively treated to allow for an earlier return to work may not be covered here. This implies that our results are reflective of the most debilitating STF injuries; the total burden of all STF injuries is likely much higher.

Second, our lost time STF claim dataset necessarily only includes injuries that were both reported by the worker to the employer and coded as snow or ice-related STF injuries, or with enough detail that they could be identified as snow or ice-related STF injuries using our text analysis method. Under-reporting of injuries is a known limitation with claims data, although we expect relatively less non-reporting for STF and other acute, event-related injuries than for chronic or latent conditions.

Third, our data were limited to a single state. Nonetheless, our findings from Wisconsin are consistent with other studies beyond Wisconsin.

Fourth, in our analysis, we were not able to recover industry codes for 7.9% of claims or occupation codes for 10.8% of claims. Our findings are similar to that of Wurzelbacher et al who found that industry codes could not be found in 10% of claims (Wurzelbacher et al., 2016). Data linkages have been key to retrieving the industry codes and the NIOCCS free-text auto-coder has helped tremendously in obtaining occupation codes. This is a call for database administrators and managers to implement industry and occupation fields in their surveillance data and conduct regular quality-assurance to ensure a good data quality.

A fifth limitation reflects the available claims data. Our analysis was based on claims reported to the Wisconsin Department of Workforce Development's Division of Workers Compensation by insurance carriers, excluding de facto claims that are outright denied by the carriers because they are not work-related. We could not address this issue. However, due to the nature of the hazard and the traumatic nature of the event, the work-relatedness of cold weather STF claims could be relatively easier to establish compared to other situations such as occupational infectious or respiratory diseases. Additionally, almost 90% of claims reported to the Wisconsin Division of Workers Compensation were compensated. We therefore considered these claims to be fairly representative of all snow or ice-related STF lost time claims.

Lastly, the WCIO classification does not clearly specify the distinction between 'strain or tear' and 'sprain or tear'. It is mostly based on narrative rather than clinical diagnosis. However, such a distinction is not vital to our findings. Clinicians or future researchers with an interest in parsing these cases can refer to the clinical diagnosis codes in the injury descriptions to assist with this distinction. It also reveals the importance of better data capture in the worker's compensation system and data integration between data systems for better surveillance.

This analysis has several strengths. First, we demonstrated that snow or ice-related STF remains a significant driver of work-related injuries, even with climate change. This is important to note even as more attention is also justifiably being devoted to heat and heat-related illness. For instance, it is important for employers, workers and medical providers in areas with ice and snow to note the continued potential for high-risk workers to experience significant injuries, especially head injuries.

Second, we developed a comprehensive definition of snow or ice-related STF claims that used free-text narratives to identify additional snow and ice-related STF claims beyond those coded as such. Having a robust operational definition will be particularly important as seasonal weather patterns continue to change in terms of both time of year and geography. For instance, the same definition could be applied to data from warmer states that experience unusual snow or ice events, where claims adjusters may be less accustomed to deploying the snow or ice-related STF code and coding errors may therefore be more pronounced.

Third, we used a prevention index to rank and compare industries and occupations. This methodological approach, which is stronger than rate only or count only, helps identify industries and occupations with the highest burden of STF injuries where an intervention might be cost-effective (Anderson et al., 2014; Meyers et al., 2018). The adjustment of occupation by industry was another strength that bridges the gap between industry-only view and occupation-only view. This provides a more comprehensive view because a worker has both an industry and an occupation. It also helps in this analysis to identify high burden occupations across industries. The nuanced use of a prevention index allows employers, insurance carriers, workers and other health and safety professionals to better target their prevention efforts. Updated and nuanced rankings such as those presented here are key to developing effective interventions, even for long-standing hazards such as snow or ice-related STFs.

5. Conclusions

Despite a changing climate, snow or ice-related STFs remain a significant driver of injury claims in Wisconsin, with no indication of downward trend. The average claim entails months of lost work time, and a fifth of these injuries warranted hospitalization. For delivery workers and others who set foot outside several times per shift, the risks posed by slippery conditions are significant. This is especially relevant for an aging workforce, as our results show older workers to be at increased risk. Unpredictable weather patterns – which are likely to be more frequent with climate change – may also entail increased risks for workers unaccustomed to snow and ice. We therefore call on other scholars and practitioners to pay renewed attention to snow and ice risks, using the methods we have deployed here (i.e., use of free-text search and prevention index) to capture relevant claims and prioritize risk groups. For injury prevention research, it would be important to determine whether the circumstances of the injuries differ by demographics to help design more targeted prevention strategies.

Ethical Considerations & Disclosure(s)

The University of Wisconsin Institutional Review Board (UW-IRB) provided written approval for the Wisconsin Fundamental-Plus Occupational Health Surveillance Program (Submission ID number: 2013-0331-CR010) under which this study was performed. The UW-IRB determined that this study met the requirements of public health surveillance as defined in the U.S. Department of Health & Human Services regulations for the protection of human subjects (45 CFR 46.102(l)(2)). This analysis did not require the informed consent of cases as these were administrative data reported to statewide public health surveillance databases.

Specific Author Contributions

All authors contributed to the conceptualization, design of the work, writing, editing, and preparation of the manuscript for publication. Authors Sheryl Bedno, Komi Modji and Katherine McCoy were responsible of the framing of the analysis. Authors Komi Modji and Katherine McCoy were primarily responsible for data acquisition, data curation and data analysis. Authors Komi Modji, Katherine McCoy and Paul D. Creswell contributed to the interpretation of findings, drafted the manuscript and revised it critically for important intellectual content. Authors Sheryl Bedno, Carrie Tomasallo, Katherine McCoy and Paul Creswell provided critical reviews and feedback to the manuscript. All authors approved the final version and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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CRediT authorship contribution statement

Komi K.S. Modji: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Katherine E. McCoy:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Paul D. Creswell:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Conceptualization. **Carrie D. Tomasallo:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition. **Sheryl Bedno:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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