



# Workers' compensation claim counts and rates by injury event/exposure among state-insured private employers in Ohio, 2007–2017



Steven J. Wurzelbacher<sup>a,\*</sup>, Alysha R. Meyers<sup>a</sup>, Michael P. Lampl<sup>b</sup>, P. Timothy Bushnell<sup>a</sup>, Stephen J. Bertke<sup>a</sup>, David C. Robins<sup>b</sup>, Chih-Yu Tseng<sup>a</sup>, Steven J. Naber<sup>b</sup>

<sup>a</sup> National Institute for Occupational Safety and Health, 1090 Tusculum Ave, Cincinnati, OH 45226-1998, United States

<sup>b</sup> Ohio Bureau of Workers' Compensation, 30 W Spring St Ste L1, Columbus, OH 43215, United States

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## ABSTRACT

**Introduction:** This study analyzed workers' compensation (WC) claims among private employers insured by the Ohio state-based WC carrier to identify high-risk industries by detailed cause of injury. **Methods:** A machine learning algorithm was used to code each claim by U.S. Bureau of Labor Statistics (BLS) event/exposure. The codes assigned to lost-time (LT) claims with lower algorithm probabilities of accurate classification or those LT claims with high costs were manually reviewed. WC data were linked with the state's unemployment insurance (UI) data to identify the employer's industry and number of employees. BLS data on hours worked per employee were used to estimate full-time equivalents (FTE) and calculate rates of WC claims per 100 FTE. **Results:** 140,780 LT claims and 633,373 medical-only claims were analyzed. Although counts and rates of LT WC claims declined from 2007 to 2017, the shares of leading LT injury event/exposures remained largely unchanged. LT claims due to Overexertion and Bodily Reaction (33.0%) were most common, followed by Falls, Slips, and Trips (31.4%), Contact with Objects and Equipment (22.5%), Transportation Incidents (7.0%), Exposure to Harmful Substances or Environments (2.8%), Violence and Other Injuries by Persons or Animals (2.5%), and Fires and Explosions (0.4%). These findings are consistent with other reported data. The proportions of injury event/exposures varied by industry, and high-risk industries were identified. **Conclusions:** Injuries have been reduced, but prevention challenges remain in certain industries. Available evidence on intervention effectiveness was summarized and mapped to the analysis results to demonstrate how the results can guide prevention efforts. **Practical Applications:** Employers, safety/health practitioners, researchers, WC insurers, and bureaus can use these data and machine learning methods to understand industry differences in the level and mix of risks, as well as industry trends, and to tailor safety, health, and disability prevention services and research.

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## 1. Introduction

Workers' compensation (WC) in the United States involves large, state-governed, administrative data collection systems. WC claims data include coded fields for the injured worker's occupation/industry, injury cause, part of body, and nature of injury, as well as unstructured narratives that describe how the incident occurred and the worker's occupation. States use a variety of coding systems, and codes for each claim are manually generated by a

combination of employers, claims administrators, insurers and/or state WC bureaus based on free text descriptions of how the incident occurred, diagnoses, and other claims information.

WC systems have been successfully utilized by several states for occupational sentinel surveillance, research, and employer work-site follow-up. Recent studies demonstrated that large state datasets of WC claims can be successfully linked to state employment data to examine claim counts and rates by industry and cause of injury (Anderson et al., 2013; Harrison, Shor, & Jackson, 2019; Massachusetts Department of Industrial Accidents, 2020; Michigan Department of Health and Human Services, 2020; Taylor, Higgins, Jones, & Wagner, 2020; Wurzelbacher, Altarawneh, & Meyers, 2016). Several of these studies were developed through cooperative agreements funded by the National Institute for Occupational Safety and Health (NIOSH) awarded to

\* Corresponding author at: National Institute for Occupational Safety and Health (NIOSH), 1090 Tusculum Ave, MS R-14, Cincinnati, OH 45226-1998, United States.

E-mail addresses: [Swr3@cdc.gov](mailto:Swr3@cdc.gov) (S.J. Wurzelbacher), [itm4@cdc.gov](mailto:itm4@cdc.gov) (A.R. Meyers), [Michael.L.1@bwc.state.oh.us](mailto:Michael.L.1@bwc.state.oh.us) (M.P. Lampl), [plb4@cdc.gov](mailto:plb4@cdc.gov) (P. Timothy Bushnell), [inh4@cdc.gov](mailto:inh4@cdc.gov) (S.J. Bertke), [David.R.1@bwc.state.oh.us](mailto:David.R.1@bwc.state.oh.us) (D.C. Robins), [cft8@cdc.gov](mailto:cft8@cdc.gov) (C.-Y. Tseng), [Steven.N.1@bwc.state.oh.us](mailto:Steven.N.1@bwc.state.oh.us) (S.J. Naber).

the states of California, Massachusetts, Michigan, Ohio, and Tennessee.

Although there are challenges with WC claim data quality and completeness, other studies have determined that machine learning techniques (Bertke et al., 2016; Lehto, Marucci-Wellman, & Corns, 2009; Marucci-Wellman et al., 2011, 2015, 2017; Measure, 2014) can be successfully applied to the incident narratives in WC claims and other similar data to gather prevention insights. For example, Liberty Mutual uses such techniques to publish their popular Safety Index (Liberty Mutual Research Institute, 2020). The US Bureau of Labor Statistics (BLS) also uses these approaches to analyze data from the Survey of Occupational Injuries and Illnesses (SOII). Researchers from NIOSH and the Ohio Bureau of Workers' Compensation (OHBC) applied these techniques to identify ergonomic and safety priorities within many specific industries (Meyers et al., 2018). Machine learning approaches are constantly evolving, and NIOSH recently sponsored a crowd-sourcing competition to improve methods for coding free text narratives in WC claims and other similar data (NIOSH Blog, 2020). NIOSH and other partners have shared machine learning programs with various WC bureaus, insurers and employers, but these approaches are not yet in widespread use in WC systems. The current analyses fill a gap in the literature to demonstrate how the next iteration of machine learning methods can enable the coding of claims to a more detailed causation level in large WC datasets to encourage wider use.

The main purpose of this study was to analyze patterns in OHBC-insured private employer WC claims to identify specific high-risk industries by detailed cause of injury. Another purpose was to summarize the leading examples of safety/health programs and interventions by cause types for higher-risk industries identified in the data. This demonstrated the opportunities for use and potential impact of the detailed analysis of claims data.

## 2. Methods and materials

The OHBC is the largest state-run WC system in the United States. From 2007 to 2017, the OHBC provided WC insurance for two-thirds of Ohio's workers. The remaining one-third of workers were either employed by a small number of larger employers (usually >500 employees) authorized to self-insure or worked at other employers (e.g., sole proprietorships) exempt from OHBC coverage. Employers can self-insure if they demonstrate the following: strong financial stability, an organizational plan for the administration of the WC law, and risk and claims management procedures for establishing a safe and more cost-effective workplace (Ohio Bureau of Workers' Compensation, 2020). Sole proprietorships are exempt from WC coverage but can electively purchase policies (Ohio Revised Code, 2020). In 2017, 54% of Ohio employers with more than 500 employees were estimated to be self-insured (692 employers), and 38% of the sole proprietorships did not purchase OHBC coverage.

WC claims for 2007–2017 from private employers insured by the OHBC were analyzed by industry and cause of injury. The dataset included accepted lost-time (LT) claims (8 or more days away from work, DAW) and medical-only (MO) claims (medical care only and/or 7 or fewer days DAW). From 2007 to 2011, OHBC manually coded only LT claims using a proprietary cause coding system and began using the ICD- External cause code system for all claims in 2013. Because the codes were incomplete and used different systems, a NIOSH-developed machine learning algorithm (Bertke et al., 2016) was used to auto-code each OHBC claim to the U.S. BLS Occupational Injury and Illness Classification System (OIICS version 2.01) 2-digit event/exposure categories (Bureau of Labor Statistics & U.S. Department of Labor, 2012;

Bureau of Labor Statistics & U.S. Department of Labor, 2020). The OIICS system was chosen because it includes an extensive coding hierarchy, instructions, and training systems and is widely recognized by employers and public health users because the BLS SOII uses this system. The machine learning algorithm was generated based on computer analysis of word frequencies and combinations in a "training set" of 7,200 WC claims that were manually coded by experts.

The algorithm assigned a probability of accuracy score to each of its code assignments. To increase the accuracy for coding the most severe injuries, LT claims with bottom quartile algorithm probabilities or high costs (95th percentile) were manually reviewed. Because the algorithm relies on observed probabilities of certain words occurring in the training datasets, and workplace violence claims were relatively rare in these training sets, claims with relatively high workplace violence probabilities and claims in industries (NAICS 11, 71, and 92) with lower than expected number of claims coded as violence were also manually reviewed. MO claims were not manually reviewed due to resource constraints.

Primarily, 1-digit event/exposure level (a.k.a. Divisions in BLS terms) counts/rates are presented in this paper. This was done to allow the results of this study to be readily compared to recent data from other state WC systems. These 1-digit codes include 1: Violence and other Injuries by Persons or Animals; 2: Transportation Incidents; 3: Fires and Explosions; 4: Falls, Slips, Trips; 5: Exposure to Harmful Substances or Environments; 6: Contact with Objects and Equipment; and 7: Overexertion and Bodily Reaction, and 9: Non-classifiable.

OHBC claims data were linked via the employer's federal tax identification number with Ohio's unemployment insurance (UI) data to identify the employer's industry code (North American Industry Classification System, NAICS) and number of employees. BLS National Labor Productivity and Costs (LPC) data (Bureau of Labor Statistics & U.S. Department of Labor, 2020) on hours worked per employee by 4-digit NAICS industry were used to adjust UI data and estimate full-time equivalents (FTE). Rates of WC claims per 100 FTE were then calculated. Methods differed slightly for single-location versus multiple-location employers, and these methods were previously developed and described in more detail in a prior study (Wurzelbacher et al., 2016). Methods in the current paper differ slightly in that BLS LPC data now represent hours worked rather than hours paid (Bureau of Labor Statistics & U.S. Department of Labor, 2020). Industry sectors were defined by NIOSH National Occupational Research Agenda (NORA) classifications (National Institute for Occupational Safety and Health (NIOSH), 2018).

NAICS codes for each National Occupational Research Agenda (NORA) sector are as follows: Agriculture, Forestry, Fishing/Hunting (AFF) = 11; Construction (CON) = 23; Health Care and Social Assistance (HCSA) = 62, 54194, 81291; Manufacturing (MNF) = 31, 32, 33; Mining (MIN) = 21; Oil & Gas (OIL) = 211, 213111, & 213112; Public Safety (PSA) = 92212, 92214, 92216, 62191; Services, except Public Safety (SRV) = 51–56, 61, 71, 72, 81, 92; Transportation, Warehousing, Utilities (TWU) = 22, 48, 49; Wholesale Trade/Retail Trade (WRT) = 42, 44, 45. Only the private sector portion of the PSA sector is included in the current analyses (62191, Ambulance Services). The sector for Support Activities for Mining, 21311, has been labelled as MIN/OIL in 5-digit NAICS level analyses because at this level it spans both the MIN and OIL sectors.

Prevention indices (PI) (Anderson et al., 2013; Silverstein, 2007) were calculated by averaging the count and rate ranks for each 5-digit NAICS code. PIs were developed by WA State researchers as a simple method to rank and prioritize industries for prevention emphasis by giving equal weighting to the total count and rate of claims. To be included in the indices, 5-digit NAICS industries

needed to report hours in 7 or more years of the study period, have an average of at least 100 FTE per year, and at least 55 claims for 2007–2017, which are proportional to the inclusion criteria developed by WA State (Anderson et al., 2013). To clarify, these criteria do not limit the inclusion of small employers, but do limit the inclusion of relatively small industries. NAICS code versions for 2007, 2012, and 2017 were harmonized to present the PI ratings over the 2007–2017 period.

Overall findings were compared to the BLS SOII and available WC data. WC data were often reported using codes for injury cause, nature, and part of body developed by the Workers' Compensation Insurance Organizations (WCIO) (Workers Compensation Insurance Organizations, 2020). The WCIO codes are more limited in the level of detail than BLS OIICS codes, and do not have a defined coding hierarchy or instructions. NIOSH, the MA Department of Public Health, and others have developed crosswalks between WCIO cause and BLS OIICS event/exposure codes at the basic 1-digit level (Massachusetts Department of Industrial Accidents et al., 2020), and these crosswalks were applied prior to comparisons. More detailed crosswalks between WCIO and OIICS are problematic because the WCIO codes are not hierarchical, are less detailed, and may map to more than one OIICS code at the 2-digit level.

All analyses were conducted using SAS version 9.4 (SAS version 9.4, 2016). This study was internally reviewed by NIOSH, and it was determined that it did not constitute human subjects research. Rather, the study involved the analysis of coded and previously collected WC administrative claims data.

### 3. Results

#### 3.1. Demographics

From 2007 to 2017, 140,780 accepted LT claims and 633,373 accepted MO claims (94.7% of the 817,103 accepted claims) for OHBWC-insured private employers could be reliably matched to UI data on NAICS and employee count and were included in subsequent event/exposure rate analyses. For a proportion of claims (11,098 claims, 1.3%), a reliable employee count could not be determined for the corresponding policy/year or quarter, and these claims are not included in reported analyses. For another proportion of claims, a reliable 5- or 6-digit NAICS code could not be assigned for certain multiple-location policies (5,677 policies, 0.3%; 31,852 claims, 3.9%), and these claims are also not included in analyses reported here. During this period, approximately 87% of WC claims received for OHBWC-insured private employers were accepted. The mean annual number of covered FTE for this period in the analyzed population of employers was 2,028,561. The mean annual number of employers with covered policies for this period

was 166,263. Number of FTEs and policies by NORA sector are provided in Table 1.

#### 3.2. Event/exposure time trends

All claims were initially coded for event/exposure using the algorithm (Bertke et al., 2016) described previously and 28,239 of 140,780 LT claims (20%) from 2007 to 2017 were manually reviewed. For LT claims, the estimated accuracy after the manual review was 87% at the 1-digit event/exposure level and 78% at the 2-digit level. For each OIICS event/exposure, Table 2 presents private sector LT claim count, rate, and percentage of total claims, for each year 2007–2017. For LT claims, Overexertion and Bodily Reaction represented the largest share of claims from 2007 to 2017, followed by Falls, Slips, and Trips and Contact with Objects and Equipment. LT counts/rates declined for all event/exposure types. Among the top three events/exposures for aggregate counts and rates, Overexertion and Bodily Reaction declined the most in both rates and counts, followed by Falls, Slips, and Trips, and Contact with Objects and Equipment. The shares of each OIICS event/exposure in the total LT count remained largely unchanged from 2007 to 2017.

#### 3.3. Event/exposures by sector and detailed industry

Table 3 presents LT claim counts and rates by 1-digit OIICS event/exposure for private employers in each NORA sector for 2007–2017. Similar information is provided for total claims (LT and MO claims combined) in Table 4. The top three event/exposures by percentage of LT and total claims for most sectors were Overexertion and Bodily Reaction; Falls, Slips, and Trips; and Contact with Objects and Equipment, although the rank order of these three divisions did vary by sector (Tables 3, 4). There were some exceptions to this pattern for LT claims, including HCSA, where Violence and Other Injuries by Persons or Animals had the third highest proportion by event/exposure type, and PSA and TWU, where Transportation Incidents had the second highest (tied with Falls, Slips, Trips) and third highest proportions, respectively.

Table 5 presents the LT-claim PI for the 5-digit NAICS codes with the lowest PIs. Low PIs correspond to high prevention priority (i.e., a high ranking). The 5-digit NAICS industries are listed in ascending order of LT PI for all events/exposures combined, and for each industry, the PI for each specific event/exposure is also reported separately. The top five 5-digit NAICS industries for LT claims for all event/exposures combined as ranked by PI included General Freight Trucking, Long-Distance (48412), Other Motor Vehicle Parts Manufacturing (33639), Ambulance Services (62191), Specialized Freight (except Used Goods) Trucking, Long-Distance (48423), and Specialized Freight (except Used Goods) Trucking, Local (48422). Many of the industries with the highest

**Table 1**  
Demographics for state-insured private employers by industry sector, 2007–2017.

Demographic	Metric	NORA <sup>a</sup> Industry Sector										
		AFF	CON	HCSA	MIN	MNF	OIL	PSA	SRV	TWU	WRT	ALL
FTE Count (full time equivalents)	Count	147,486	1,757,873	3,040,615	44,708	3,638,072	48,568	52,056	9,141,110	831,781	3,611,898	22,314,167
	% of all FTE	0.66%	7.88%	13.63%	0.20%	16.30%	0.22%	0.23%	40.97%	3.73%	16.19%	100.00%
Policy Count	Count	12,063	203,880	201,690	1,864	135,605	4,372	1,102	870,824	55,591	341,900	1,828,891
	% of all policies	0.66%	11.15%	11.03%	0.10%	7.41%	0.24%	0.06%	47.61%	3.04%	18.69%	100.00%

NORA Sectors by North American Industry Classification System (NAICS) codes include: Agriculture, Forestry, Fishing/Hunting (AFF) = 11; Construction (CON) = 23; Health Care and Social Assistance (HCSA) = 62, 54194, 81291; Manufacturing (MNF) = 31, 32, 33; Mining (MIN) = 21; Oil & Gas (OIL) = 211, 213111, & 213112; Public Safety (PSA) = 92212, 92214, 92216, 62191; Services, except Public Safety (SRV) = 51–56, 61, 71, 72, 81, 92; Transportation, Warehousing, Utilities (TWU) = 22, 48, 49; Wholesale Trade/Retail Trade (WRT) = 42, 44, 45. Only the private sector portion of the PSA sector is included in the current analyses (62191, Ambulance Services).

<sup>a</sup> NORA = National Occupational Research Agenda.

**Table 2**  
Lost-time<sup>a</sup> claim counts, proportions, and rates<sup>b</sup> by event/exposure, 2007–2017.<sup>c</sup>

Year	Metric	Violence and Other Injuries by Persons or Animals	Transportation Incidents	Fires and Explosions	Falls, Slips, Trips	Exposure to Harmful Substances or Environments	Contact with Objects and Equipment	Overexertion and Bodily Reaction	Non-classifiable	Total
2007	Count	447	1,108	80	5,555	542	4,183	6,414	81	18,410
	% of all LT claims	2.43%	6.02%	0.43%	30.17%	2.94%	22.72%	34.84%	0.44%	100.00%
	Rate	0.02	0.05	0.00	0.26	0.03	0.20	0.30	0.00	0.86
2008	Count	424	1,051	76	5,252	412	3,641	5,332	36	16,224
	% of all LT claims	2.61%	6.48%	0.47%	32.37%	2.54%	22.44%	32.86%	0.22%	100.00%
	Rate	0.02	0.05	0.00	0.25	0.02	0.18	0.26	0.00	0.78
2009	Count	349	753	48	3,882	312	2,312	3,971	24	11,651
	% of all LT claims	3.00%	6.46%	0.41%	33.32%	2.68%	19.84%	34.08%	0.21%	100.00%
	Rate	0.02	0.04	0.00	0.21	0.02	0.12	0.21	0.00	0.62
2010	Count	345	890	62	4,343	333	2,767	4,595	22	13,357
	% of all LT claims	2.58%	6.66%	0.46%	32.51%	2.49%	20.72%	34.40%	0.16%	100.00%
	Rate	0.02	0.05	0.00	0.23	0.02	0.15	0.24	0.00	0.71
2011	Count	297	898	63	3,998	336	2,759	4,210	38	12,599
	% of all LT claims	2.36%	7.13%	0.50%	31.73%	2.67%	21.90%	33.42%	0.30%	100.00%
	Rate	0.02	0.05	0.00	0.21	0.02	0.14	0.22	0.00	0.66
2012	Count	287	837	50	3,364	330	2,719	3,997	37	11,621
	% of all LT claims	2.47%	7.20%	0.43%	28.95%	2.84%	23.40%	34.39%	0.32%	100.00%
	Rate	0.01	0.04	0.00	0.17	0.02	0.14	0.21	0.00	0.60
2013	Count	282	812	38	3,708	338	2,827	3,961	62	12,028
	% of all LT claims	2.34%	6.75%	0.32%	30.83%	2.81%	23.50%	32.93%	0.52%	100.00%
	Rate	0.01	0.04	0.00	0.19	0.02	0.14	0.20	0.00	0.60
2014	Count	243	887	49	3,898	361	2,774	3,783	46	12,041
	% of all LT claims	2.02%	7.37%	0.41%	32.37%	3.00%	23.04%	31.42%	0.38%	100.00%
	Rate	0.01	0.04	0.00	0.19	0.02	0.14	0.19	0.00	0.59
2015	Count	271	952	44	3,785	326	2,684	3,557	68	11,687
	% of all LT claims	2.32%	8.15%	0.38%	32.39%	2.79%	22.97%	30.44%	0.58%	100.00%
	Rate	0.01	0.05	0.00	0.18	0.02	0.13	0.17	0.00	0.56
2016	Count	282	863	22	3,386	293	2,611	3,415	63	10,935
	% of all LT claims	2.58%	7.89%	0.20%	30.96%	2.68%	23.88%	31.23%	0.58%	100.00%
	Rate	0.01	0.04	0.00	0.16	0.01	0.12	0.16	0.00	0.51
2017	Count	284	863	31	3,081	312	2,422	3,171	63	10,227
	% of all LT claims	2.78%	8.44%	0.30%	30.13%	3.05%	23.68%	31.01%	0.62%	100.00%
	Rate	0.01	0.04	0.00	0.14	0.01	0.11	0.14	0.00	0.47
2007–2017	Count	3511	9,915	563	44,257	3,895	31,703	46,411	540	140,780
	% of all LT claims	2.49%	7.04%	0.40%	31.44%	2.77%	22.52%	32.97%	0.38%	100.01%
	Rate	0.016	0.04	0.003	0.20	0.017	0.14	0.21	0.00	0.63
2007–2017	Count % Change	–36.47%	–22.11%	–61.25%	–44.54%	–42.44%	–42.10%	–50.56%	–22.22%	–44.45%
	Rate % Change	–38.23%	–24.28%	–62.33%	–46.08%	–44.04%	–43.71%	–51.94%	–24.39%	–45.99%

<sup>a</sup> Eight or more days away from work.

<sup>b</sup> Rate per 100 full-time equivalents.

<sup>c</sup> Among state-insured private employers.

rankings overall had high injury rates/counts for several specific types of event/exposures. PIs for specific event/exposures that are among the five lowest are highlighted, but note that while Table 5 includes industries with the lowest PIs overall, the table is not long enough to include all industries with a PI among the five lowest for any event/exposure. Table 6 presents LT and LT + MO claim counts and rates by 2-digit event/exposure, for all industries combined.

### 3.3.1. Violence and Other Injuries by Persons or Animals

The sectors with the highest proportions of LT claims for Violence and Other Injuries by Persons or Animals were AFF (12.2%), HCSA (10.4%), and SRV (2.6%) (Table 3). The top five, 5-digit NAICS industries for LT claims for event/exposures of this type, as ranked by PI, included Spectator Sports (71121), Residential Mental Retardation Facilities (62321), Residential Mental Health and Substance Abuse Facilities (62322), Other Residential Care Facilities (62399), and Psychiatric and Substance Abuse Hospitals (62221). Veterinary Services (54194) were also highly ranked (Table 5). Across all industries, half of LT Violence and Other Injuries by Persons or Ani-

mals claims were due to Intentional Injuries by Person (50%), followed by Unintentional or Intent Unknown Injuries by Person (29%) and Animal or Insect Related Incidents (21%) (Table 6).

### 3.3.2. Transportation Incidents

The sectors with the highest proportions of LT claims for Transportation Incidents were TWU (19.4%), PSA (16.8%), and OIL (11.9%) (Table 3). Most sectors had at least one 5-digit NAICS industry with very high LT claims for Transportation Incidents as ranked by PIs. The top five 5-digit NAICS industries for LT claims as ranked by PI for Transportation Incidents included Specialized Freight (except Used Goods) Trucking, Local (48422), General Freight Trucking, Long-Distance (48412), General Freight Trucking, Local (48411), School and Employee Bus Transportation (48541), and Other Transit and Ground Passenger Transportation (48599). Ambulance Services (62191) were also highly ranked (Table 5). The majority of LT Transportation Incidents claims across all industries were due to Roadway Incidents, Motorized Land Vehicles (78%), followed by Pedestrian Vehicular Incidents (12%) (Table 6).

**Table 3**  
 Lost-time <sup>a</sup> claim counts, proportions, and rates <sup>b</sup> by event/exposure by industry sector, 2007–2017.<sup>c</sup>

Event/Exposure Type	Metric	NORA <sup>d</sup> Industry Sector										
		AFF	CON	HCSA	MIN	MNF	OIL	PSA	SRV	TWU	WRT	ALL
All Event/Exposures	Count	861	16,186	18,213	502	30,823	523	867	39,769	11,875	21,161	140,780
	% of all LT claims	0.61%	11.50%	12.94%	0.36%	21.89%	0.37%	0.62%	28.25%	8.44%	15.03%	100.00%
	Rate	0.584	0.921	0.599	1.123	0.847	1.077	1.666	0.435	1.428	0.586	0.631
Violence and Other Injuries by Persons or Animals	Count	105	67	1,898	4	87	1	10	1,027	79	233	3,511
	% of all LT claims	2.99%	1.91%	54.06%	0.11%	2.48%	0.03%	0.28%	29.25%	2.25%	6.64%	100.00%
	% of sector LT claims	12.20%	0.41%	10.42%	0.80%	0.28%	0.19%	1.15%	2.58%	0.67%	1.10%	2.49%
Transportation Incidents	Count	70	1,018	1,131	46	671	62	146	2,916	2,301	1,553	9,914
	% of all LT claims	0.71%	10.27%	11.41%	0.46%	6.77%	0.63%	1.47%	29.41%	23.21%	15.66%	100.00%
	% of sector LT claims	8.13%	6.29%	6.21%	9.16%	2.18%	11.85%	16.84%	7.33%	19.38%	7.34%	7.04%
Fires and Explosions	Count	3	106	10	5	157	16	1	121	31	113	563
	% of all LT claims	0.53%	18.83%	1.78%	0.89%	27.89%	2.84%	0.18%	21.49%	5.51%	20.07%	100.00%
	% of sector LT claims	0.35%	0.65%	0.05%	1.00%	0.51%	3.06%	0.12%	0.30%	0.26%	0.53%	0.40%
Falls, Slips, Trips	Count	287	5,753	6,684	120	6,257	142	146	14,346	3,992	6,525	44,252
	% of all LT claims	0.65%	13.00%	15.10%	0.27%	14.14%	0.32%	0.33%	32.42%	9.02%	14.75%	100.00%
	% of sector LT claims	33.33%	35.54%	36.70%	23.90%	20.30%	27.15%	16.84%	36.07%	33.62%	30.84%	31.43%
Exposure to Harmful Substances or Environments	Count	21	501	250	8	1125	12	3	1529	114	332	3895
	% of all LT claims	0.54%	12.86%	6.42%	0.21%	28.88%	0.31%	0.08%	39.26%	2.93%	8.52%	100.00%
	% of sector LT claims	2.44%	3.10%	1.37%	1.59%	3.65%	2.29%	0.35%	3.84%	0.96%	1.57%	2.77%
Contact with Objects and Equipment	Count	239	3,954	1,264	193	10,741	173	38	8,536	1,717	4,844	31,699
	% of all LT claims	0.75%	12.47%	3.99%	0.61%	33.88%	0.55%	0.12%	26.93%	5.42%	15.28%	100.00%
	% of sector LT claims	27.76%	24.43%	6.94%	38.45%	34.85%	33.08%	4.38%	21.46%	14.46%	22.89%	22.52%
Overexertion and Bodily Reaction	Count	129	4,730	6,917	122	11,673	114	521	11,132	3,595	7,473	46,406
	% of all LT claims	0.28%	10.19%	14.91%	0.26%	25.15%	0.25%	1.12%	23.99%	7.75%	16.10%	100.00%
	% of sector LT claims	14.98%	29.22%	37.98%	24.30%	37.87%	21.80%	60.09%	27.99%	30.27%	35.31%	32.96%
Non-classifiable	Count	7	57	59	4	112	3	2	162	46	88	540
	% of all LT claims	1.30%	10.56%	10.93%	0.74%	20.74%	0.56%	0.37%	30.00%	8.52%	16.30%	100.00%
	% of sector LT claims	0.81%	0.35%	0.32%	0.80%	0.36%	0.57%	0.23%	0.41%	0.39%	0.42%	0.38%
	Rate	0.005	0.003	0.002	0.009	0.003	0.006	0.004	0.002	0.006	0.002	0.002

<sup>a</sup> Eight or more days away from work.  
<sup>b</sup> Rate per 100 full-time equivalents.  
<sup>c</sup> Among state-insured private employers.  
<sup>d</sup> NORA = National Occupational Research Agenda; NORA Sectors by North American Industry Classification System (NAICS) codes include: Agriculture, Forestry, Fishing/Hunting (AFF) = 11; Construction (CON) = 23; Health Care and Social Assistance (HCSA) = 62, 54194, 81291; Manufacturing (MNF) = 31, 32, 33; Mining (MIN) = 21; Oil & Gas (OIL) = 211, 213111, & 213112; Public Safety (PSA) = 92212, 92214, 92216, 62191; Services, except Public Safety (SRV) = 51–56, 61, 71, 72, 81, 92; Transportation, Warehousing, Utilities (TWU) = 22, 48, 49; Wholesale Trade/Retail Trade (WRT) = 42, 44, 45. Only the private sector portion of the PSA sector is included in the current analyses (62191, Ambulance Services).

3.3.3. Fires and Explosions

The sectors with the highest proportions of LT claims for Fires and Explosions claims were OIL (3.1%) and MIN (1.0%) (Table 3). Most sectors had at least one 5-digit NAICS industry with a high LT PI for Fires and Explosions. The top five 5-digit NAICS industries for LT claims as ranked by PI for Fires and Explosions included Recyclable Material Merchant Wholesalers (42393), Ferrous Metal Foundries (33151), Tire Dealers (44132), Support Activities for Mining (21311), and Iron and Steel Mills and Ferro Alloy Manufacturing (33111) (data not shown). Automotive Mechanical and Electrical Repair and Maintenance (81111) was also highly ranked (Table 5). Across all industries, the majority of LT Fires and Explosions claims were due to Explosions (69%) followed by Fires (31%) (Table 6).

3.3.4. Falls, Slips, and Trips

The sectors with the highest proportions of LT Falls, Slips, and Trips claims were HCSA (36.7%), SRV (36.1%), and CON (35.5%) (Table 3). Almost every sector had at least one 5-digit NAICS industry that was very high in LT claims as ranked by PI for Falls, Slips, and Trips. The top five 5-digit NAICS industries for LT claims as

ranked by PI for Falls, Slips, and Trips included General Freight Trucking, Long-Distance (48412), Roofing Contractors (23816), Specialized Freight (except Used Goods) Trucking, Local (48422), General Freight Trucking, Local (48411), and Specialized Freight (except Used Goods) Trucking, Long-Distance (48423) (Table 5). Across all industries, most LT Falls, Slips, and Trips claims were Falls on Same Level (50%), followed by Falls to Lower Level (29%), and Slip or Trip without Fall (21%) (Table 6).

3.3.5. Exposure to Harmful Substances or Environments

The sectors with the highest proportions of LT claims for Exposure to Harmful Substances or Environments were SRV (3.8%), MNF (3.7%), CON (3.1%), and OIL (2.3%) (Table 3). The top five 5-digit NAICS industries for LT claims as ranked by PI for Exposure to Harmful Substances or Environments included Nonferrous Metal Foundries (33152), Ferrous Metal Foundries (33151), Other Basic Organic Chemical Manufacturing (32519) (data not shown), Coating, Engraving, Heat Treating, and Allied Activities (33281), and Recyclable Material Merchant Wholesalers (42393) (Table 5). The majority of LT Exposure to Harmful Substances or Environments claims across all industries were due to Exposure to Temperature

Extremes (56%), followed by Exposure to Other Harmful Substances (35%) (Table 6).

### 3.3.6. Contact with Objects and Equipment

The sectors with the highest proportions of LT claims for Contact with Objects and Equipment were MIN (38.4%), MNF (34.9%), and OIL (33.1%) (Table 3). However, two of the top 5-digit NAICS for Contact with Objects and Equipment were in the WRT sector. The top five 5-digit NAICS industries for LT claims as ranked by PI for Contact with Objects and Equipment included Forging and Stamping (33211), Recyclable Material Merchant Wholesalers (42393), Metal Service Centers and Other Metal Merchant Wholesalers (42351), Plate Work and Fabricated Structural Product Manufacturing (33231), and Ferrous Metal Foundries (33151). Temporary Help Services (56132) was also highly ranked (Table 5). The majority of LT Contact with Objects and Equipment claims across all industries were due to Struck by Objects or Equipment (57%), followed by Caught in or Compressed by Equipment or Objects (24%) and Struck Against Object or Equipment (16%) (Table 6).

### 3.3.7. Overexertion and Bodily Reaction

The sectors with the highest proportions of LT Overexertion and Bodily Reaction claims were PSA (60.1%), HCSA (38.0%), and MNF (37.9%) (Table 3). However, every NORA sector had at least one 5-digit NAICS industry that was highly ranked for Overexertion and Bodily Reaction. The top five 5-digit NAICS industries for LT claims as ranked by PI for Overexertion and Bodily Reaction included Other Motor Vehicle Parts Manufacturing (33639), Ambulance Services (62191), General Warehousing and Storage (49311), Nursing Care Facilities (62311), and Beer and Ale Merchant Wholesalers (42481) (Table 5). The majority of LT Overexertion and Bodily Reaction claims across all industries were due to Overexertion Involving Outside Sources (80%) followed by Other Exertions or Bodily Reactions (14%) (Table 6).

## 3.4. Comparisons to BLS SOII and other WC systems

Overall proportions of injury events/exposures from OHBWC insured private employers were similar to those among private employers in data from the U.S. national and Ohio BLS SOII (Bureau of Labor Statistics & U.S. Department of Labor, 2017). In 2017, Overexertion and Bodily Reaction represented the largest share of LT injuries in all three datasets (BLS National, 33.6%; BLS Ohio, 33.5%; OHBWC, 31.0%), followed by Contact with Objects and Equipment (BLS National, 26.0%; BLS Ohio, 29.3%; OHBWC, 23.7%), Falls, Slips, Trips (BLS National, 25.8%; BLS Ohio, 25.8%; OHBWC, 30.1%), Transportation Incidents (BLS National, 5.5%; BLS Ohio, 4.5%; OHBWC, 8.4%), Violence and Other Injuries by Persons or Animals (BLS National, 4.5%; BLS Ohio, 3.9%; OHBWC, 2.8%), Exposure to Harmful Substances or Environments (BLS National, 4.3%; BLS Ohio, 2.8%; OHBWC, 3.1%), and Fires and Explosions (BLS National, 0.1%; BLS Ohio private, 0.0%; OHBWC, 0.3%).

Similar overall proportions of injury events/exposures for 2014–2017 were also found in other state WC systems in CA, MA, MI, TN, and WA, and these are summarized in Table 7. The definition of LT varied in these states and there are a number of other system differences that preclude direct comparison. Although the WA WC system data are perhaps most comparable to OHBWC in terms of the type of administrative data, size, and timeframe, there are still notable differences. For example, the WA data include public employers, and the event/exposure data fields are manually coded. Also, the WA LT cases are defined as having four or more DAW. Despite these differences, shares of injury event/exposures types in total (both LT and MO) claims in OHBWC data from 2007 to 2017 are similar to those reported for state-insured

employers in WA State from 2007 to 2017 among all accepted WC claims (both LT and MO) (Adams, 2020). The count ranking of event/exposure type is the same, although there are differences in their shares, especially for Contact with Objects and Equipment and Overexertion and Bodily Reaction (Table 7). These differences in reported events/exposures could reflect differences in the mix of employer types and industries within each dataset. As noted, this study did not include public employers, and overall there were a greater proportion of MNF and HCSA employers in the OHBWC dataset (Bureau of Labor Statistics & U.S. Department of Labor, 2020).

The National Council on Compensation Insurance (NCCI) recently published 2016 data for LT claims for over 30 states combined. The definition of LT in these states ranged from four to eight DAW (Davis & Brown, 2020). NCCI reported WC LT claim frequencies using WCIO codes for injury cause, nature, and part of body (Workers Compensation Insurance Organizations, 2020), and NIOSH applied the WCIO-OIICS crosswalks to the published NCCI data report. The event/exposure proportions for LT claims as reported by NCCI for 2016 were highly correlated (0.92) with the proportions in the OHBWC insured private employer data for the same period. Comparisons are limited because NCCI did not report WCIO code proportions for several smaller OIICS event/exposure types (Table 7).

## 4. Discussion

### 4.1. Machine learning comparisons

This study used an algorithm based on logistic regression (Bertke et al., 2016) to determine 1- and 2-digit OIICS event/exposures (up to forty-six categories). Overall, findings were consistent with a prior study (Meyers et al., 2018) that used an earlier algorithm based on Bayesian analyses to determine three broad categories of causation (Bertke et al., 2012). Additionally, more recent published data (National Institute for Occupational Safety and Health (NIOSH), 2020) indicated that shares of the three broad causation categories [musculoskeletal disorders due to overexertion and bodily reaction (31%), slips, trips, falls (33%), and other causes (35%)] were very similar to shares found in this study for 1-digit event/exposure divisions [Overexertion and Bodily Reaction (33%) and Falls, Slips, and Trips (31%) and all other 1-digit events/exposures (35%)] for the same time period and population. Proportions were also similar at NORA industry levels (data not shown).

These findings demonstrate the consistency between results, despite different statistical approaches, and this provides some support for the validity of both methods. The results also show that the new algorithm builds on the prior research primarily by expanding the ability to code subcategories of causation within Falls, Slips, Trips (e.g., falls from height vs. on level) and further defining other event/exposures by sub-type (Contact with Objects and Equipment, Transportation Incidents, Exposure to Harmful Substances or Environments, Violence and Other Injuries by Persons or Animals, and Fires and Explosions). This is an important advance. Compared to the three broad categories, the additional levels of detail help to develop prevention insights and the OIICS categories are being used by a growing number of comparable data sources (such as BLS SOII and other state WC data) with results coded at this level of causation and more detailed levels.

Currently, the coding of WC claims is a manually intensive process that is conducted by a number of parties within the WC system (insurers, claims administrators, employers, and state bureaus) using a variety of coding systems (WCIO, OIICS, etc.). This study provides additional evidence that the use of machine learning approaches can likely be expanded in WC and related systems to improve the efficiency and accuracy of claims coding and harmonize the coding of narratives to utilize the BLS OIICS coding system

**Table 4**  
Total (medical-only and lost-time <sup>a</sup>) claim counts, proportions, and rates <sup>b</sup> by event/exposure by industry sector, 2007–2017. <sup>c</sup>

Event/Exposure Type	Metric	NORA <sup>d</sup> Industry Sector										
		AFF	CON	HCSA	MIN	MNF	OIL	PSA	SRV	TWU	WRT	ALL
All Events/Exposures	Count	4,901	72,416	113,982	2,356	194,117	1,901	4,658	227,273	36,769	115,780	774,153
	% of all LT claims	0.63%	9.35%	14.72%	0.30%	25.07%	0.25%	0.60%	29.36%	4.75%	14.96%	100.00%
	Rate	3.323	4.120	3.749	5.270	5.336	3.914	8.948	2.486	4.421	3.206	3.469
Violence and Other Injuries by Persons or Animals	Count	258	913	15,763	15	841	28	144	6,073	535	1,639	26,209
	% of all LT claims	0.98%	3.48%	60.14%	0.06%	3.21%	0.11%	0.55%	23.17%	2.04%	6.25%	100.00%
	% of sector LT claims	5.26%	1.26%	13.83%	0.64%	0.43%	1.47%	3.09%	2.67%	1.46%	1.42%	3.39%
	Rate	0.175	0.052	0.518	0.034	0.023	0.058	0.277	0.066	0.064	0.045	0.117
Transportation Incidents	Count	128	2,208	3,348	103	1,527	127	527	6,619	4,014	4,073	22,674
	% of all LT claims	0.56%	9.74%	14.77%	0.45%	6.73%	0.56%	2.32%	29.19%	17.70%	17.96%	100.00%
	% of sector LT claims	2.61%	3.05%	2.94%	4.37%	0.79%	6.68%	11.31%	2.91%	10.92%	3.52%	2.93%
Fires and Explosions	Count	4	116	19	7	191	16	8	164	40	135	700
	% of all LT claims	0.57%	16.57%	2.71%	1.00%	27.29%	2.29%	1.14%	23.43%	5.71%	19.29%	100.00%
	% of sector LT claims	0.08%	0.16%	0.02%	0.30%	0.10%	0.84%	0.17%	0.07%	0.11%	0.12%	0.09%
Falls, Slips, Trips	Count	993	15,076	27,555	438	25,136	424	645	52,469	9,825	23,631	156,192
	% of all LT claims	0.64%	9.65%	17.64%	0.28%	16.09%	0.27%	0.41%	33.59%	6.29%	15.13%	100.00%
	% of sector LT claims	20.26%	20.82%	24.17%	18.59%	12.95%	22.30%	13.85%	23.09%	26.72%	20.41%	20.18%
Exposure to Harmful Substances or Environments	Count	240	3,079	3,682	78	10,552	110	82	16,578	911	3,535	38,847
	% of all LT claims	0.62%	7.93%	9.48%	0.20%	27.16%	0.28%	0.21%	42.68%	2.35%	9.10%	100.00%
	% of sector LT claims	4.90%	4.25%	3.23%	3.31%	5.44%	5.79%	1.76%	7.29%	2.48%	3.05%	5.02%
	Rate	0.163	0.175	0.121	0.174	0.290	0.226	0.158	0.181	0.110	0.098	0.174
Contact with Objects and Equipment	Count	2386	36,056	31,131	1,258	110,864	833	784	103,481	11,325	54,646	352,764
	% of all LT claims	0.68%	10.22%	8.82%	0.36%	31.43%	0.24%	0.22%	29.33%	3.21%	15.49%	100.00%
	% of sector LT claims	48.68%	49.79%	27.31%	53.40%	57.11%	43.82%	16.83%	45.53%	30.80%	47.20%	45.57%
	Rate	1.618	2.051	1.024	2.814	3.047	1.715	1.506	1.132	1.362	1.513	1.581
Overexertion and Bodily Reaction	Count	862	14,715	32,146	447	44,397	353	2,449	41,102	9,996	27,797	174,264
	% of all LT claims	0.49%	8.44%	18.45%	0.26%	25.48%	0.20%	1.41%	23.59%	5.74%	15.95%	100.00%
	% of sector LT claims	17.59%	20.32%	28.20%	18.97%	22.87%	18.57%	52.58%	18.08%	27.19%	24.01%	22.51%
	Rate	0.584	0.837	1.057	1.000	1.220	0.727	4.705	0.450	1.202	0.770	0.781
Non-classifiable	Count	30	253	338	10	609	10	19	787	123	324	2503
	% of all LT claims	1.20%	10.11%	13.50%	0.40%	24.33%	0.40%	0.76%	31.44%	4.91%	12.94%	100.00%
	% of sector LT claims	0.61%	0.35%	0.30%	0.42%	0.31%	0.53%	0.41%	0.35%	0.33%	0.28%	0.32%
	Rate	0.020	0.014	0.011	0.022	0.017	0.021	0.036	0.009	0.015	0.009	0.011

<sup>a</sup> Eight or more days away from work.

<sup>b</sup> Rate per 100 full-time equivalents.

<sup>c</sup> Among state-insured private employers.

<sup>d</sup> NORA = National Occupational Research Agenda; NORA Sectors by North American Industry Classification System (NAICS) codes include: Agriculture, Forestry, Fishing/Hunting (AFF) = 11; Construction (CON) = 23; Health Care and Social Assistance (HCSA) = 62, 54194, 81291; Manufacturing (MNF) = 31, 32, 33; Mining (MIN) = 21; Oil & Gas (OIL) = 211, 213111, & 213112; Public Safety (PSA) = 92212, 92214, 92216, 62191; Services, except Public Safety (SRV) = 51–56, 61, 71, 72, 81, 92; Transportation, Warehousing, Utilities (TWU) = 22, 48, 49; Wholesale Trade/Retail Trade (WRT) = 42, 44, 45. Only the private sector portion of the PSA sector is included in the current analyses (62191, Ambulance Services).

in a manner similar to the SOII. NIOSH and other partners are continuing to share open source algorithms and technical assistance to WC bureaus and others interested in applying the methods.

4.2. Comparisons to BLS SOII and other WC systems

Comparison of OHBWC data to SOII are limited because event/exposure divisions for the BLS SOII data are only available for cases

with one or more DAW. By contrast, the OHBWC LT cases are defined to have eight or more DAW. There are also several other differences between the data collection systems, such as the sizes and industry types of employers included, because the OHBWC data only includes insured employers, which generally have 500 or fewer employees (Wurzelbacher et al., 2016). SOII data are collected from a national sample of employers via surveys, whereas OHBWC data are population-level, collected from all insured

**Table 5**  
Lost-time <sup>a</sup> claim counts, rates <sup>b</sup>, and prevention indices <sup>c</sup> by event/exposure by detailed industry sector, 2007–2017.<sup>d</sup>

NAICS <sup>e</sup> Code	NAICS Description	NORA <sup>f</sup> Sector	Mean Annual FTE	All Event/Exposures Combined						Violence and other injuries by persons or animals LT PI Rank	Transportation incidents LT PI Rank	Fires and explosions LT PI Rank	Falls, slips, trips- LT PI Rank	Exposure to harmful substances or environments LT PI Rank	Contact with objects and equipment LT PI Rank	Overexertion and bodily reaction LT PI Rank
				LT Claim Rate	LT Claim Rate Rank	LT Claim Count	LT Claim Count Rank	LT PI	LT PI Rank							
48412	General Freight Trucking, Long-Distance	TWU	17,938	1.89	7	3728	4	5.5	1	95	2	46	1	94.5	37	6
33639	Other Motor Vehicle Parts Manufacturing	MNF	9,080	1.52	31	1518	11	21.0	2	120	99	143	57	31	17	1
62191	Ambulance Services	PSA	4,732	1.67	14	867	32	23.0	3	40.5	6	133	64.5	235	234.5	2
48423	Specialized Freight (except Used Goods) Trucking, Long-Distance	TWU	2,845	2.18	4	683	47	25.5	4	62	7	19	5	18	87.5	10
48422	Specialized Freight (except Used Goods) Trucking, Local	TWU	7,125	1.53	30	1198	22	26.0	5	49.5	1	37	3	103	105	48
42393	Recyclable Material Merchant Wholesalers	WRT	5,102	1.57	23	879	30	26.5	6	99.5	33.5	1	24	5	2	70.5
33151	Ferrous Metal Foundries	MNF	2,865	2.10	5	661	49	27.0	7.5	224	206	2	86	2	5	8
33152	Nonferrous Metal Foundries	MNF	3,404	1.85	8	693	46	27.0	7.5	233	248.5	8	85	1	7	9
49311	General Warehousing and Storage	TWU	8,122	1.41	38	1264	19	28.5	9	84	24	256	27	83.5	20.5	3.5
33211	Forging and Stamping	MNF	7959	1.39	40	1218	21	30.5	10.5	251	157	71	77	27	1	11
48411	General Freight Trucking, Local	TWU	8,675	1.36	44	1294	17	30.5	10.5	114	4	75	4	156	99.5	29
56211	Waste Collection	SRV	3,228	1.77	10	630	53	31.5	12	70	8	41	21	96.5	32.5	12
42481	Beer and Ale Merchant Wholesalers	WRT	2,761	1.96	6	595	58	32.0	13	89	47	120	13	208	86	5
56132	Temporary Help Services	SRV	46,587	1.16	71	5920	2	36.5	14	55	57.5	48	43.5	14	6	16
48541	School and Employee Bus Transportation	TWU	1,794	2.24	2	443	75	38.5	15	24	4	106	11	331	259	62
62311	Nursing Care Facilities (Skilled Nursing Facilities)	HSA	40,133	1.13	75	5002	3	39.0	16	8	196	119	8	51	140	3.5
42351	Metal Service Centers and Other Metal Merchant Wholesalers	WRT	7,646	1.25	53	1048	26	39.5	17	78	127	40	58	58.5	3	37
23829	Other Building Equipment Contractors	CON	4,283	1.36	43	639	50	46.5	18	60.5	71	86	9	12	36	26
33231	Plate Work and Fabricated Structural Product Manufacturing	MNF	5,805	1.23	57	785	37.5	47.3	19	305.5	176.5	43	78	39.5	4	44
56173	Landscaping Services	SRV	15,047	1.08	91	1786	8	49.5	20	63	15	91.5	36	86.5	8	67
48421	Used Household and Office Goods Moving	TWU	1,979	1.74	12	379	87.5	49.8	21	210	49.5	256	23	331	58	17
23816	Roofing Contractors	CON	5,397	1.21	61	719	45	53.0	22	77	84.5	95	2	30	80	105.5
21311	Support Activities for Mining	MIN/OIL	3,961	1.32	48	574	60	54.0	23	237	16.5	4	50	72	11	110
33142	Copper Rolling, Drawing, Extruding, and Alloying	MNF	2,021	1.64	16	365	92.5	54.3	24	116	108	32	106	55	22	14
33131	Alumina and Aluminum Production and Processing	MNF	1,864	1.64	15	337	99	57.0	25	305.5	213	30	84	29	12.5	46
23812	Structural Steel and Precast Concrete Contractors	CON	1,967	1.61	19	349	96.5	57.8	26	305.5	218.5	31	22	145	24	60.5
62331	Continuing Care Retirement Communities and Assisted Living Facilities for the Elderly	HSA	12,064	1.04	102	1376	14	58.0	27	14	264	256	20	80	187.5	7
62321	Residential Intellectual and Developmental Disability Facilities	HSA	12,945	1.00	108	1427	13	60.5	28	2.5	36	145	19	210	170	39.5
32732	Ready-Mix Concrete Manufacturing	MNF	2,004	1.56	24	345	98	61.0	29	75	14	54	18	46	92	103
23814	Masonry Contractors	CON	4,739	1.16	70	605	55	62.5	30	126	114.5	55	15	75	77	24
23731	Highway, Street, and Bridge Construction	CON	5,950	1.11	84	727	43	63.5	31.5	189	11	25	47	34	23	109
53111	Lessors of Residential Buildings and Dwellings	SRV	6,872	1.07	92	810	35	63.5	31.5	33	205	66	7	53	111.5	20

(continued on next page)

Table 5 (continued)

NAICS ° Code	NAICS Description	NORA Sector	Mean Annual FTE	All Event/Exposures Combined						Violence and other injuries by persons or animals	Transportation incidents	Fires and explosions	Falls, slips, trips-	Exposure to harmful substances or environments	Contact with objects and equipment	Overexertion and bodily reaction
				LT Claim Rate	LT Claim Rate Rank	LT Claim Count	LT Claim Count Rank	LT PI	LT PI Rank							
62431	Vocational Rehabilitation Services	HSA	4,505	1.16	69	577	59	64.0	33	23	53	256	6	186	152.5	59
32629	Other Rubber Product Manufacturing	MNF	5,011	1.13	76	622	54	65.0	34.5	132	320	256	121.5	7	25	13
33122	Rolling and Drawing of Purchased Steel	MNF	1,809	1.57	22	313	108	65.0	34.5	205	270	52	134.5	93	12.5	47
33281	Coating, Engraving, Heat Treating, and Allied Activities	MNF	9,150	1.01	107	1021	28	67.5	36	122	130	13	95	<b>3.5</b>	15.5	33.5
44411	Home Centers	WRT	3,607	1.17	66	466	71	68.5	37	105	109	126	101.5	221	26	19
32621	Tire Manufacturing	MNF	1,032	2.18	3	248	139	71.0	38	305.5	242	39	238	26	30.5	18
42441	General Line Grocery Merchant Wholesalers	WRT	3,095	1.20	64	409	80	72.0	40	145	31.5	256	41	160	110	27.5
48599	Other Transit and Ground Passenger Transportation	TWU	1,535	1.61	20	272	124	72.0	40	47	<b>4</b>	256	163	331	286	192
56133	Professional Employer Organizations	SRV	10,137	0.97	120	1078	24	72.0	40	82	35	256	30	62.5	65.5	35.5
32721	Glass and Glass Product Manufacturing	MNF	2,128	1.37	41	320	104	72.5	42	305.5	279	256	137	81	28	21
32619	Other Plastics Product Manufacturing	MNF	12,736	0.94	130	1315	16	73.0	43	162	197.5	42	79	15	32.5	15
32192	Wood Container and Pallet Manufacturing	MNF	2,735	1.23	58	369	91	74.5	45	222	116	256	186	185	9	102
33637	Motor Vehicle Metal Stamping	MNF	6,427	1.02	105	723	44	74.5	45	194	203	138	112	79	14	23
71121	Spectator Sports	SRV	1,442	1.62	18	257	131	74.5	45	<b>1</b>	92	256	225	331	206.5	121
62322	Residential Mental Health and Substance Abuse Facilities	HSA	2,365	1.28	51	332	101	76.0	47	<b>2.5</b>	80	256	56	285	255.5	167
23891	Site Preparation Contractors	CON	8,268	0.96	125	871	31	78.0	48	163	21	9	40	43	29	129.5
48841	Motor Vehicle Towing	TWU	1,662	1.49	33	272	124	78.5	49	106	9	51	54	222	103	160
56291	Remediation Services	SRV	2686	1.18	65	349	96.5	80.8	50	87	93	62	32	16	67	124
23811	Poured Concrete Foundation and Structure Contractors	CON	4,203	1.06	95	489	67	81.0	51	117	94	256	28	48	65.5	76
33299	All Other Fabricated Metal Product Manufacturing	MNF	6,906	0.96	124	730	42	83.0	52.5	195	189	36	199	101	10	31
56179	Other Services to Buildings and Dwellings	SRV	1,659	1.44	37	262	129	83.0	52.5	68	31.5	50	38	28	133	89
81111	Automotive Mechanical and Electrical Repair and Maintenance	SRV	10,956	0.87	146	1050	25	85.5	54	129	54	<b>5.5</b>	99	92	43	45
23711	Water and Sewer Line and Related Structures Construction	CON	5,191	0.99	110	565	62	86.0	55	138	39	33.5	43.5	104	30.5	141
31151	Dairy Product (except Frozen) Manufacturing	MNF	1,898	1.30	49	272	124	86.5	56	305.5	216	107	49	6	90	74
23899	All Other Specialty Trade Contractors	CON	7,817	0.91	137	785	37.5	87.3	57	133.5	44	68.5	75.5	9	47.5	85
62412	Services for the Elderly and Persons with Disabilities	HSA	15,830	0.83	164	1451	12	88.0	58	7	26	148	16	139	208.5	72
23822	Plumbing, Heating, and Air-Conditioning Contractors	CON	28,215	0.81	172	2500	5	88.5	59	151.5	67	23.5	37	22	71	57
62399	Other Residential Care Facilities	HSA	2171	1.21	62	288	115.5	88.8	60	<b>4</b>	89	256	48	284	250	201
23611	Residential Building Construction	CON	14,787	0.84	163	1360	15	89.0	61	144	95.5	70	12	76	68.5	91
23819_	Other Foundation, Structure, and	CON	6,608	0.94	131	680	48	89.5	62	115	150.5	139	26	89	91	35.5
23831_	Building Exterior Contractors (23819),															
23833	Drywall and Insulation Contractors (23831), and Flooring Contractors (23833)															
23821	Electrical Contractors and Other Wiring Installation Contractors	CON	20,722	0.80	174	1820	7	90.5	63	109	63	21	17	9	109	79
48111	Scheduled Air Transportation	TWU	1,699	1.35	46	252	135.5	90.8	64	197.5	162	256	52.5	278	175	25
42449	Other Grocery and Related Products Merchant Wholesalers	WRT	2,338	1.15	72	296	110.5	91.3	65	123	120	256	46	238	167	30

Table 5 (continued)

NAICS <sup>e</sup> Code	NAICS Description	NORA <sup>f</sup> Sector	Mean Annual FTE	All Event/Exposures Combined						Violence and other injuries by persons or animals LT PI Rank	Transportation incidents LT PI Rank	Fires and explosions LT PI Rank	Falls, slips, trips- LT PI Rank	Exposure to harmful substances or environments LT PI Rank	Contact with objects and equipment LT PI Rank	Overexertion and bodily reaction LT PI Rank
				LT Claim Rate	LT Claim Rate Rank	LT Claim Count	LT Claim Count Rank	LT PI	LT PI Rank							
32611	Plastics Packaging Materials and Unlaminated Film and Sheet Manufacturing	MNF	2,997	1.08	88	357	95	91.5	66.5	305.5	290	67	239.5	107	15.5	41
56172	Janitorial Services	SRV	19,390	0.80	173	1710	10	91.5	66.5	74	45	115	14	32.5	111.5	86
42443	Dairy Product (except Dried or Canned) Merchant Wholesalers	WRT	1,491	1.46	35	239	149	92.0	68	186	174	256	69	273	61	51
56221	Waste Treatment and Disposal	SRV	2,398	1.12	78	296	110.5	94.3	69	218	51	10	39	62.5	144	104
62221	Psychiatric and Substance Abuse Hospitals	HSA	999	1.76	11	193	178	94.5	70	5	179	256	114	256	327	94.5
42447	Meat and Meat Product Merchant Wholesalers	WRT	1,237	1.55	25	211	164.5	94.8	71	305.5	37	256	81	147	54.5	97.5
23713	Power and Communication Line and Related Structures Construction	CON	3,173	1.05	99	365	92.5	95.8	72	148.5	48	73	83	45	64	88
48819	Other Support Activities for Air Transportation	TWU	1,373	1.46	36	220	158	97.0	73.5	179	69.5	256	59	331	142	53
62161	Home Health Care Services	HSA	26,920	0.75	188	2230	6	97.0	73.5	17	19	153	35	127	196	52
42448	Fresh Fruit and Vegetable Merchant Wholesalers	WRT	1,601	1.35	45	238	150	97.5	75	103	42.5	256	51	131.5	120.5	78
23622	Commercial and Institutional Building Construction	CON	14,514	0.79	176	1258	20	98.0	76.5	209	101	146	33	71	59.5	94.5
44132	Tire Dealers	WRT	3,984	0.97	118	425	78	98.0	76.5	305.5	81	3	147	122	63	49

Bolded cells identify industries in the top-5 PI ranking for either all event/exposures combined or an individual event/exposure. Due to space limitations, entire top 5 PI lists for all individual event/exposures are not provided in this table. For Fires and Explosions, this includes Iron and Steel Mills and Ferro Alloy Manufacturing (33111), which had a PI rank of 5.5. For Exposure to Harmful Substances or Environments, this includes Other Basic Organic Chemical Manufacturing (32519), which had a PI rank of 3.5.

<sup>a</sup> Eight or more days away from work.

<sup>b</sup> Rate per 100 full-time equivalents.

<sup>c</sup> PI = Prevention Index (Mean LT Claim Rate and Count Rank).

<sup>d</sup> Among state-insured private employers.

<sup>e</sup> All North American Industry Classification System (NAICS) codes are 2017 version terms. Certain NAICS were impacted by code changes and were combined across 2007, 2012, and 2017 versions. For this table, this includes 23819\_23831\_23833.

<sup>f</sup> NORA = National Occupational Research Agenda; NORA Sectors by North American Industry Classification System (NAICS) codes include: Agriculture, Forestry, Fishing/Hunting (AFF) = 11; Construction (CON) = 23; Health Care and Social Assistance (HCSA) = 62, 54194, 81291; Manufacturing (MNF) = 31, 32, 33; Mining (MIN) = 21; Oil & Gas (OIL) = 211, 213111, & 213112; Public Safety (PSA) = 92212, 92214, 92216, 62191; Services, except Public Safety (SRV) = 51-56, 61, 71, 72, 81, 92; Transportation, Warehousing, Utilities (TWU) = 22, 48, 49; Wholesale Trade/Retail Trade (WRT) = 42, 44, 45. Only the private sector portion of the PSA sector is included in the current analyses (62191, Ambulance Services).

employers. Despite these system differences, proportions and rates of LT OHBWC claims by 1-digit injury event/exposure divisions were largely similar to those among private employers in data from the U.S. national and Ohio BLS SOII (Bureau of Labor Statistics & U.S. Department of Labor, 2017). Differences in proportions are likely a function of the higher relative severity of OHBWC LT claims, differences in injury patterns nationally versus Ohio, the absence of claims from self-insured employers in the OHBWC data, and other noted differences compared with the BLS SOII and state WC systems.

Other WC data systems may contain data that are more similar to OHBWC data than SOII, but generally these data are not publicly available for the same time period (2007–2017) except for data from WA State and NCCI. A NIOSH surveillance grant resulted in such data becoming more readily available in several states (Harrison et al., 2019; Massachusetts Department of Industrial Accidents et al., 2020; Michigan Department of Health and Human Services, 2020; Taylor et al., 2020) for more recent years 2014–2017 and moving forward. Despite differences in state WC systems, industry mixes, and covered employer populations (private employers with 500 or fewer employees in some states, and all employers in other states), shares of events/exposure types in total claim counts in data published by NCCI and other individual states for 2014–2017 were similar to those in OHBWC data. However, OHBWC total claim (LT + MO) data did tend to have a higher proportion of Contact with Objects and Equipment compared to other states (Tables 4, 6, and 7).

In summary, although there are many differences between the BLS SOII and state WC systems, similar overall proportions of injury event/exposures for 2014–2017 were generated by these data sources, especially when comparing injury measures using similar severity criteria.

#### 4.3. Event/exposure time trends

Counts and rates of WC LT claims among state-insured private employers in OH declined substantially from 2007 to 2017 (46% decline in rate per 100 FTE), and downward trends for this time period have also been noted nationally in WC systems and the BLS SOII for all claims overall and LT claims specifically. Overall U.S. private industry SOII LT rates (1 or more DAW or restricted duty) for private industries dropped from 1.22 per 100 FTE in 2007 to 0.89 in 2017 (–26.8% decline) (Bureau of Labor Statistics & U.S. Department of Labor, 2007, 2017). NCCI noted a 19% decline in the number of LT claims per unit of earned premium for over thirty states (with the LT definition ranging from four to eight DAW) from 2011 to 2016 (Davis & Brown, 2020). Reasons for this national trend may include safety and technological improvements (Davis & Brown, 2020; Davis & Crotts, 2009; Davis, 2020), underreporting (Morse et al., 2005), and economic factors such as unemployment trends (Davis, 2020; Moore & Tompa, 2011). Understanding these national trends is a complex task that requires additional discussion and research beyond the scope of the current analyses.

Despite declining counts and rates, the ranking of leading injury event/exposures remained largely unchanged among OHBWC-insured private employer LT claims from 2007 to 2017 (Table 2). Trends of leading injury event/exposures did differ by NORA industry sector (Tables 3 and 4) and specific 5-digit NAICS industries (Table 5), and this is important to understand to develop tailored prevention programs.

#### 4.4. Industry and prevention insights by event/exposure

Statistics that point to high numbers and rates of certain types of injuries in certain industries are only useful if they assist in tar-

geting actions to reduce those injuries. The downward trends we have seen may indicate that some progress has been made in Ohio and nationally in developing effective OSH programs and interventions to reduce injuries. But challenges remain, especially in certain industries, to develop new interventions and perhaps increase adoption of existing approaches for specific event/exposures. This section of the discussion provides a brief overview of available methods of injury reduction and relates them to the needs of industries with high rates of major injury types that we have identified in Ohio. The purpose is to help point the way to more detailed matching of interventions to industries that still more detailed analysis of workers compensation data could support in the future.

On the broadest level, research has indicated that OSH programs that include several integrated elements (management commitment, employee participation, hazard identification, hazard control, training, and program evaluation) can be effective in reducing workplace exposure and injuries (Andersen et al., 2019; López-Ruiz & Martínez, 2013; National Institute for Occupational Safety and Health (NIOSH), 2020; Occupational Safety and Health (OSHA) & United States Department of Labor, 2020; Robson, Clarke, & Cullen, 2007; Tompa, Dolinschi, de Oliveira, & Irvin, 2009). These programs and their elements can be evaluated by using leading indicators to measure performance (Occupational Safety and Health (OSHA) & United States Department of Labor, 2020), develop specific program improvement plans, and eliminate future injuries.

The OSH principle of the hierarchy of controls (National Institute for Occupational Safety and Health (NIOSH), 2020) also suggests that hazard elimination and control is most effective through fundamental design and process changes, followed by engineering controls and equipment to improve physical and cognitive aspects of the worksite. If these approaches are not sufficiently protective or practical by themselves, personal protective equipment (PPE) and administrative controls to reduce an individual worker's exposure through practices such as job rotation and job enlargement are the next most effective approach. Specific examples of OSH programs and interventions are discussed below for industries with high risks for each major event/exposure type.

##### 4.4.1. Overexertion and bodily reaction

Overexertion and Bodily Reaction represented the highest proportion of LT claims in all sectors combined (33.0%) among OHBWC-insured private employers (Table 3). The majority of these injuries were due to Overexertion Involving Outside Sources (Table 6). Many of the top 5-digit NAICS industries for Overexertion and Bodily Reaction LT claims (Table 5) involve heavy manual material handling in manufacturing or warehousing/delivery or patient handling activities. Two of these industries were also highlighted in recent OHBWC-NIOSH claim analyses for Ambulance Services (Reichard, Al-Tarawneh, & Konda, 2018) and Nursing Care Facilities (Bush, Reichard, Wurzelbacher, Tseng, & Lampl, 2020).

There is some evidence that broad ergonomic programs are effective at reducing overexertion-related injuries (Rivlis et al., 2006; Sultan-Taïeb, Parent-Lamarche, & Gaillard, 2017; Tompa, Dolinschi, de Oliveira, Amick, & Irvin, 2010). Specific equipment interventions can also be effective. A number of studies have demonstrated the effectiveness of patient handling equipment in reducing Overexertion and Bodily Reaction injuries in healthcare settings (Collins, Wolf, Bell, & Evanoff, 2004; Fujishiro, Weaver, Heaney, Hamrick, & Marras, 2005; Li, Wolf, & Evanoff, 2004; Ohio Bureau of Workers' Compensation (OHBWC), 2020; Park, Bushnell, Bailer, Collins, & Stayner, 2009; Wurzelbacher, Bertke, & Lampl, 2014), and material handling equipment in construction (Lowe et al., 2020) and manufacturing settings (Marras, Allread, Burr, & Fathallah, 2000; Van der Molen, Frings-Dresen, & Sluiter, 2010; Vink, Urlings, & Van der Molen, 1997; Wurzelbacher,

Lampl, Bertke, & Tseng, 2020). Patient-handling intervention examples include powered cots (to move patients to/from vehicles), gurney lifts (to move patients to/from beds), and transfer sheets. Construction intervention examples include electrical cable feeding/pulling systems, concrete sawing equipment, skid steer attachments for concrete breaking, and boom lifts. Manufacturing material handling intervention examples include lift and tilt tables, powered hand trucks, jibs and cranes, and vacuum lift assists. Model ergonomic programs (National Institute for Occupational Safety and Health (NIOSH), 2020), methods for ergonomic risk factor identification (American Industrial Hygiene Association (AIHA), 2020), and compilations of control interventions and best practices are available online for specific industries including construction (International Ergonomic Association (IEA), 2020; Ohio Bureau of Workers' Compensation (OHBWC), 2020; The Center for Construction Research and Training, 2020), agriculture, manufacturing (Ohio Bureau of Workers' Compensation (OHBWC), 2020), mining, healthcare (Ohio Bureau of Workers' Compensation (OHBWC), 2020), wholesale retail trade (International Ergonomic Association (IEA), 2020; National Institute for Occupational Safety and Health (NIOSH), 2020), and public employers (Ohio Bureau of Workers' Compensation (OHBWC), 2020).

#### 4.4.2. Falls, Slips, and Trips

Falls, Slips, and Trips represented the second highest proportion of LT claims in all sectors (31.4%) among OHBWC-insured private employers (Table 3). Falls to Lower Level represented 29% of these injuries (Table 6). The number of transportation-related industries in the top 5 LT PI rankings (Table 5) highlights the importance of Falls, Slips, Trips prevention in this sector. Many of these injuries occur while workers are entering/exiting vehicles, especially in wet and icy conditions. WA State has developed a special emphasis program called Trucking Injury Reduction Emphasis (TIRES) (Washington State Labor and Industries, 2020) and maintains a specific website (Washington State Labor and Industries, 2020) to highlight prevention activities. Example interventions include slip-resistant footwear and improved vehicle access.

Construction industries also have known hazards for Falls, Slips, Trips including the use of ladders and scaffolding equipment. Fall prevention in construction (especially among roofers) has been an emphasis area for many years (The Center for Construction Research and Training, 2020), and specific fall protection standards and awareness campaigns have been developed (American National Standards Institute - American Society of Safety Professionals, 2020; Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020). Example Falls, Slips, Trips interventions include a reduction in ladder use by building stairways early in the construction process (National Institute for Occupational Safety and Health (NIOSH), 2020), improved ladder/scaffolding designs to improve stability and detect unsafe conditions, reduction of worksite clutter, and use of slip-resistant footwear (The Center for Construction Research and Training, 2020).

Falls, Slips, Trips prevention programs are also important in healthcare industries and involve several elements including slip-resistant footwear and flooring, and best practices to reduce slippery conditions and trip hazards (National Institute for Occupational Safety and Health (NIOSH), 2020; Bell, Collins, & Dalsey, 2020; Bell, Collins, & Wolf, 2008). Slip resistant footwear has been shown to be effective in variety of industries, including food service (Bell, Collins, & Chiou, 2019; Verma et al., 2011, 2014) and healthcare settings service (Bell et al., 2008). Slip-resistant flooring has also been shown to be effective in reducing the frequency and cost of WC claims (Wurzelbacher et al., 2014).

#### 4.4.3. Contact with Objects and Equipment

Contact with Objects and Equipment represented the third highest proportion of LT claims in all sectors (22.5%) among OHBWC-insured private employers (Table 3). The majority of these injuries were due to Struck by Objects or Equipment, followed by Caught in or Compressed by Equipment or Objects (Table 6). Many of the top 5-digit NAICS industries for Contact with Objects and Equipment LT claims (Table 5) involve the usage of machinery with known hazards for Contact with Objects and Equipment injuries.

The use of standardized machine guarding review checklists is encouraged in metal-working and similar industries to identify hazards as well as general safety program assessments to identify larger system deficiencies (Parker et al., 2015, 2009, 2015). Such programs are important in all industries but may be especially critical in industries involving the work of temporary help services, where workers have less safety training (Foley, 2017), shorter tenure, and higher injury rates for Contact with Objects and Equipment claims (Al-Tarawneh, Wurzelbacher, & Bertke, 2020; Smith, Silverstein, Bonauto, Adams, & Fan, 2010), compared to peers performing similar work.

Once hazards are recognized, a number of specific interventions have been shown to be effective in reducing Contact with Objects and Equipment injuries. This includes machine guarding, safety saws (Wurzelbacher et al., 2014), and active suspension seats to reduce whole body vibration among truck drivers (Kim, Zigman, Dennerlein, & Johnson, 2018). PPE, including safety glasses (Forst, Lacey, & Chen, 2004; Lipscomb, 2000), gloves (Leslie et al., 1996; Salkin, Stuchin, Kummer, & Reininger, 1995), and general awareness campaigns (Mancini, Baldasseroni, & Laffi, 2005) has also been shown to help reduce Contact with Objects and Equipment injuries when integrated as part of an overall safety program. The NIOSH Manufacturing Sector NORA Council recently developed a Hazardous Energy Control (Lockout and Other Means) Resource Guide to help summarize approaches to prevent Contact with Objects and Equipment injuries in the manufacturing industry (National Institute for Occupational Safety and Health (NIOSH), 2020).

#### 4.4.4. Transportation Incidents

Transportation Incident claims represented the fourth highest proportion of LT claims in all sectors (7.0%) among OHBWC-insured private employers (Table 3). The majority of these injuries were due to Roadway Incidents, Motorized Land Vehicles (Table 6). Many of the top 5-digit NAICS industries for Transportation Incidents LT claims (Table 5) require workers to spend the majority of their work shift driving vehicles, which increases opportunities and hazards for Transportation Incidents. Several prevention programs and interventions have been developed to address these hazards (Hickman & Geller, 2003; Tiesman et al., 2019; Vivoda, Pratt, & Gillies, 2019). For example, the WA SHARP TIRES program (Washington State Labor and Industries, 2020) highlights many interventions designed to prevent transportation incidents. Certain interventions such as in-vehicle monitoring systems (Bell, Taylor, Chen, Kirk, & Leatherman, 2017; Hickman & Hanowski, 2011; Horrey, Lesch, Dainoff, Robertson, & Noy, 2012) have been shown to reduce Transportation Incidents from occurring. Other interventions have focused on improving survivability after incidents through improved vehicle design and engineering (National Institute for Occupational Safety and Health (NIOSH), 2020). Newer technologies are rapidly developing, including systems to monitor driver fatigue and proximity sensors to detect where workers are located throughout worksites to alert when possible Transportation Incidents are imminent (National Institute for Occupational Safety and Health (NIOSH), 2020).

**Table 6**  
Lost-time<sup>a</sup> and total (medical-only and lost-time) claim counts and rates<sup>b</sup> by 2-digit event/exposure, 2007–2017.<sup>c</sup>

Event/ Exposure	Event/Exposure Description	Lost-time claims				Medical-only and lost-time claims			
		Count	% among all 2- digit codes	% within 1- digit code	Rate	Count	% among all 2- digit codes	% within 1- digit code	Rate
10	Violence Or Other Injuries By Persons Or Animals, Unspecified	3	0.00%	0.09%	0.0000	3	0.00%	0.01%	0.000
11	Intentional Injuries By Person	1,770	1.26%	50.41%	0.0079	8,050	1.04%	30.71%	0.036
12	Unintentional Or Intent Unknown Injuries By Person	1,011	0.72%	28.80%	0.0045	3,443	0.44%	13.14%	0.015
13	Animal Or Insect Related Incidents	727	0.52%	20.71%	0.0033	14,713	1.90%	56.14%	0.066
20	Transportation Incident, Unspecified	2	0.00%	0.02%	0.0000	2	0.00%	0.01%	0.000
21	Aircraft Incident	49	0.03%	0.49%	0.0002	50	0.01%	0.22%	0.000
22	Rail Vehicle Incident	17	0.01%	0.17%	0.0001	17	0.00%	0.07%	0.000
23	Animal And Other Non-Motorized Vehicle Transportation Incidents	34	0.02%	0.34%	0.0002	36	0.00%	0.16%	0.000
24	Pedestrian Vehicular Incidents	1,226	0.87%	12.37%	0.0055	1,758	0.23%	7.75%	0.008
25	Water Vehicle Incidents	12	0.01%	0.12%	0.0001	12	0.00%	0.05%	0.000
26	Roadway Incidents, Motorized Land Vehicles	7,762	5.51%	78.29%	0.0348	19,847	2.56%	87.53%	0.089
27	Non-Roadway Incidents, Motorized Land Vehicles	810	0.58%	8.17%	0.0036	950	0.12%	4.19%	0.004
29	Transportation Incident, Nec	2	0.00%	0.02%	0.0000	2	0.00%	0.01%	0.000
31	Fires	173	0.12%	30.73%	0.0008	230	0.03%	32.86%	0.001
32	Explosions	390	0.28%	69.27%	0.0017	470	0.06%	67.14%	0.002
40	Falls, Slips, Trips, Unspecified	93	0.07%	0.21%	0.0004	94	0.01%	0.06%	0.000
41	Slip Or Trip W/O Fall	9,100	6.46%	20.56%	0.0408	33,362	4.31%	21.36%	0.150
42	Falls On Same Level	21,969	15.61%	49.65%	0.0985	86,774	11.21%	55.56%	0.389
43	Falls To Lower Level	12,766	9.07%	28.85%	0.0572	35,209	4.55%	22.54%	0.158
44	Jumps To Lower Level	316	0.22%	0.71%	0.0014	745	0.10%	0.48%	0.003
45	Fall Or Jump Curtailed By Personal Fall Arrest System	8	0.01%	0.02%	0.0000	8	0.00%	0.01%	0.000
50	Exposure To Harmful Substances Or Environments, Unspecified	4	0.00%	0.10%	0.0000	6	0.00%	0.02%	0.000
51	Exposure To Electricity	291	0.21%	7.47%	0.0013	1,363	0.18%	3.51%	0.006
52	Exposure, Radiation And Noise	52	0.04%	1.34%	0.0002	1,320	0.17%	3.40%	0.006
53	Exposure To Temperature Extremes	2162	1.54%	55.51%	0.0097	18,774	2.43%	48.33%	0.084
54	Exposure To Air And Water Pressure Changes	4	0.00%	0.10%	0.0000	4	0.00%	0.01%	0.000
55	Exposure To Other Harmful Substances	1,374	0.98%	35.28%	0.0062	17,372	2.24%	44.72%	0.078
56	Exposure To Oxygen Deficiency	2	0.00%	0.05%	0.0000	2	0.00%	0.01%	0.000
57	Exposure To Traumatic Or Stressful Event	4	0.00%	0.10%	0.0000	4	0.00%	0.01%	0.000
59	Exposure To Harmful Substances Or Environments, Nec	2	0.00%	0.05%	0.0000	2	0.00%	0.01%	0.000
60	Contact With Objects And Equipment, Unspecified	735	0.52%	2.32%	0.0033	6,197	0.80%	1.76%	0.028
61	Needlestick Without Exposure To Harmful Substance	50	0.04%	0.16%	0.0002	8,088	1.04%	2.29%	0.036
62	Struck By Objects Or Equipment	17,945	12.75%	56.61%	0.0804	219,851	28.40%	62.32%	0.985
63	Struck Against Object Or Equipment	5,181	3.68%	16.34%	0.0232	77,182	9.97%	21.88%	0.346
64	Caught In Or Compressed By Equipment Or Objects	7,633	5.42%	24.08%	0.0342	38,127	4.92%	10.81%	0.171
65	Struck, Caught, Or Crushed In Collapsing Structures, Equipment Or Materials	70	0.05%	0.22%	0.0003	77	0.01%	0.02%	0.000
66	Rubbed Or Abraded By Friction Or Pressure	63	0.04%	0.20%	0.0003	3,218	0.42%	0.91%	0.014
67	Rubbed, Abraded Or Jarred By Vibration	19	0.01%	0.06%	0.0001	19	0.00%	0.01%	0.000
69	Contact With Objects And Equipment, Nec	3	0.00%	0.01%	0.0000	5	0.00%	0.00%	0.000
70	Overexertion And Bodily Reaction, Unspecified	697	0.50%	1.50%	0.0031	1,595	0.21%	0.92%	0.007
71	Overexertion Involving Outside Sources	37,083	26.34%	79.91%	0.1662	144,065	18.61%	82.67%	0.646
72	Repetitive Motions Involving Microtasks	1,754	1.25%	3.78%	0.0079	3,569	0.46%	2.05%	0.016
73	Other Exertions Or Bodily Reactions	6716	4.77%	14.47%	0.0301	24,843	3.21%	14.26%	0.111
74	Bodily Conditions, Nec	56	0.04%	0.12%	0.0003	58	0.01%	0.03%	0.000
78	Multiple Types Of Overexertions And Bodily Reactions	98	0.07%	0.21%	0.0004	132	0.02%	0.08%	0.001
79	Overexertion And Bodily Reaction And Exertion, Nec	2	0.00%	0.00%	0.0000	2	0.00%	0.00%	0.000
99	Non-classifiable	540	0.38%	NA	0.0024	2,503	0.32%	NA	0.011
	TOTAL	140,780	1		0.6309	774,153	100%		3.469

<sup>a</sup> Eight or more days away from work.<sup>b</sup> Rate per 100 full-time equivalents.<sup>c</sup> Among state-insured private employers.

#### 4.4.5. Exposure to Harmful Substances or Environments

Exposure to Harmful Substances or Environments claims represented the fifth highest proportion of LT claims in all sectors (2.8%) among OHBWC-insured private employers (Table 3). Most of these

injuries were due either to Exposure to Temperature Extremes or Exposure to Other Harmful Substances (Table 6). Although the top LT PI for Exposure to Harmful Substances or Environments was dominated by MNF industries, several SRV industries (resta-

**Table 7**  
Comparison of event/exposure proportions in selected WC systems 2014–2017.

Event/Exposure <sup>a</sup>	Lost-time <sup>b</sup> + medical-only claim count %						Lost-time <sup>b</sup> claim count %			
	OH 2014–2016	OH 2015–2017	OH 2007–2017	WA 2007–2017	CA 2015–2017	TN 2014–2016	OH 2007–2017	WA 2007–2017	MA 2014–2016	NCCI 2016
Violence and Other Injuries by Persons or Animals	4%	4%	3%	4%	3%	5%	2%	3%	4%	
Transportation Incidents	3%	3%	3%	3%	2%	4%	7%	4%	4%	5%
Fires and Explosions	0.08%	0.07%	0.09%	<1%	<1%	0.14%	0.4%	<1%	0.03%	
Falls, Slips, Trips	21%	20%	20%	17%	15%	20%	31%	23%	22%	28%
Exposure to Harmful Substances or Environments	5%	5%	5%	5%	3%	5%	3%	3%	3%	
Contact with Objects and Equipment	46%	46%	46%	37%	25%	35%	23%	19%	15%	31%
Overexertion and Bodily Reaction	22%	22%	23%	31%	37%	27%	33%	45%	30%	31%
Non-classifiable	0.33%	0.38%	0.32%			3%	0.38%		22%	
Other				2%	9%			3%		6%
Multiple					6%					

<sup>a</sup> NIOSH cross-walked the event/exposure from WCIO codes in CA, TN, and NCCI.

<sup>b</sup> Lost-time definition: OH (8 or days away from work, DAW); WA (4 DAW), MA (6 DAW), NCCI states (4–8 DAW).

rans, dry cleaning/laundry services and janitorial services) and one WRT industry were also represented. Many of these industries involve exposures to temperature extremes as well as chemical, electrical, and non-ionizing radiation hazards (Table 5).

WC data systems predominantly capture injuries versus long-term illnesses (Hollenbeck et al., 2013). It follows that WC claims frequencies due to Exposure to Harmful Substances or Environments are undercounted to a greater extent than other event/exposure types. However, it is still useful to conduct analyses of WC claims data because other data sources are lacking. This helps to highlight industries such as restaurants and janitorial services that might be typically overlooked.

Heat stress prevention among outdoor workers and those indoors in manufacturing and other hot environments has been a focus of NIOSH, OSHA, and others for some time (National Institute for Occupational Safety and Health (NIOSH), 2020). These groups recently developed a smartphone app that features real-time, location specific, heat indices, and hourly forecasts as well as tailored recommendations (National Institute for Occupational Safety and Health (NIOSH), 2020). Additional detailed WC claims analyses are also providing heat stress prevention insights (Bonauto, Anderson, Rauser, & Burke, 2005).

Reducing chemical exposures has also been one of the main prevention focus areas of NIOSH, OSHA, and other organizations for many years (American Conference of Governmental Industrial Hygienists (ACGIH®), Threshold Limit Values (TLVs®) & Biological Exposure Indices (BEIs®), 2020; National Institute for Occupational Safety and Health (NIOSH), 2020; National Institute for Occupational Safety and Health (NIOSH), 2020; National Institute for Occupational Safety and Health (NIOSH), 2020; Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020) General prevention approaches should follow the hierarchy of controls, where process changes or substitution of materials are used first to eliminate or reduce some exposures. Industrial ventilation controls are then typically used next to reduce hazards (American Industrial Hygiene Association (AIHA), 2007; Fransman et al., 2008; National Institute for Occupational Safety and Health (NIOSH), 2020; Roelofs, Barbeau, Ellenbecker, & Moure-Eraso, 2003) PPE, such as respirators (Cherrie, Semple, & Brouwer, 2004; National Institute for Occupational Safety and Health (NIOSH), 2020), and administrative controls, such as reducing exposure times through job rotation and enlargement, are used as last steps when exposures cannot be further reduced through the other more effective methods. OSHA also provides online guidance for prevention of Exposure to Harmful

Substances or Environments for specific industries such as restaurants (Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020).

Despite known control methods, respiratory protection standard violations are still some of the most frequent OSHA citations (National Safety Council, Safety and Health Magazine, 2019), and occupational exposure information is lacking in the United States (Moore, Wurzelbacher, & Shockey, 2018; Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020; Shockey, Babik, Wurzelbacher, Moore, & Bisesi, 2018). Standardized data collection forms may enable future pooling of data in OSHA and WC systems (Babik, Shockey, Moore, & Wurzelbacher, 2018), and new direct reaching sensor technologies may be used to understand more fully workplace exposures (National Institute for Occupational Safety and Health (NIOSH), 2020).

#### 4.4.6. Violence and Other Injuries by Persons or Animals

Claims related to Violence and Other Injuries by Persons or Animals represented the sixth highest proportion of LT claims in all sectors (2.5%) among OHBWC-insured private employers (Table 3). Most of these injuries were due to Intentional Injuries by Person (Table 6). Many of top 5-digit NAICS industries for Violence and Other Injuries by Persons or Animals LT claims involve potential violence from patients, hazards for animal related injuries, or sports-related violence (Table 5).

Violence directed at caregivers in HCSA settings is a recognized concern (Groenewold, Sarmiento, & Vanoli, 2018; Miranda, Punnett, & Gore, 2014; National Institute for Occupational Safety and Health (NIOSH), 2020), although it is likely underreported (Galizzi, Miesmaa, & Punnett, 2010; Gates, 2004). Workers in nursing homes and residential mental health and substance abuse facilities may be especially vulnerable because those receiving care may lack the ability to control behaviors that lead to violence toward caregivers (Gillespie, Gates, & Miller, 2010; Miranda et al., 2014). Staff shortages may also increase the possibility that the caregiver is working alone, which may increase the risk of violent incidents.

Integrated violence-prevention programs can be effective in preventing violence-related incidents in HCSA facilities (Gillespie et al., 2010; Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020) Such programs include engineering controls (controlled access areas within facilities and security systems to alert additional staff of situations), standing health and safety committees, and training for staff

and management (Hartley, Ridenour, & Craine, 2012; National Institute for Occupational Safety and Health (NIOSH), 2020; Ohio Bureau of Workers' Compensation (OHBC), 2020).

Prevention of bites and other animal-related injuries in the veterinary and pet care industries is also a priority (Gabel & Gerberich, 2002; Jeyaretnam, Jones, & Phillips, 2000). Interventions include engineering controls (such as passive restraints and animal handling equipment) as well as specialized training to recognize situations that may trigger aggressive behavior in pets, body language that precedes attacks, and methods for de-escalation (American Veterinary Medical Association (AVMA), 2020).

#### 4.4.7. Fires and Explosions

Fires and Explosions represented the lowest proportion of LT claims in all sectors (0.4%) among OHBC-insured private employers (Table 3). The majority of these injuries were due to Explosions (Table 6). The number of WRT and SRV industries in the top rankings (Table 5) points to the importance of applying Fire and Explosion prevention principles beyond heavy manufacturing industries. As an example, Fires and Explosions have become a growing concern among recycling operations, and a recent fire prevention and management program has been developed specifically for this industry (Institute of Scrap Recycling Industries, 2020). As another example, a number of explosions in WRT and SRV are related specifically to tire explosions, and prevention approaches for these incidents have been developed and are available online (Washington State Labor and Industries, 2020).

Although the relative frequency of Fires and Explosions was low, these events clearly can be high severity incidents that result in disabling injuries or death. Process safety is a focused OSH field that deals with the prevention of large-scale, catastrophic events such as building fires and plant explosions (Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020). OSHA has developed a fire-prevention plan standard and numerous regulations have been designed to identify electrical, mechanical, and chemical circumstances that could lead these events (Occupational Safety and Health Administration (OSHA) & United States Department of Labor, 2020).

## 5. Limitations

As with other data sources, there are several limitations associated with the use of WC claims data for OSH surveillance. This includes underreporting, which differs by industry, especially for illnesses (Azaroff et al., 2002, 2013; Biddle, Roberts, Rosenman, & Welch, 1998; Fan, Bonauto, Foley, & Silverstein, 2006; Lipscomb, Dement, Silverstein, Cameron, & Glazner, 2009; Rosenman, Gardiner, & Wang, 2000; Scherzer & Wolfe, 2008; Sears, Bowman, Adams, & Silverstein, 2013; Shannon & Lowe, 2002). There are also still a limited (although growing) number of comparable datasets because there are several differences between state-based WC systems and the BLS SOII. This analysis also was focused on OHBC-insured private employers and does not include self-insured or public employers. There are also limitations to the FTE estimation methods used as described previously (Wurzelbacher et al., 2016). Finally, this study employed machine learning algorithms to determine event/exposure for most claims. Despite these limitations, several states and organizations (Anderson et al., 2013; Harrison et al., 2019; Massachusetts Department of Industrial Accidents et al., 2020; Michigan Department of Health and Human Services, 2020; Taylor et al., 2020; Wurzelbacher et al., 2016) have recently demonstrated that WC data are useful in augmenting traditional surveillance sources such as BLS SOII and the Census of Fatal Occupational Injuries (CFOI) to provide insight into

injury causes, identify higher risk industries, and develop prevention approaches.

## 6. Conclusions

Although counts and rates of WC LT claims declined for all injury types among OHBC-insured private employers from 2007 to 2017, the relative ranking of leading injury event/exposures remained largely unchanged. The majority of claims were due to three main event/exposure types: Overexertion and Bodily Reaction; Falls, Slips, and Trips; and Contact with Objects and Equipment. The other event/exposures in decreasing order of LT frequency include Transportation Incidents; Exposure to Harmful Substances or Environments; Violence and Other Injuries by Persons or Animals; and Fires and Explosions. Despite many differences between the BLS SOII and state WC systems, these systems all reported similar proportions of injury event/exposures for 2014–2017 and overall declines in injury counts and rates. However, the relative ranking of leading injury event/exposures differed by NORA industry sector and specific NAICS industries in OH and other states, and this is important to understand to target prevention efforts and develop tailored prevention programs. These patterns and time trends may indicate that progress has been made in developing effective OSH programs and interventions to reduce injuries.

Challenges remain, especially in certain industries, to develop new approaches and perhaps increase adoption of known prevention approaches for specific event/exposures. Available evidence on intervention effectiveness was summarized and mapped to the analysis results to demonstrate how the results can be used to guide future prevention efforts. As next steps, several focused industry type/exposure WC claims studies (Bush et al., 2020; Reichard et al., 2018) are being conducted to help identify actionable interventions for specific hazards.

This study and others (Anderson et al., 2013; Harrison et al., 2019; Massachusetts Department of Industrial Accidents et al., 2020; Michigan Department of Health and Human Services, 2020; Taylor et al., 2020; Wurzelbacher et al., 2016) have shown that WC data are a useful and complementary source to the SOII and other survey data. Because WC data are a census, analyses can be conducted on a more detailed level, both by injury type and by industry within states. This study also demonstrated that machine learning approaches can be applied to large WC datasets to code claims narratives to detailed levels of causation. Such methods can be expanded and used by WC insurers, bureaus, and employers to improve the accuracy and efficiency of using WC systems to identify prevention priorities. NIOSH and other partners will continue to share open source coding algorithms and offer technical assistance. In conclusion, this study highlights the need for states to continue to use both SOII and WC as well as other data sources to identify specific prevention needs and leverage machine learning approaches to optimize and harmonize case coding processes.

## 7. Practical applications

Employers can use these data to benchmark their safety and health performance against industry peers and develop data-driven plans for prevention. OSH practitioners and researchers can also use these data to understand industry differences in the level and mix of risks, as well as industry trends, and to tailor safety, health, and disability prevention services and research. WC bureaus, regulators, insurers, and employers can use the open source machine learning algorithms and methods to code narrative incident information within injury and illness tracking systems.

## Authors' contributions

- SJW, ARM, MPL, PTB, SJB, and DCR contributed to study conception and design.
- DCR, MPL, CYT, SJW, and ARM contributed to data acquisition.
- SJW, CYT, DCR, SJB, ARM, MPL, and SJN contributed to data analysis.
- SJW, ARM, PTB, MPL, SJB, DCR, CYT, and SJN contributed to data interpretation.
- SJW, SJB, ARM, CYT, DCR, and MPL contributed to methods development.
- CYT, DCR, SJW, SJB, and ARM were key contributors for data management.
- SJW and ARM coordinated the manual coding of claims for the training and quality control data sets.
- SJW drafted the manuscript and led the coauthor and peer review process.
- All authors were involved in revising the manuscript for important intellectual content.
- All authors read and approved the final manuscript 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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## Institution and Ethics approval and informed consent

- This work was performed at both the National Institute for Occupational Safety and Health (NIOSH) and the Ohio Bureau of Workers' Compensation. This study was internally reviewed by NIOSH and it was determined that it did not constitute human subjects research. Rather, the study involved the analysis of coded and previously-collected WC administrative claims data.

## Disclaimer

- The findings and conclusions in this report are those of the authors and do not necessarily represent the official positions of the National Institute for Occupational Safety and Health nor the Ohio Bureau of Workers' Compensation.

## Research data for this article

- To prevent the identification of individual workers or employers, claims-level data cannot be shared. Extensive aggregate claims data are shared in this article.

## 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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**Steve Wurzelbacher** directs the Center for Workers' Compensation Studies at the National Institute for Occupational Safety and Health. In this role, he coordinates workers' compensation claim analyses, exposure assessment research, safety/health intervention effectiveness studies, and health services research with public and private sector partners. Steve has worked in the safety/health field since 1998, as both a researcher and a practitioner. Steve earned a PhD in Occupational Safety and Ergonomics from the University of Cincinnati, a BS in Chemical Science from Xavier University, is a Certified Professional Ergonomist (CPE), and holds the Associate in Risk Management (ARM) designation.

**Alysha R. Meyers**, PhD, CPE is an epidemiologist and ergonomist dedicated to promoting musculoskeletal health. Since 2010, Dr. Meyers has been an epidemiologist at NIOSH, working in the NIOSH Center for Workers' Compensation Studies since its inception in 2013. Her research interests include using workers' compensation data for occupational safety and health, preventing work-related musculoskeletal disorders, and Total Worker Health®. As a Principle Investigator at NIOSH, she is responsible for overseeing, implementing and evaluating occupational health epidemiologic studies. Dr. Meyers earned a PhD in Occupational and Environmental Health from the University of Iowa.

**Michael Lampl** is the Director of Research & Training at the Ohio Bureau of Workers' Compensation (BWC), Division of Safety and Hygiene. Mike's BS is in Industrial & Systems Engineering from the Ohio State University and his MS is in Occupational Health from the Medical College of Ohio. He is a Certified Professional Ergonomist. Mike has worked in the occupational safety and health field both in private industry and at BWC since 1993.

**Tim Bushnell** is an economist in the Economic Research and Support Office at the National Institute for Occupational Safety and Health. He also serves as economist in the NIOSH Center for Workers' Compensation Studies, and as a coordinator for the Healthy Work Design and Well-being program. His research interests include costs of work-related illness and injury, industry differences in illness and injury rates, and impacts of work schedules, prevention measures, and work arrangements. He holds a PhD in economics from Michigan State University, specializing in industrial organization, and a master's in public administration from the Harvard Kennedy School of Government.

**Stephen Bertke** is a Mathematical Statistician at the National Institute for Occupational Safety and Health. He assists with many projects within NIOSH analyzing data related to workplace safety and health. In particular, he is the lead statistician within the Center for Workers' Compensation Studies where he advises on methods and study designs of workers' compensation studies. He holds a PhD in mathematics with a concentration in statistics from University of Cincinnati.

**David Robins** has been a Management Analyst for the Ohio Bureau of Workers' Compensation Division of Safety and Hygiene since 2004 and has been with the Bureau since 1990. David gained an Associates of Applied Science in Microcomputing Technology in 2001 and has years of experience in developing data reports, SQL queries, and data report applications. David has worked on innumerable projects to coalesce multiple data-sources to analyze and summarize large data sets.

**Chih-Yu Tseng** has worked for the National Institute for Occupational Safety and Health (NIOSH) since 1998 and has been involved in Center for Workers' Compensation Studies (CWCS) projects since 2013. She became a full-time member of the CWCS team in 2015. She earned her MS degree in Statistics from The Ohio State University. Prior to joining NIOSH, she was a Research Data Analyst at the University of Cincinnati, Department of Environmental Health, Epidemiology and Biostatistics Division. As an IT Specialist, Chih-Yu provides programming, database and data visualization support to research projects.

**Steven Naber** is the Analytics Manager with the Ohio Bureau of Workers' Compensation (BWC) Division of Safety and Hygiene. In his role, he oversees analysis of workers' compensation policy and claims data for the purposes of assisting BWC in identifying and applying resources to employers and for occupational safety research. Steve earned a PhD in Mathematical Statistics from The Ohio State University with a specialty in geostatistics and has spent his career as a statistical consultant for federal and state governmental agencies, universities, and private industries before taking his current position at the Ohio BWC.