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RESEARCH ARTICLE

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Surveillance of acute nonfatal occupational inhalation injuries treated in US hospital emergency departments, 2014–2017

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Abstract

Background: Acute nonfatal occupational inhalation injuries are caused by exposures to airborne toxicants and contaminants in the workplace. A 1990s study found that US emergency department (ED)-based inhalation injury rates were higher than those seen in the United Kingdom and Canada. This study examines 4 years of hospital ED data to estimate current rates of occupational inhalation injuries.

Methods: Data from the National Electronic Injury Surveillance System Occupational Supplement were used to identify nonfatal occupational inhalation injuries treated in US hospital EDs from 2014 to 2017. A workplace inhalation injury was defined as any worker treated in an ED as a result of inhaling a harmful substance at work.

Results: From 2014 to 2017, there were an estimated 2.2 occupational inhalation injuries per 10,000 full-time equivalents (FTE) (95% confidence interval [CI]: 1.6–2.8) treated in EDs, a rate nearly four times that found in Bureau of Labor Statistics data. Although men incurred 60% (95% CI: 56%–64%) of the injuries, the overall injury rates for men and women were similar at 2.3 (95% CI: 1.7–2.9) and 2.1 (95% CI: 1.4–2.7) per 10,000 FTE, respectively. By age group, workers less than 25 years of age were at greater risk of injury at 4.1 injuries per 10,000 FTE (95% CI: 2.8–5.3).

Conclusions: These results illustrate the burden of nonfatal occupational inhalation injuries, providing an understanding of how injuries are distributed based on demographics. While inhalation injury rates have declined over the last two decades, additional research is needed to determine whether interventions have reduced risk, or if the availability of alternate sources of medical treatment is a factor.

KEYWORDS
inhalation, injury, occupational, surveillance

1 | INTRODUCTION

Acute nonfatal occupational inhalation injuries are caused by exposures to airborne toxicants and contaminants in the workplace. They can damage the respiratory system, exacerbate existing conditions (such as asthma), or affect other body systems. Little is known regarding the burden of work-related inhalation injuries in the United States. Most nonfatal inhalation injuries are described in published case reports and case series. Currently, there is no nationwide occupational health surveillance system that captures information about exposures to airborne toxicants and contaminants and nonfatal occupational inhalation injuries. The occupational health surveillance systems that do exist in the United States often do not enforce reporting requirements, are limited to a few states, and may not include the full range of inhalation cases. Various surveillance efforts to identify the prevalence of inhalational injuries have used

poison control centers, physician reports, hospital discharge records, and hospital emergency department (ED) records.[1–3]

This study utilized hospital ED data from the National Electronic Injury Surveillance System Occupational Supplement (NEISS-Work)[4]. Previous work by Henneberger et al.[2] used NEISS data to analyze occupational prevalence rates from hospital EDs in the United States during 1995–1996. Henneberger[2] found the number of inhalation injury and illness cases presented to US hospital EDs was higher than those presented from physician reports collected in Canada and the United Kingdom from the 1990s. The current study examined occupational inhalation injuries treated in hospital EDs from 2014 to 2017 to estimate updated rates of occupational inhalation injuries for worker demographics, industries, and compounds (or harmful substances) leading to injuries.

2 | METHODS

Data from the NEISS-Work[1] were used to identify nonfatal civilian occupational inhalation injury cases treated in US hospital EDs from 2014 to 2017. The National Institute for Occupational Safety and Health (NIOSH), in collaboration with the Consumer Product Safety Commission, collects surveillance data on work-related nonfatal injuries and illnesses treated in US hospitals with a 24-h ED. The sample of hospitals is a national stratified probability sample of 67 US hospitals divided into strata by hospital size, based on number of annual ED visits. An injury is considered work-related if it occurred to a civilian, noninstitutionalized worker who was working for pay, performing farm-related activities, traveling between locations as part of a job requirement, or volunteering for an organized group. Injuries are identified from ED medical records by trained coders at each participating hospital. To calculate national estimates, each case is assigned a statistical weight based on the inverse probability of selection of the hospital in the sample, and adjustments are made for nonresponding hospitals during each calendar year.

In addition to the demographic and injury variables collected through NEISS-Work, NIOSH staff assign codes for source and event of the injury using the Bureau of Labor Statistics, Occupational Injury and Illness Classification System (OIICS[5]).

An occupational inhalation injury was defined as any worker who sought treatment in a hospital ED as a result of inhaling a harmful substance from chemical, mineral, or organic sources that resulted in an injury. Due to the lack of a coding structure that would identify all inhalation cases based on this definition, criteria were established to best capture inhalation cases. A case must have fit one of these guidelines to be included in the analysis. First, all cases that were coded with the OIICS[5] (v2.01) event/exposure code Inhalation of Harmful Substance "552" were included. Second, all cases with a NEISS-Work diagnosis of "Anoxia" were identified and manually reviewed by two researchers to ensure they were inhalation cases. Finally, a keyword search and manual review of the narrative comment field were performed on all remaining cases not identified in the two previous steps. These keywords included terms such as fume, vapor, smoke, gas, aerosol, and particulate. These keywords were chosen based on prior review of inhalation cases and their relevance to the occupational health and safety field. The keywords used in the search and their derivatives are listed below:

The cases that were identified through the keyword search and anoxia diagnosis were then classified as confirmed, probable, or noninhalation. A confirmed case either had a diagnosis of anoxia (NEISS-Work code "65") or contained a clear inhalation event and explicitly stated the word "inhalation" in the narrative field. An example of the narrative for a confirmed case would be "65-year-old male presents with wheezing and coughing after inhaling spray paint on the job." A case was classified as probable if an inhalation injury was suggested, but not clearly stated or diagnosed (i.e., the quality of the narrative was poor). The researchers could easily speculate based on the available data (e.g., working conditions and worker's environment) that the case was an inhalation injury; however, without a clear inhalation statement in the narrative, it could not be classified as confirmed. For example, "a female experienced intense coughing episode after working in a grain silo." In this case, it could be easily assumed that her coughing is a side effect from working in adverse environmental conditions, yet there is no explicit inhalation statement; therefore, this case would be classified as probable. The only time a narrative without a clear inhalation statement was classified as confirmed, occurred if a carboxyhemoglobin (COHb) test was performed to determine the amount of carbon monoxide (CO) that was in the blood. According to the World Health Organization,[6] dermal and gastrointestinal absorption of CO are expected to be negligible, so inhalation is the only route of exposure.

The analyses for the current paper aggregated confirmed and probable cases together. Of the positive inhalational cases, approximately 95% were classified as confirmed. To avoid overrepresentation of certain firefighter-related exposures, firefighters were removed from the source of injury analyses as their occupation includes unique occupational exposures not incurred by all other workers. Firefighters are included in the total estimates and were only omitted from the analysis by source. To identify firefighter injuries, the narrative information was manually reviewed in the NEISS-Work fields, including occupation title, name of business, and the injury narrative field.

Estimates of the employed population were derived from the Current Population Survey (2014–2017) using the online Employed Labor Force (ELF) query system.[7] This employment estimate was used to calculate overall rates, which are reported per 10,000 full-time equivalents (FTE). One FTE equals 40 h of work per week for 50 weeks or 2000 working hours. This FTE denominator was used for consistency with Henneberger et al.[2]

SAS® 9.4 Proc Survey[8] was used for the calculation of 95% confidence intervals (CIs) to incorporate the stratified sample design of NEISS-Work. Variables such as sex, age group, source of injury (OIICS), and industry (Bureau of Census [BOC] industry codes) were examined. In addition, a coder reliability analysis was conducted to examine accuracy between the two coders. Two coders independently, manually reviewed each of the anoxia and keyword search cases. The analysis showed strong interrater reliability at 99%.

3 | RESULTS

There were approximately 125,600 (95% CI: 92,100–159,000) acute nonfatal occupational inhalation (i.e., confirmed and probable) cases treated in US hospital EDs from 2014 to 2017. The overall rate was 2.2 injuries per 10,000 FTE (95% CI: 1.6–2.8). Table 1 shows the demographic characteristics of workers who experienced an inhalation injury. Although men comprised 60% of the injuries, the rates for men and women were similar at 2.3 (95% CI: 1.7–2.9) and 2.1 (95% CI: 1.4–2.7) per 10,000 FTE, respectively.

When examining inhalation injuries by age groups, workers who were 25–34 years of age accounted for the largest percentage of injuries (28%). Notably, workers less than 25-years old were at greater risk of injury with 4.1 injuries per 10,000 FTE (95% CI: 2.8–5.3). This pattern of greater risk in the younger working population was consistent for both sexes with men having the highest risk at 4.7 per 10,000 FTE (95% CI: 3.2–6.2) in the youngest age group (Figure 1).

The distribution of work-related nonfatal inhalation injuries by industry sector is presented in Table 2. The highest percentage of inhalation injuries occurred in the service industries (35%), followed by manufacturing (14%) and public administration (13%). Within the services industry, the health care and social assistance sector accounted for 36% of the injuries, with a rate of 2.1 cases per 10,000 FTE (95% CI: 1.3–2.8). Seventy-six percent of the inhalation injuries in the public administration sector occurred in the justice, public order, and safety activities sector (i.e., firefighters and law enforcement officers).

Sixty-one percent of the inhalation-related injuries in the services industries were incurred by women (26,800; 95% CI: 16,300–37,500) in comparison to men (17,000; 95% CI: 10,600–23,400). Within services, 84% (13,200; 95% CI: 7800–18,600) of the injuries in the health care and social assistance sector were to women. Whereas, within public administration industries 84% (13,600; 95% CI: 9500–17,700) of the injuries were to men. Within manufacturing industries, 67% of injuries were to men (11,300; 95% CI: 7000–15,600).

Figure 2 shows the injury rates by sex for select industry sectors. In the services, manufacturing, and retail trade industries, women had higher inhalation injury rates than men. However, in the public administration industries, the inhalation injury rate for men was four times that of women.

The majority (94%) of the inhalation injury cases which presented to EDs were treated and released or examined and released without treatment (118,100; 95% CI: 86,600–149,500). Four percent of cases required hospital admission (4400; 95% CI: 2300–6600).

An examination of the leading sources of injury (Table 3), excluding firefighters, showed that chemicals were the most prevalent primary source for inhalation injuries treated in EDs (76%). Among chemicals,

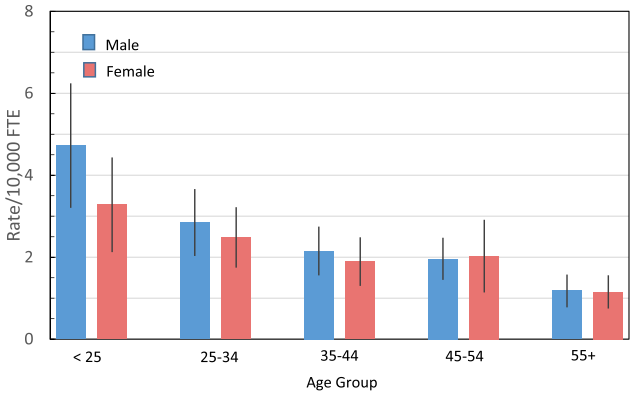

FIGURE 1 National estimates of injury rates for work-related nonfatal inhalation injuries treated in hospital emergency departments by sex and age group, United States 2014–2017. *Source*: National Electronic Injury Surveillance System Occupational Supplement, 2014–2017.

TABLE 1 National estimates of injuries and rates for work-related nonfatal inhalation injuries treated in hospital emergency departments, United States 2014–2017.

Characteristic	Inhalation Injuries	95% CI	Percentage	Rate per 10,000 FTE	95% CI
Total	125,600	92,100–59,000	100	2.2	1.6–2.8
Sex					
Male	74,900	55,300–94,400	60	2.3	1.7–2.9
Female	50,700	35,300–66,000	40	2.1	1.4–2.7
Age group (years)					
<25	24,100	16,700–31,500	19	4.1	2.8–5.3
25–34	35,100	25,800–4400	28	2.7	2.0–3.4
35–44	25,700	18,500–32,900	21	2.0	1.5–2.6
45–54	26,100	18,600–33,500	21	2.0	1.4–2.6
55+	14,600	10,100–19,100	12	1.2	0.8–1.5

Abbreviations: CI, confidence interval; FTE, full-time equivalent.

Source: National Electronic Injury Surveillance System Occupational Supplement, 2014–2017.

TABLE 2 National estimates of work-related nonfatal inhalation injuries treated in hospital emergency departments by industry, United States 2014–2017.

Industry (BOC code)	Inhalation Injuries	95% CI	%	Rate[a]	95% CI
Services (6470–9290)	43,800	±16,300	34.9	1.4	0.9, 1.9
Health care and social assistance	15,700	±5800	35.7	2.1	1.3, 2.8
Accommodation and food services	7700	±3700	17.6	7.1	3.7, 10.5
Admin/support/waste management	6200	±3100	14.1	2.4	1.2, 3.6
Manufacturing (1070–3990)	16,900	±6300	13.5	2.6	1.6, 3.6
Public administration (9370–9890)	16,200	±4500	12.9	5.8	4.2, 7.5
Justice, public order, and safety activities	13,500	±4300	83.2	11.5	7.8, 15.2
Transportation and warehousing (6070–6390)	8900	±3600	7.1	2.7	1.6, 3.9
Construction (0770)	8100	±3400	6.4	2.0	1.1, 2.8
Retail Trade (4670–5790)	7300	±2800	5.8	1.2	0.8, 1.7
All other industry[b]	24,300	[c]	19.4	[c]	[c]
Total	125,600	±32,000	100.0	2.2	1.6, 2.8

Abbreviations: CI, confidence interval; FTE, full-time equivalent.

[a]Rate is per 10,000 FTE.

[b]All other industry includes agriculture/forestry/fishing/hunting; mining; utilities; wholesale trade; and unknown.

[c]95% CI and rate not calculated due to the inclusion of unknowns.

Source: National Electronic Injury Surveillance System Occupational Supplement, 2014–2017.

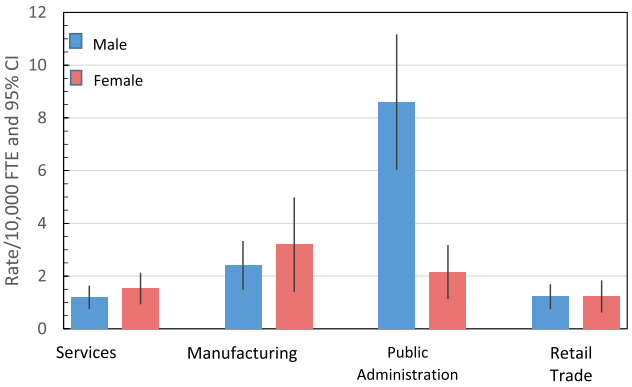

FIGURE 2 National estimates of injury rates for work-related nonfatal inhalation injuries treated in hospital emergency departments by sex and select industries, United States 2014–2017. *Source*: National Electronic Injury Surveillance System Occupational Supplement, 2014–2017.

oxygen and oxygen compounds were the most prevalent sources of injury (22%). Eighty-nine percent of the oxygen- and oxygen compound-related injuries were caused by carbon monoxide. Other common chemical sources included chlorine and chlorine compounds (10%), and cleaning and polishing agents and disinfectants (8%).

When examining injury source by sex, chemicals remained the most prevalent injury source for both men (73%; 95% CI: 68%–78%) and women (79%; 95% CI: 75%–83%). Among men, the most common chemical source of injury was carbon monoxide (24%; 95% CI: 19%–29%), whereas among women, exposure to chlorine and chlorine compounds (13%; 95% CI: 7%–18%) were more common.

Firefighters comprised 7800 (95% CI: 5000–10,600), or 6% of the total ED-treated inhalation injuries. The majority were men (7600; 95% CI: 4900–10,400) and between the ages of 25–34 years (2000; 95% CI: 1100–3000) and 35–44 years (2100; 95% CI: 1000–3200).

4 | DISCUSSION

The overall magnitude and burden of nonfatal occupational inhalation injuries treated in US EDs were 125,600, with a rate of 2.2 cases per 10,000 FTE from 2014 to 2017. Data from the BLS Survey of Occupational Injuries and Illnesses[9] reports an estimated 24,750 injuries requiring days away from work due to inhalations of harmful substances (OIICS event code 552), with an average injury rate of 0.6 per 10,000 FTE for the study period. Although a direct comparison to the BLS data cannot be made due to methodological and case identification differences, it is important to note the magnitudes of difference between their rates and those found in NEISS-Work.

A comparison of our result to those of Henneberger et al.,[2] who previously examined NEISS data using the same case identification criteria and methodology, are more valid. Henneberger et al. reported an average annual rate of 3.6 cases per 10,000 FTE and a greater risk among men compared to women (4.4 vs 2.6 cases per 10,000 FTE) during 1995–1996. More than two decades later, this study, using the same methodology and definitions as Henneberger et al., found an overall decrease of 39% for all inhalation injuries treated in EDs.

TABLE 3 National estimates of work-related inhalation injuries treated in hospital emergency departments (excluding firefighters) by primary source of injury, United States 2014–2017.

Primary source (OIICS code)	National estimate	95% CI	Percentage
Chemicals and chemical products (1)	89,000	±23,200	75.6
Other chemicals (17)	29,100	±8700	32.7
Oxygen and oxygen compounds (174)	19,900	±6600	22.3
Carbon monoxide (1741)	17,700	±5800	19.8
Halogens and halogen compounds (13)	10,800	±4100	12.1
Chlorine and chlorine compounds (131)	9000	±4200	10.1
Chlorine, chlorine bleach (1311)	6700	±3600	7.5
Chemical products—general (18)	21,200	±8100	23.8
Cleaning and polishing agents, disinfectants (183)	7400	±2400	8.3
Paint, lacquer, shellac, varnish (186)	3800	±2400	4.3
Persons, plants, animals, and minerals (5)	4700	±1800	4.0
Structures and Surfaces (6)	4800	±2200	4.1
Buildings—office, plant, residential (62)	4300	±2100	90.0
Other sources (9)[a]	19,200	[b]	16.3
Nonclassifiable (9999)	2700	[b]	2.2
Total	117,700	29,900	100.0

[a]Other sources include furniture, fixtures, containers, machinery, parts and materials, tools, instruments and equipment, and vehicles.

[b]Standard error not calculated due to the inclusion of unknown.

Source: National Electronic Injury Surveillance System Occupational Supplement, 2014–2017.

This decrease, however, was not consistent for men and women. Males, in this study, had an injury rate of 2.3, a 48% decrease when compared to Henneberger et al.[2] For females, the injury rate decreased by only 19% (2.6 vs. 2.1). In this study, after accounting for the number of hours worked, men and women were found to have similar rates of injury, which differs from Henneberger's findings, where men had an injury rate nearly twice that of women. Research into differing injury risks by sex has often been complicated by deficiencies in controlling for task and hazard exposure.[10] However, recent studies in select industries, which controlled for these variables, have found that women had an equal or higher injury rate than men.[10,11]

Consistent with the findings in Henneberger,[2] workers who were 25–34 years of age comprised the largest percentage of injuries, and workers less than 25-years old exhibited the greatest risk of injury, with the highest risk among young men. Previous research has identified several areas that could contribute to the high rate of injuries among young workers, including a lack of experience, an underestimation of risk, and the lack of fully developed cognitive control systems.[12–14] However, additional analyses including task and occupational variables are needed to determine if the high injury rates for young workers are related to high-risk tasks or other factors.

Analyses by primary source of injury showed that chemicals were responsible for most injuries. Injuries associated with exposure to chlorine and chlorine compounds were more common among women and exposure to carbon monoxide among men. This may be explained by gendered job assignments, such as men more commonly working with machinery and engines that expel carbon monoxide, and women more commonly assigned tasks related to cleaning products.[15] Occupation was not examined in this study, however; the inclusion of occupation in future analyses would allow for a more complete assessment of the hazards associated with certain job tasks or populations.

Workers in the public administration subsector of justice, public order, and safety activities (i.e., fire fighters and law enforcement) had the highest injury rate at 11.5 per 10,000 FTE, followed by workers in the accommodation and food services (7.1 per 10,000 FTE). Although the service industries had more than twice the number of inhalation injuries compared to other industries, their injury rate (1.4) was considerably lower than the rate for all industries combined (2.2). The high proportion of injuries in services is consistent with the findings of Henneberger[2] (23%), however, service industries in the current study represented a much higher proportion of the overall injuries. Although this increase is notable, the proportion of workers employed the service industries also increased from 28% to 38% over the same period.[16]

4.1 | Strengths/weaknesses

A major strength of this study was that NEISS-Work is a large study[17] with robust occupational data that makes it possible to (1) identify

cases and (2) perform a manual review of the data to identify additional cases. For this study, the interrater reliability was 99%, which signifies a concise definition and strong agreement between coders for the identification of nonfatal work-related inhalation injuries. Using NEISS-Work was advantageous for this study as it is not restricted by age, employer size, or type of employer or industry. However, this surveillance system only captures injuries treated in hospital EDs, while injuries treated in other medical treatment settings go uncaptured. Additionally, NEISS-Work does not collect information on geographic area, workers compensation, or other temporal variables, which limits some analyses.

Although NEISS-Work provides robust occupational data, there are several limitations to this study that could lead to underreporting. NEISS-Work contains a narrative for almost every injury, which allows analysis beyond the coded variables, as utilized here. However, there are no specific guidelines for completing the narratives and the provision of detail within each narrative can vary.[18] This study characterized several criteria for work-related inhalation injuries to best capture cases; nonetheless, there were still difficulties classifying cases as probable and confirmed (even though these two classifications were aggregated during analysis) due to the quality of the narrative.

Furthermore, patients themselves or ED staff may leave out details that would associate the injury with the patient's workplace.[17] Patients could omit the work-relatedness of their injury for several reasons, including fear of employer reprisals, lack of management responsiveness after prior reports, wanting to use their own health insurance, and a desire not to lose their usual job.[17,19] NEISS-Work heavily relies on the patient reporting that their reason for their ED visit was work-related and that medical records capture this information. Additionally, there may be occupational inhalation injuries that are not being captured because their level of severity does not warrant visiting an ED. Therefore, the magnitude of work-related inhalation injuries may be underreported.

There were several difficulties with classification that must be addressed. For example, some injuries that included damage to the airway were not included as inhalation injury in this analysis. For example, unintentional ingestion of a foreign object that blocked/damaged the airway was not considered an inhalation incident. Workers exposed to smoke but lacking an inhalation statement in their narrative or diagnosis field were counted as probable. We could infer that the smoke was inhaled because it is suspended in air, but since an inhalation was not clearly indicated, the reason this worker went to the ED may have been for something else, such as eye irritation or skin exposure. Another classification difficulty concerned secondary injuries. If a worker sought treatment in the ED for a broken wrist because they fell after inhaling gas (e.g., CO), and the narrative contained an inhalation statement, the case was counted as confirmed. Finally, allergic reactions to harmful substances were counted as confirmed if the condition was exacerbated by some contaminant at work and inhalation was stated in the narrative (e.g., worker inhales dust that irritates occupational asthma). Swelling of the airway from an allergic reaction due to dermal contact was not included in the analysis.

A final issue is related to the primary source coding of injury in OIICS. OIICS provides a hierarchical coding structure with up to four levels of detail represented by numeric codes. Due to this structure, particularly in relation to chemical sources, some components are grouped together with vastly different properties. For example, although carbon monoxide is clearly an oxygen compound, it has adverse effects and properties that differ from other oxygen compounds. Future research may wish to explore alternative methods for discerning the source of inhalation injuries.

5 | CONCLUSION

These results provide insight into the burden of acute nonfatal occupational inhalation injuries and an understanding of how injuries treated in EDs were distributed based on demographics. While the inhalation injury rates appear to have declined over the last two decades, additional research is needed to determine whether workplace interventions have reduced risk, or if the availability of alternate sources of medical treatment, such as the rise of urgent care facilities, could be partially responsible for this decrease. The disparity found between NEISS-Work occupational inhalation rates and BLS SOII rates should also explored. Although ED-treated occupational inhalation injuries decreased overall, the decline was not consistent across sexes. Further research is also needed to discover if the comparability of injury rates between men and women is consistent for other types of injury events.

AUTHOR CONTRIBUTIONS

Kitty Hendricks contributed to the analysis and interpretation of the data, writing, and editing of the manuscript, as well as guiding the document through the institutional review process. Larry Layne and Angela Javurek were involved in the conception of the work, acquisition of the data, and analyses. Patricia Schleiff and Larry Layne also contributed to the writing and editing of the paper. All authors approve of the submitted version and agree to be accountable for all aspects of the work.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

INSTITUTION AND ETHICS APPROVAL AND INFORMED CONSENT

All work was performed and reviewed at the Division of Safety Research, National Institute for Occupational Safety and Health. Data were obtained from an existing surveillance system of hospital emergency department. No human subjects review or informed consent was required.

ENDNOTE

[1] NIOSH collects NEISS-Work data in collaboration with the Consumer Product Safety Commission (CPSC), which operates the base NEISS hospital system for the collection of data on consumer product-related injuries. The CPSC product-related injury estimates exclude work-related injuries, whereas NEISS-Work estimates include all work-related injuries regardless of product involvement (i.e., NEISS and NEISS-Work cases are mutually exclusive).

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