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RESEARCH ARTICLE

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Descriptive evaluation of methods for identifying work-related emergency department injury visits

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Abstract

Background: Use of worker's compensation (WC) as payer underestimates work-related (WR) injuries. We evaluated three methods to identify WR injuries: WC as payer, ICD-9-CM work-status codes E000.0/E000.1, and other ICD-9-CM external cause codes.

Methods: We identified injury-related emergency department visits from North Carolina's syndromic surveillance system (2010-2013). Characteristics were compared by indicator. We manually reviewed 800 admission notes to confirm if the visit was WR or non-WR; WR keywords from the review were applied to all visits.

Results: 133 156 injury-related visits (age, 16 years or older) were identified: WC = 69%, work-status codes = 18%, other ICD-9-CM codes = 13%. Among manually reviewed visits: few visits identified by WC (0.3%) or work-status codes (2%) were non-WR, while 12% of other ICD-9-CM code identified visits were non-WR; 53%, 46%, and 31% of visits identified by WC, work-status codes, and other ICD-9-CM codes were WR, respectively.

Conclusions: Findings support use of WC and work-status codes to capture WR injuries; other ICD-9-CM codes should be used with caution or in combination with other indicators.

KEYWORDS

administrative data, emergency department, ICD-9-CM, injuries, occupational, syndromic surveillance, worker's compensation, work-related

1 | INTRODUCTION

Work-related (WR) injuries and illnesses result in a considerable human and economic burden on workers, employers, and society.[1,2] In 2012 the Bureau of Labor Statistics reported approximately 3.0 million nonfatal injuries and illnesses among private industry employers in the United States (US).[3] However, this is likely a gross underestimation of the true count of nonfatal injuries and illnesses.[4,5] Accurate public health surveillance is an essential part of reducing the burden of occupational injuries and illnesses by providing estimates of the magnitude of the problem, identifying high-risk groups, and directing and evaluating prevention strategies.[6–8] Administrative billing data (eg, hospital discharge and emergency department [ED] data) are one of the few sources in the US used for population-based nonfatal occupational injury surveillance.[6]

Within administrative billing data, the ubiquitous way to identify work relatedness is through recorded indications of worker's compensation (WC) as the expected payer.[4,6,7] However, WC does not cover all workers, does not cover all occupational injuries, and barriers to reporting eligible conditions are present (eg, employee/coworker retaliation, and alternative health insurance).[9] Further, lack of awareness of the WC system by workers, employers, and medical personnel (eg, at the hospital, ED, or doctor's office) may limit the number of workers applying for WC.[9] It has been estimated that WC misses approximately

one-third to one-half of all WR injuries and illnesses.[4,7,10] Cases missed by WC are differential with respect to occupation, race/ethnicity, geography, diagnosis, and type of medical facility (profit/not-for-profit).[4,11]

International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) or *International Classification of Diseases, 10th Revision, Clinical Modification* (ICD-10-CM) external cause codes (E-codes) may be another way to identify WR visits within administrative billing data. The ICD-9-CM work-status codes E000.0 and E000.1 or other work accident or location E-codes may indicate WR injuries.[12,13] Few prior studies have evaluated E-codes for identifying WR injuries and none using ED data.[14–17]

Not all medical event data sources include potential payer, making it difficult to extract WR cases using traditional WC as payer method. For instance, payer is not a required field in syndromic surveillance systems.[18] Syndromic surveillance systems, which provide near-real-time (eg, hourly or daily) information, may be a new source for occupational injury surveillance.[19,20] Many syndromic surveillance systems collect discharge diagnosis codes and E-codes, as well as text information from the patient's chief complaint and nurse's triage notes (ie, admission notes).[18,21] WR visits may be determined from keywords included in the injury situation found in the admission notes.[20] WR keywords or ICD-9/10-CM codes are required to identify WR injuries in systems that do not collect expected payer.

The primary study goal was to assess the ability of potential WR ICD-9-CM codes to capture non-WC identified WR visits in data sets that include ICD-9-CM codes (eg, administrative billing data). The secondary goal was to identify WR keywords to identify WR visits in data sets that include admission notes (eg, syndromic surveillance systems). To accomplish these goals the study analyzed data from North Carolina's (NC) syndromic surveillance system (NC Disease Event Tracking and Epidemiologic Collection Tool [NC DETECT]), which includes elements essential to both administrative billing data and syndromic surveillance systems. Since 2005, all civilian EDs in NC are mandated, by state law,[22] to provide information on all ED visits to NC DETECT. Twice daily demographic information, patient vitals, expected payer (eg, insurance type or self-pay), and admission notes (ie, chief complaints or triage notes) are transmitted to NC DETECT. Each visit record is later updated by the facility with administrative billing information including discharge diagnosis codes and E-codes.

2 | METHODS

NC DETECT captures over 99% of eligible ED visits in NC and represents more than 124 EDs.[23] In addition to the variables collected in an administrative billing data set (eg, discharge diagnosis codes and E-codes), NC DETECT collects admission notes (ie, triage notes and chief complaints) for each ED visit. The chief compliant is a brief description of the patient's primary symptoms while the triage note provides an expanded history of the presenting illness/injury.[19] Both are recorded by the nurse at intake.

Data were obtained for 2010 through 2013 from NC DETECT for all injuries, which we defined as any ED visit for which an ICD-9-CM injury code (800–999) was found in any of the 11 diagnosis fields. We excluded all injury visits which had at least one of the following external cause of injury codes (E-code) found in any of the five E-code fields: suicide/self-harm (E950–E959), homicide/assault (E960–E969), or undetermined intent (E980–E989). The resulting analysis data set included all visits with an unintentional injury.

2.1 | Case definition: work relatedness

We classified an unintentional injury visit as WR if one or more of the following method definitions were met:

Method 1: all injuries with WC listed as the expected payer in the single-insurance coverage field were classified as WR. This method is traditionally used when identifying WR injuries in administrative billing data sets.[7,14,24] This will be referred to as the WC method.

Method 2: all injuries with a work-status E-code found in any of the E-code fields: E000.0 (civilian activity done for income or pay) or E000.1 (military activity) were classified as WR. These codes were added to the ICD-9-CM codebook in October 2009.[25] This will be referred to as the work-status codes method.

Method 3: all injuries with codes found in Table 1 which included the E-codes for transport accidents involving employees, two V-codes (ie, codes in the ICD-9-CM chapter: Supplementary Classification of Factors Influencing Health Status and Contact with Health Services) which may indicate a work incident, and E-codes for potential work location (ie, farm, industrial place or premise, or mine or quarry) were classified as WR. This will be referred to as the other-WR codes method.

2.2 | Evaluation methods

Characteristics of injury-related visits identified using each method were compared. The three WR identification methods are not mutually exclusive. Cases may have been identified based on: only one method; identification by two methods; or, by all three methods. This resulted in seven groups. Demographic information and visit-specific information (eg, time of visit, disposition, and transport) were obtained from variables within NC DETECT. Information on race was not available. E-codes were used to assess activity and location type (eg, residential, street, and park) at the time of injury. The Barell Injury Diagnosis Matrix, which relies on ICD-9-CM diagnostic codes, was used to classify the injury body region and nature of injury.[26]

This analysis lacked a gold standard as none of the identification methods completely overlapped. This is discussed further in the limitations section. Instead, we used agreement with admission notes to evaluate the accuracy of the WR identification methods. Facilities are required to submit chief complaints to NC DETECT; submission of triage notes is optional.[19] As a result, approximately a third of NC DETECT records contain a triage note. However, as the triage note contains information on the current injury history, this data field was necessary to provide information on the situation of injury. Manual

TABLE 1 Summary of emergency department injury visits (age, ≥16 years) by work-related (WR) *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) code stratified by identification method, North Carolina 2010-2013[a]

Description (ICD-9-CM code)	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	Column %
	Work-status codes only		*All WR Codes*		*Worker's Compensation and work-status codes*		*Work-status codes and other-WR codes*		*Total*	
Work-status codes Total	14 570	37.8	6235	16.2	7981	20.7	9713	25.2	38 499	100.0
Civilian work (E000.0)	14 247	37.41	6233	16.37	7971	20.93	9629	25.29	38 080	28.60
Military work (E000.1)	323	77.09	2	0.48	10	2.39	84	20.05	419	0.31
	Other-WR codes only		*All WR Codes*		*Worker's Compensation and other-WR codes*		*Work-status codes and other-WR codes*		*Total*	
Other-WR codes Total	16 897	40.4	6235	14.9	9030	21.6	9713	23.2	41 875	100.0
Railway transport (E800-E807, 4th digit = 0)	14	73.68	1	5.26	3	15.79	1	5.26	19	0.01
Air transport (E830-E838, 4th digit = 2 or 6)	15	60.00	1	4.00	3	12.00	6	24.00	25	0.02
Water transport (E840-845, 4th digit = 2 or 8)	66	84.62	4	5.13	1	1.28	7	8.97	78	0.06
Vehicle used on industrial/commercial premises (E846)	28	73.68	2	5.26	6	15.79	2	5.26	38	0.03
Farm (E849.1)	573	70.39	48	5.90	39	4.79	154	18.92	814	0.61
Mine or quarry (E849.2)	147	92.45	4	2.52	6	3.77	2	1.26	159	0.12
Industrial places/premises (E849.3)	16 054	39.43	6155	15.12	8963	22.01	9542	23.44	40 714	30.58
Psychosocial: Adverse effects of work environment (V62.1)	–	0.00	–	0.00	1	100.00	–	0.00	1	0.00
Observation following work accident (V71.3)	6	6.19	51	52.58	24	24.74	16	16.49	97	0.07

[a]There is overlap in the table as visits may have more than one ICD-9-CM code (eg, 6235 visits had a work-status code and at least one other-WR code). There were 70 records included in the table that had multiple ICD-9-CM codes: 54 with E849.3 and V71.3; two with E849.3 and E849.1; five with E849.3 and E846; four with E849.3 and E840-845 [4th digit = 2 or 8]; four with E849.3 and E830-E838 [4th digit = 2 or 6]; one with E849.3 and E800-E807 [4th digit = 0]. There were 68 730 visits identified only by payer equal to worker's compensation, these visits are not included in the table as they do not contain a WR ICD-9-CM code.

review was completed for a random subsample of 700 WR cases as identified by method 1, 2, or 3 for which a triage note was available.

The majority of records (92.7%) in the other-WR code-only group were identified by E849.3 (place of occurrence: industrial place and premises). Therefore, to assess the accuracy of the other ICD-9-CM codes within that group, an additional 100 records were sampled from the other-WR code-only group excluding records with E849.3. All triage notes and chief complaints (ie, admission notes) were manually reviewed and the records were classified as confirmed WR, probable WR, possible WR, not WR, or unclassifiable. To be confirmed WR, the admission note included work keywords (eg, at work, works at, at his/her work/job), type of worker (eg, construction worker, carnival worker, and fire fighter), or a work activity/equipment (eg, forklift and paving asphalt). If the admission note listed a scenario or phrase likely to be related to a work activity or equipment typically used in a work setting, the visits was classified as probable WR. Examples of probable WR visits included, fell/fall (eg, fell off ladder, fell off scaffold, fell off combine, and fell out of barn), caught in (eg, caught in conveyor belt, caught in truck lift, caught in crimping machine, and caught in mattress slider), working on (eg, working on tree and working on large tire), doing construction, or equipment (eg, meat/deli slicer). Admission notes with scenarios or phrases that may be related to a work activity/incident or equipment often used in a work setting were classified as possible WR. Examples of possible WR visits included, cut body part on equipment (eg, cut finger or arm on piece of metal/steel, table saw, or auger), fell out of office chair, chemical splashed, or backpack leaf blower. A confirmed WR injury was assumed to be a true WR injury. False positives were visits identified as non-WR.

As part of the manual review process, we identified WR keywords in the chief complaints and triage notes from confirmed WR injury visits. Additional WR keywords were obtained by querying the managers of other state-based syndromic surveillance systems.[20,27] The following list of WR syndrome keywords was used: at work, at her|his|my work, at job, at her|his|my job, on her|his|my|the|a job, work comp, workman|workmen comp, worker comp, work man|men comp, OTJ (on the job), work inj, workplace inj, work wound, work acc, accident work, work-related. These keywords were first applied to all WR injuries among those age 16 years or older identified by at least one of the three WR identification methods. Next, the identified WR keywords were applied to the entire universe of injuries within the study time-period to identify any additional WR injuries not captured by the three WR identification methods. Visits with a WR syndrome keyword that had been identified by one of the WR ascertainment methods were considered true positives. False positives—non-WR visits captured by one of the three WR identification methods—could not be determined because a lack of a work-keyword does not indicate non–work-relatedness.

Finally, post hoc manual review of triage notes for ED visits identified by the other-WR code method alone were conducted among the elderly (≥70) and for specific codes (eg, E846) with less than 100 total ED visits.

3 | RESULTS

During the study period (2010-2013), 92 778 ED visits for WR injuries were identified by the WC method. However, a small percentage of those ED visits (n = 802) occurred to children between the ages of 0 and 15 years. To improve the potential sensitivity of the descriptive results, the data presented in this section were restricted to those age 16 years or older.

A total of 133 156 ED visits for WR injuries to individuals' age 16 years or older were identified by one or more of the three WR identification methods: WC = 91 976 (69.1%), work-status code = 24 283 (18.2%), and other-work codes = 16 897 (12.7%). The overlap between the three identification methods is presented as a Venn diagram in Figure 1. The proportions of injury visits for each ICD-9-CM code are presented in Table 1 stratified by identification method. Among visits with a work-status code, 37% (14 204 of 38 080) of visits were identified by both the E-code for civilian work and the WC method. In contrast only 2.9% (12 of 419) of visits were identified by both the E-code for military activity and the WC method. Among WR visits identified by the other-WR code methods, within each ICD-9-CM code the majority of WR injuries were identified by that method alone (range, 60.0%-92.5%). There were three exceptions were the majority of visits (range, 60.5%-100%) were also identified by at least one of the other two methods; ICD-9-CM code for industrial place or premise (E849.3), observations following work accident (V71.3), and adverse effects of the work environment (V62.1).

For surveillance and research purposes, the three identification methods will most likely be used in combination with each

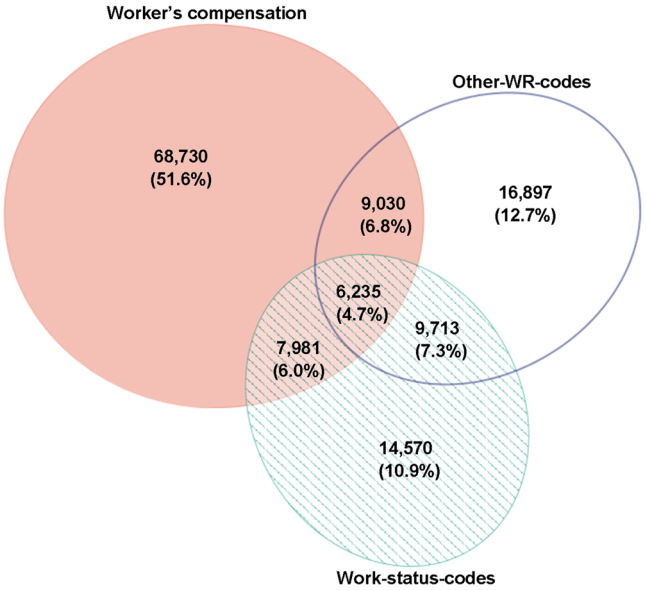

FIGURE 1 Venn diagram indicating the number of emergency department (ED) visits of those age 16 years or older stratified by work-related (WR) identification method (2010-2013). Total identified ED visits = 133 156 [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Demographic and information for emergency department (ED) injury visits (age, ≥16 years) stratified by work-related (WR) identification method North Carolina 2010–2013

Demographic variable	Worker's compensation, N (%)	Work-status codes,[a] N (%)	Other-WR codes,[b] N (%)	Total, N (column %)
Total	91 976 (69.1)	24 283 (18.2)	16 897 (12.7)	133 156 (100)
Gender				
Male	56 846 (67.1)	16 641 (19.6)	11 203 (13.2)	84 690 (63.6)
Female	35 124 (72.5)	7640 (15.8)	5693 (11.7)	48 457 (36.4)
Missing	6 (66.7)	2 (22.2)	1 (11.1)	9 (–)
Year				
2010	22 962 (69.7)	5697 (17.3)	4273 (13)	32 932 (24.7)
2011	24 309 (71.7)	5205 (15.3)	4411 (13)	33 925 (25.5)
2012	22 790 (68.6)	6400 (19.3)	4009 (12.1)	33 199 (24.9)
2013	21 915 (66.2)	6981 (21.1)	4204 (12.7)	33 100 (24.9)
Working hours/week				
Mon-Fri, 8-5:59 PM	46 390 (71)	11 116 (17)	7802 (11.9)	65 308 (24.9)
Nonworking hours	45 586 (67.2)	13 167 (19.4)	9095 (13.4)	67 848 (24.9)
Nature of Injury				
Fractures	6330 (73.3)	1164 (13.5)	1140 (13.2)	8634 (8.7)
Dislocation	684 (69.4)	179 (18.2)	122 (12.4)	985 (1)
Sprains & strains	14 493 (60.8)	5397 (22.7)	3935 (16.5)	23 825 (24)
Internal organ	1,086 (73.1)	224 (15.1)	176 (11.8)	1,486 (1.5)
Open wounds	17 198 (71.9)	3925 (16.4)	2805 (11.7)	23 928 (24.1)
Amputations	733 (81.1)	88 (9.7)	83 (9.2)	904 (0.9)
Blood vessels	44 (73.3)	5 (8.3)	11 (18.3)	60 (0.1)
Contusions/superficial	12 880 (72.5)	2758 (15.5)	2130 (12)	17 768 (17.9)
Crushing	1082 (71.7)	244 (16.2)	184 (12.2)	1510 (1.5)
Burns	2501 (74.4)	495 (14.7)	365 (10.9)	3361 (3.4)
Nerves	57 (71.3)	10 (12.5)	13 (16.3)	80 (0.1)
Unspecified	9134 (67.4)	2940 (21.7)	1474 (10.9)	13 548 (13.6)
System-wide & late effects	2163 (65.2)	677 (20.4)	478 (14.4)	3318 (3.3)
Missing	23 591 (69.9)	6177 (18.3)	3981 (11.8)	33 749 (–)
Injury location				
Traumatic brain injury	1025 (73.3)	209 (14.9)	165 (11.8)	1399 (1.7)
Other head, face, or neck	8774 (75)	1666 (14.2)	1261 (10.8)	11 701 (13.8)
Spinal cord	21 (87.5)	2 (8.3)	1 (4.2)	24 (0)
Vertebral column	5249 (59.7)	2046 (23.3)	1498 (17)	8793 (10.4)
Torso	4270 (61.1)	1713 (24.5)	1007 (14.4)	6990 (8.2)
Upper extremity	19 538 (69)	5122 (18.1)	3651 (12.9)	28 311 (33.4)
Lower extremity	14 204 (68.3)	3711 (17.8)	2883 (13.9)	20 798 (24.5)
Other & unspecified	2415 (71.1)	600 (17.7)	380 (11.2)	3395 (4)
System-wide & late effects	2163 (65.2)	677 (20.4)	478 (14.4)	3318 (3.9)
Missing	34 317 (70.9)	8537 (17.6)	5573 (11.5)	48 427 (–)
Transport to ED				
Ambulance	10 949 (81.2)	1385 (10.3)	1144 (8.5)	13 478 (11.6)
Walk-in	65 236 (67.4)	19 484 (20.1)	12 061 (12.5)	96 781 (83.6)
Walk-in (law enforcement)	167 (78.4)	24 (11.3)	22 (10.3)	213 (0.2)
Other	3390 (63.8)	1322 (24.9)	600 (11.3)	5312 (4.6)
Missing	12 234 (70.4)	2068 (11.9)	3070 (17.7)	17 372 (–)
Volunteer Work (yes)	11 (68.8)	0 (0)	5 (31.3)	16 (0)

[a]Work-status codes excluding those identified by worker's compensation.
[b]Other-WR codes excluding those identified by worker's compensation or identified by a work-status code.

other. For the remainder of this first section (Tables 2–4 and Figure 2), the results comparing the characteristics for each of the WR identification methods are presented as three nonoverlapping categories based on hypothesized hierarchical order of WR identification accuracy. This was done to highlight the additional/different information obtained by combining identification methods. Table 2 reports the number of ED visits identified by WC, identified by work-status codes excluding those identified by WC, and all other visits identified only by the other-WR codes method. Results stratified by the original seven groups (eg, identified by only one method; identification by two methods; or by all three methods) are located in Tables S1-S3.

The demographics and information specific to the ED visit (eg, age, sex, and visit time of day) varied by WR identification method and are presented in Table 2 and Figure 2. For the work-status code and other-WR codes methods, the primary payer for the majority of visits within each identification method was either self-pay (work-status code: 12 144/24 283 = 50.0%; other-WR codes: 7839/16 886 = 46.4%) or an insurance company (work-status code: 6109/24 283 = 25.2%; other-WR codes: 5310/16 886 = 31.5%).

TABLE 3 Cause of injury for emergency department (ED) injury visits (age, ≥16 years) stratified by work-related (WR) identification method North Carolina 2010-2013 (N = 101 200)

Cause of injury	Worker's compensation, N (%)	Work-status codes,[a] N (%)	Other-WR codes,[b] N (%)	Total, N (column %)
Motor vehicle traffic/nontraffic/other road vehicle	8040 (91.9)	423 (4.8)	281 (3.2)	8744 (8.6)
Vehicle accidents not elsewhere classified	63 (75)	10 (11.9)	11 (13.1)	84 (0.1)
Other poisonings	402 (66.1)	74 (12.2)	132 (21.7)	608 (0.6)
Falls	18 153 (69)	4568 (17.4)	3587 (13.6)	26 308 (26)
Fire/flame	463 (78.1)	71 (12)	59 (9.9)	593 (0.6)
Natural/environmental	2579 (64.1)	941 (23.4)	503 (12.5)	4023 (4)
Drowning/suffocation	16 (76.2)	2 (9.5)	3 (14.3)	21 (0)
Foreign body in eye	858 (56.4)	409 (26.9)	255 (16.8)	1522 (1.5)
Foreign body in other orifice	106 (72.6)	18 (12.3)	22 (15.1)	146 (0.1)
Caught in/between	3747 (71.9)	805 (15.4)	661 (12.7)	5213 (5.2)
Machinery-related	3651 (73.6)	763 (15.4)	547 (11)	4961 (4.9)
Cutting/piercing	12 403 (68.9)	3402 (18.9)	2206 (12.2)	18 011 (17.8)
Explosions/firearms/explosive/hot substance/corrosive/caustic/steam/electric current/radiation	2767 (72.6)	640 (16.8)	406 (10.6)	3813 (3.8)
Overexertion	10 162 (47)	7110 (32.9)	4347 (20.1)	21 619 (21.4)
Other/unspecified (noise and vibration)	4775 (68.5)	1191 (17.1)	1007 (14.4)	6973 (6.9)

[a]Work-status codes excluding those identified by worker's compensation.
[b]Other-WR codes excluding those identified by worker's compensation or identified by a work-status code.

TABLE 4 Activity at time of injury for emergency department (ED) injury visits (age, ≥16 years) stratified by work-related (WR) method North Carolina 2010–2013 (N = 16 064)

Activity at time of injury	Worker's compensation, N (%)	Work-status codes,[a] N (%)	Other-WR codes,[b] N (%)	Total, N
Walking and running	1004 (60.6)	490 (29.6)	162 (9.8)	1656
Property and land maintenance, building and construction	465 (31.9)	780 (53.6)	211 (14.5)	1456
Person providing caregiving	637 (56.7)	458 (40.7)	29 (2.6)	1124
Food preparation, cooking, and grilling	616 (56.9)	371 (34.3)	95 (8.8)	1082
Personal hygiene and household maintenance	154 (47.2)	127 (39)	45 (13.8)	326
Sports and athletics played as a team or group	169 (73.5)	29 (12.6)	32 (13.9)	230
Animal care	104 (49.8)	66 (31.6)	39 (18.7)	209
Sports and athletics played individually	54 (47)	28 (24.3)	33 (28.7)	115
Snow and ice	84 (81.6)	10 (9.7)	9 (8.7)	103
Climbing, rappelling, and jumping off	33 (41.3)	33 (41.3)	14 (17.5)	80
Other specified sports and athletics	36 (46.8)	28 (36.4)	13 (16.9)	77
Dancing and other rhythmic movement	18 (26.5)	37 (54.4)	13 (19.1)	68
Other muscle strengthening exercises	35 (53.8)	25 (38.5)	5 (7.7)	65
Other cardiorespiratory exercise	22 (36.7)	35 (58.3)	3 (5)	60
Water and water craft	20 (50)	13 (32.5)	7 (17.5)	40
Roller coasters and other types of external motion	28 (75.7)	9 (24.3)	0 (0)	37
Arts and handcrafts	10 (50)	8 (40)	2 (10)	20
Computer technology and electronic devices	3 (33.3)	4 (44.4)	2 (22.2)	9
Playing musical instrument	0 (0)	0 (0)	1 (100)	1
Unspecified activity	2400 (53.9)	1425 (32)	626 (14.1)	4451
Other activity	2454 (50.3)	1891 (38.8)	531 (10.9)	4876

[a]Work-status codes excluding those identified by worker's compensation.
[b]Other-WR codes excluding those identified by worker's compensation or identified by a work-status code.

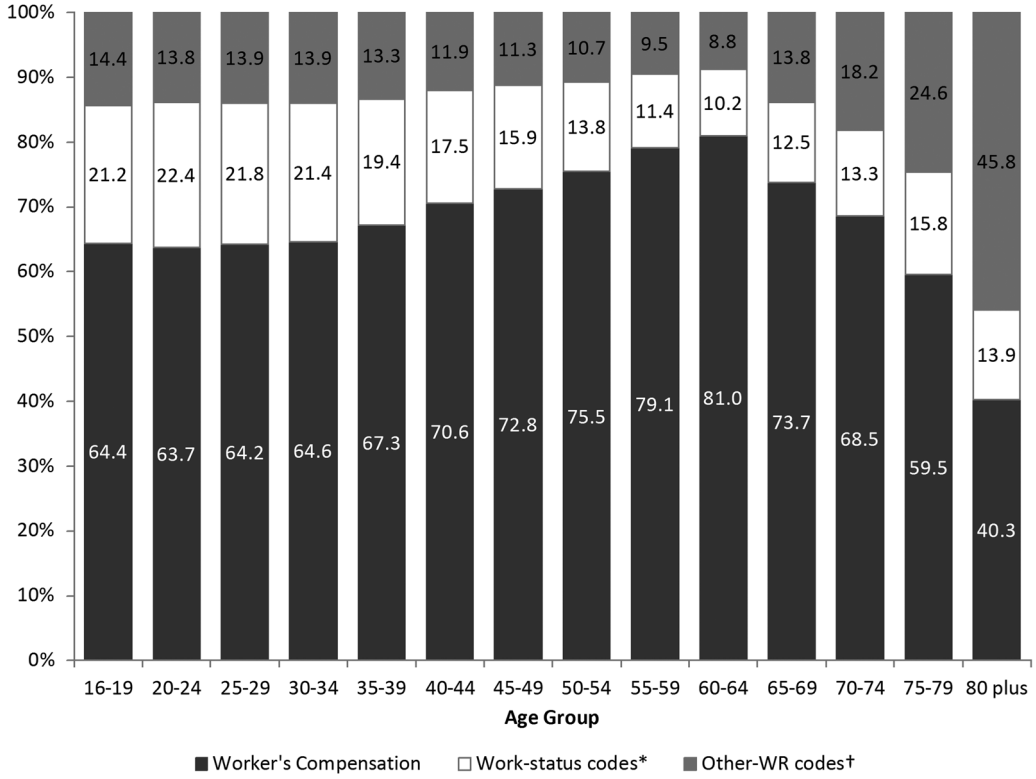

FIGURE 2 Age distribution of emergency department (ED) visits of those age 16 years or older stratified by work-related (WR) identification method (2010-2013). *Work-status codes excluding those identified by worker's compensation. †Other-WR codes excluding those identified by worker's compensation or identified by a work-status code

The WC method identified 81.1% of WR amputations but only 60.8% of strains and sprains (Table 2). For the location of injury, the WC method identified 73.3% of traumatic brain injuries and 59.7% of injuries to the vertebral column. In general, within each nature of injury or location of injury category, a larger proportion of ED visits was identified by the work-status code method than by the other-WR codes method. However, the proportion of visits identified by the other-WR codes method, within each category, was still greater than 10% (Table 2).

An E-code indicating the cause of injury was available for 76.0% (101 200 of 133 156) of ED visits for WR injury (Table 3). Among the various causes of injury where a method other than WC identified work relatedness, a larger proportion of visits were identified by the work-status code method followed by other-WR codes method. The only exceptions were for other poisonings, foreign body in other orifice, and vehicle accidents not elsewhere classified (Table 3).

While few ED visits had an activity E-code (16 064/133 156 = 12.1%), the activity codes may shed some light on the potential job duties when the injury occurred. Only the activity categories where the total number of injuries was 100 or greater are listed in Table 4. The WC method identified 47.2% and 31.9% of injuries where the activity was *personal hygiene and household maintenance* and *property and land maintenance, building and construction*, while the work-status code method identified 39.0% and 53.6%, respectively.

3.1 | Manual review of admission notes

A total of 800 ED visits of all ages were selected for manual review of the triage notes and chief complaints (Table S4). Forty-four percent (349 of 800) of all sampled visits were unclassifiable. The groups with the highest number of confirmed WR visits were: WC and work-status codes (n = 50/100), WC and other-WR codes (n = 53/100), and those visits identified by all three methods (n = 48/100). The largest number of false positives occurred when WR status was identified by other-WR codes with (n = 7/100) and without (n = 16/100) the E-code for industrial place or premise.

No difference between the proportional agreement/disagreement for the 400 manually reviewed records with WC was observed ($P = 0.01$) (confirmed or probable: 53.0% [212 of 400]; false positive: 0.25% [1 of 400]; undetermined: 38.5% [154 of 400]) and the 200 manually reviewed records with work-status codes and without WC as expected payer (confirmed or probable: 46.0% [92 of 200]; false positive: 1.5% [3 of 200]; undetermined: 44.5% [89 of 200]). A difference was observed between the 200 manually reviewed records identified only by other-WR codes and the 400 records with WC ($P < 0.0001$). The other-WR codes had a smaller proportion of confirmed or probable WR (31.0% = 62/200) and a larger proportion of false positives (11.5% = 23/200) and undetermined records (53% = 106/200).

Of the 200 manually reviewed records sampled from the other-WR code group, 180 were identified by a location E-code:

90 industrial place/premise (confirmed or probable: 38.9% [n = 35]; false positive: 2.2% [n = 2]; undetermined: 53.3% [n = 48]), 75 farm (confirmed or probable: 32.0% [n = 24]; false positive: 10.7% [n = 8]; undetermined: 50.7% [n = 38]), and 15 mine/quarry (false positive: 33.3% [n = 5]; undetermined: 66.7% [n = 10]). Among the false positives, almost half of the ED visits were to those under 16 years of age (industrial = 1, farm = 4, mine/quarry = 2).

Manual review of ED visits with an employee transport accident E-code found two of the five injuries to railway employees and one of the seven injuries to water transport employees were false positives; the rest were undetermined. Both of the manually reviewed visits identified by air transport (n = 2) were confirmed WR. There were only five records within the random sample which had a code for *vehicle used on industrial or commercial premises*–four of these records were false positives (below 16 years: n = 2) and one was undetermined.

The majority of WR injuries, identified by one of the three methods, for those age 16 years or older contained a nonmissing chief complaint (133 033/133 156 = 99.9%), while only 23% (31 015 of 133 156) of WR injuries contained a nonmissing triage note. After applying the WR syndrome keywords, on average, 25.4% (7869 of 31 015) of visits with a triage note and 4.3% (5676/133 033) of visits with a chief complaint had at least one of the work keywords. The proportions of true positives, as determined by the presence of a work-keyword, stratified by the seven identification method groups are presented in Figure 3. The groups with the largest proportion of true positives for both triage notes and chief complaints were: WC and work-status codes (triage note: 637/1857 = 33.6%; chief complaints: 541/7965 = 6.8%), WC and other-WR codes (triage note: 789/2348 = 33.6%; chief complaints: 632/9027 = 7.0%), and those visits identified by all three methods (triage note: 637/2020 = 31.5%; Chief complaints: 340/6232 = 5.5%). Applying the work keywords to all injuries among individuals 16 years and older identified an additional 6487 WR injuries that were not identified by the three WR identification methods assessed in this analysis.

4 | DISCUSSION

Administrative data sets such as hospital discharge and ED data are an important source for nonfatal occupational injury surveillance.[7,24] WR cases in administrative data sets are typically identified by WC as the expected payer.[7,14,24] In our study of unintentional WR injuries (2010-2013), we identified 91 976 ED visits among patients 16 years older with expected payer as WC. Similar to prior studies that evaluated payer to identify WR injuries, we found that in NC DETECT WC identified WR visits.[7,16,17] However, while WC identifies work relatedness,[14,24] it does not identify all WR cases leading to underestimation of the number of events, and potentially biased estimates of exposure-outcomes associations.[4,7] To reduce misclassification, additional methods are required to identify work relatedness.

An objective of this study was to evaluate two ICD-9-CM based methods of identifying WR injuries not captured by WC; ED visits identified by ICD-9-CM E-codes for work-status (civilian activity done for income/pay [E000.0]; military activity [E000.1]) and visits identified by other ICD-9-CM WR codes. Agreement between a WR identification method and an admission note indicating work

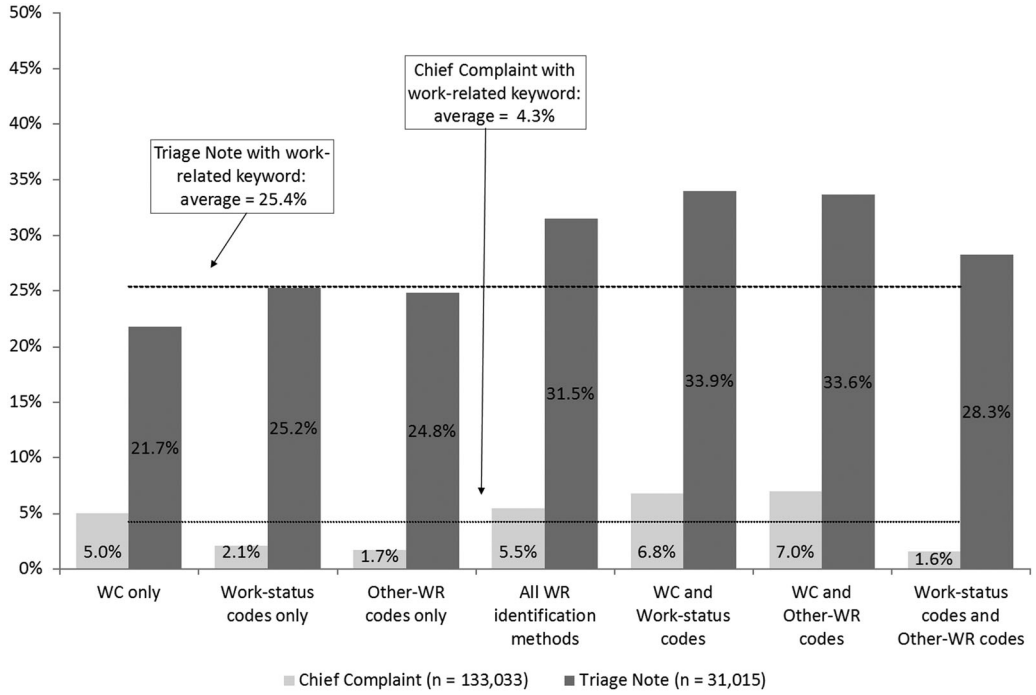

FIGURE 3 The proportion of emergency department (ED) visits of those age 16 years or older with a chief complaint or triage note which had a work-related (WR) keyword (2010-2013). WC: worker's compensation

relatedness was used to determine the accuracy of the WR classification. Unfortunately, 38.5% of WC identified ED visits and 48.8% of ED visits identified only by the other two methods could not be determined as confirmed, probable, possible, or false positives. Therefore, as part of the process evaluating the effectiveness of the work-status code and the other-WR code methods for identifying work relatedness we loosely compare the proportional agreement of the two methods with the admission notes to the proportional agreement between the WC method and the admission notes. The assumption being that if the two methods identified work relatedness, the proportional agreement with the admission notes would be similar or better than the proportional agreement between the WC method and the admission notes.

4.1 | Evaluation of the work-status code method

The results of our paper support the strong assumption indicated by the ICD-9-CM codebook definition that the records with a work-status code E000.0 or E000.1 are work-related. The proportional agreement/disagreement with WR admission notes was similar for the random sample of manually reviewed records with WC as expected payer (53.0%) and those with work-status codes without WC as expected payer (46.0%). Among all identified ED injury visits with a triage note, there was a similar proportion of visits with a WR triage note and work relatedness identified by the work-status code and not WC as expected payer (26.7%) and WR triage notes and ED visits with WC as the expected payer (25.1%). Further, work-status codes may be identifying injuries to those individuals who may not be covered by WC. In NC, WC does not cover domestic services or independent contractors, and those with fewer than three employees are exempt from providing coverage.[28] Among the small proportion of WR injuries with an activity code, 53.6% of WR ED visits with a code for *property and land maintenance, building and construction* and 40.8% of WR ED visits with a code for *person providing caregiving* had work relatedness identified by a work-status code and not by WC.

4.2 | Evaluation of the other-WR code method

When visits were identified only by the other-WR code method, we found only minimal effectiveness of the other-WR codes to identify work relatedness. The proportional agreement with WR admission notes was smaller for the WR visits identified by other-WR codes alone (31.0%) than for WR visits identified by WC as expected payer (53.0%). The proportion of false positives was larger for the other-WR codes (11.5%) method than for WC method (0.25%). The age distribution for WR visits identified by other-WR codes was skewed towards those aged 70 years or older. Manual review of triage notes within this group suggested that the other-WR codes may not effectively identify WR injuries in older individuals. In general, the effectiveness of the other-WR codes may be dependent on the codes which comprise this group: work incident V-codes, employee transport accident E-codes, and, work location E-codes. These categories will be discussed individually below.

The use of the codes V71.3, *observation following a work accident*, and V62.1, *psychosocial: adverse effects of work environment*, for identifying work relatedness is not recommended as the frequency of occurrence was negligible. During the 4-year study period, only five ED visits were identified by V71.3 alone (one confirmed; four undetermined) and zero ED visits were identified by V62.1 alone.

Employee transport accident E-codes should be used with caution, even though the codebook defines these codes as WR. Only a tiny proportion (0.6%) of WR ED visits of all ages identified by other-WR code alone had an employee transport accident E-code. Among the small number (n = 14) of manually reviewed ED visits of all ages with an employee transport accident E-code, three were false positives and two were confirmed WR.

The code E846, *vehicle used on industrial or commercial premises*, may not be effective at identifying work relatedness, even though, E846 has been noted by the codebook to be primarily occupational.[15] Code E846 identified an even smaller percentage (0.2%) of WR ED visits of all ages than the employee transport accident E-codes. We also found that four of the five manually reviewed ED visits were false positives. A further examination of admission notes for all ED visits with this code indicated that the code was being used for a mix of accidents associated with motor vehicles or nontraditional vehicles (eg, four wheeler, electric scooter, and bikes).

The three codes that imply a work location were E849.1 (farm), E849.2 (mine or quarry), and E849.3 (industrial place or premise). The vast majority (95.0%) of ED visits within our study identified solely by other-WR codes had the location code for industrial place or premise within the record. Manual review identified very few false positives but for most of the sampled records (53.3%) confirmed, probable, possible or false positive could not be determined. Among records with a triage note and work relatedness identified solely by industrial place or premise, the proportion of WR triage notes (36.1%) was larger than the same proportion among visits where WC was the expected payer (25.1%). For both the farm and the mine/quarry location, a substantial proportion of ED visits were false positives (farm = 10.7%, mine/quarry = 33.3%), suggesting these codes be used with caution. We did observe, however, that the number of false positives could be reduced by restricting the ED visits to those 16 years or older.

4.3 | Prior studies

The benefits of multiple WR injury case ascertainment methods have been noted in prior studies.[7,16,29] In addition to WC as the expected payer, these may include an injury-at-work variable, medical record review, or active follow-up.[7,11,30] Work-status E-codes are an additional case ascertainment method. Our results are supported by a study from Washington State that also evaluated the work-status E-codes and found that when the work-status E-codes were used, the positive predictive values were comparable to WC as payer.[17] The increased use of the work-status codes by medical facilities should be actively encouraged.

Prior studies have also examined the potential of other ICD-9-CM E-codes to identify work relatedness.[15,16,29] In these studies, the ICD-9-CM method used to identify WR injuries required the presence of an employee transport accident E-code, the presence of E846 (*vehicle use on industrial/commercial premise*), or the presence of a work location E-code in conjunction with a cause of injury E-code. A British Columbia study found moderate agreement between ICD-9-CM WR identification method and worker's compensation claims.[15] However, a study using data from the Washington State Trauma Registry indicated that the ICD-9-CM WR identification method should be used with caution.[29] The ICD-9-CM method used in these prior studies was similar to the other-WR code method in our study. However, we choose not to require the location codes to be found in conjunction with a cause of injury E-code to evaluate a broader applicable WR E-code method since many administrative data sets in the US only contain one E-code field.[31] The evaluation of our looser definition agrees with the Washington study conclusions—that these codes should be used with caution.

The plurality of WR visits identified solely by ICD-9-CM E-code in the Washington Trauma Registry contained a farm location while in our data the majority of ED visits identified by other-WR-method alone contained an industrial place or premise E-code.[29] The difference between the studies may indicate a large variation in the use of specific WR E-codes by state and/or data set (eg, trauma registry and ED visits), supporting the assertion that the E-codes comprising the other-WR code method should be evaluated by system and jurisdiction before use.

4.3.1 | ICD-10-CM

In October of 2015, the US switched from ICD-9-CM to ICD-10-CM for coding morbidity data. A forward and backwards crosswalk of the two coding systems was completed; however, a separate evaluation of the utility of these codes should be conducted. Within ICD-10-CM the external cause codes are still not required for reimbursement, so there may be continued under-usage. The work-status codes are still available in ICD-10-CM: Y99.0 (*civilian activity for work or pay*) and Y99.1 (*military activity*). If the results presented in this paper are extrapolated to ICD-10-CM, the work-status codes could be used to identify work-relatedness. ICD-10-CM codes do provide some expansion on the ICD-9-CM codes. For instance, both farm location (Y92.71-Y92.79) and industrial place or premise location (Y92.61-Y92.69) have six different ICD-10-CM codes. Y92.61 is for buildings under construction and Y92.73 is for farm field as the place of occurrence which may help identify workers not covered by WC. The code for *occupant of special vehicle mainly used on industrial premises* (V83.0XXX–V83.9XXX) includes a 7th character which designates the encounter (ie, initial [A], subsequent [D], or sequela[S]). Finally, while the ICD-9-CM V-codes assessed in this analysis were not useful for identifying work-relatedness, the additional codes found within the ICD-10-CM chapter "Factors influencing health status and contact with health services" may be useful, especially Z57.0–Z57.9 (*occupational exposure risk factors*) and possibly Z04.2 (*observation following work accident*) or Z56 (*problems related to (un)employment*).

4.4 | Strength and limitations

A limitation of this study is the lack of a gold standard, which makes it impossible to identify true negatives. A lack of a gold standard also makes any sensitivity calculations potentially unreliable. As previously mentioned, WC identifies work relatedness but due to the usage and non-usage of WC by workers and limits to which workers NC's WC system covers, a significant proportion of WR injuries are not identified by this method.[4,7,10] Both of the potential gold standards, WC or admission notes, only identify a segment of the true positives and false negatives within the study population. It is recommended that future studies employ a more stringent gold standard such as a medical record review or active follow-up. Future studies should also employ statistical methods that use multiple imprecise case identification methods to correct for measurement error.[32]

A significant strength of this study was the data source, which in addition to the fields typically collected in administrative data sets (eg, payer and diagnostic codes) contained admission notes (ie, triage notes and chief complaints) that often provided free text information on the situation of injury. Manual review of the triage notes allowed for the classification of confirmed, probable, possible, and false positives for each of the WR identification methods. While the sample size for manually reviewed notes was small, the results did provide compelling information on the use of ICD-9-CM codes for identifying work relatedness. The availability of the admission notes also allowed for the identification of probable true positives, false positives, and false negatives in the entire study population by using WR keywords. Unfortunately, the admission notes could not provide correct classification for all the ED visits due to missing triage notes (~70% of records) or lack of information about work relatedness in the note. The lack of information does not indicate a non-WR injury. Further, without manual review, the WR keywords may misclassify work relatedness.

A further strength was the availability of five E-code fields. This allowed for separate characterization of the injury mechanism, intent, location, and activity. In our study, over 92% of visits had at least one E-code, 62% had two E-codes, and 29% had three E-codes. However, our work may not generalize to the effectiveness in using E-codes to identify work relatedness in other jurisdictions or administrative data sources (eg, hospital discharge data) due to differing availability and use of E-codes. Even within our study we found considerable variation in usage between ED facilities (Figure S1). Additionally, E-codes are not required for billing and reimbursement purposes[33] and not all states require them for administrative data purposes. In NC, the collection of E-codes is not required by the state but the legislation mandating submission of ED visit data for syndromic surveillance does require that they be submitted to NC DETECT when they are collected.[34] In 2011, approximately 85% of ED injury visits had an E-code and ED injury visits with a missing E-code could be attributed to a small number of facilities.[35]

Even when an E-code is present, some skepticism may be appropriate. A systematic review of the accuracy of E-code assignment in hospital discharge data reported the average percent

agreement of coders to be 64% for a completed E-code and 82% for broader code agreement.[36] A Massachusetts study of ED Visits (1999-2000) found that less than a third of sampled medical records had location of injury and approximately half of those had an E-code. Among the medical records with a location of injury and an E-code, 85% were accurately coded.[37]

5 | CONCLUSION

This study assessed three methods of identifying work relatedness among ED visits: WC as expected payer, ICD-9-CM work-status E-codes, and other ICD-9-CM WR codes. The work-status E-codes are a valuable supplemental case ascertainment method; if the code is present the visit may be counted as WR. This may be especially useful in systems that do not collect payer, although the number of captured visits will depend on the system's E-code usage. The location of injury E-codes (farm, mine/quarry, industrial place/premise) should be used with caution. However, when combined with other-WR ascertainment or verification methods, the location of injury E-codes may provide useful for identifying WR visits. This study also identified WR syndromic surveillance keywords. These keywords could potentially be used to identify WR injuries and noninjuries but require further exploration. The methodology presented in this paper will also be applicable to evaluating potential ICD-10-CM WR codes. Exploration and verification of WR ICD-10-CM codes need to be conducted.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

DISCLOSURE BY AJIM EDITOR OF RECORD

Rodney Ehrlich declares that he has no conflict of interest in the reviewand publication decision regarding this article.

AUTHOR CONTRIBUTIONS

LHM conceived of the analysis. All authors participated in the design of the work. SP and LHM obtained the data. LHM analyzed the data. All authors participated in the interpretation of the results. LHM drafted the manuscript and all authors participated in the revisions to ensure accuracy and integrity of the intellectual content. All authors approved the final version to be published and agree to be accountable for all aspects of the work, including addressing questions and concerns related to the work.

ETHICAL APPROVAL AND INFORMED CONSENT

The work was IRB approved by expedited review (study number: 14-0928). A waiver of informed consent was given, as this was a retrospective study using secondary data and data are only displayed as summary statistics.

DISCLAIMER

The NC DETECT Data Oversight Committee does not take responsibility for the scientific validity of accuracy of methodology, results, statistical analyses, or conclusions presented.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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