

Evaluation of Diagnostic Codes in Morbidity and Mortality Data Sources for Heat-Related Illness Surveillance

Public Health Reports
2017, Vol. 132(3) 326-335
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DOI: 10.1177/0033354917699826
journals.sagepub.com/home/phr



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Abstract

Objectives: The primary objective of this study was to identify patients with heat-related illness (HRI) using codes for heat-related injury diagnosis and external cause of injury in 3 administrative data sets: emergency department (ED) visit records, hospital discharge records, and death certificates.

Methods: We obtained data on ED visits, hospitalizations, and deaths for Florida residents for May 1 through October 31, 2005-2012. To identify patients with HRI, we used codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* to search data on ED visits and hospitalizations and codes from the *International Classification of Diseases, Tenth Revision (ICD-10)* to search data on deaths. We stratified the results by data source and whether the HRI was work related.

Results: We identified 23 981 ED visits, 4816 hospitalizations, and 140 deaths in patients with non-work-related HRI and 2979 ED visits, 415 hospitalizations, and 23 deaths in patients with work-related HRI. The most common diagnosis codes among patients were for severe HRI (heat exhaustion or heatstroke). The proportion of patients with a severe HRI diagnosis increased with data source severity. If ICD-9-CM code E900.1 and ICD-10 code W92 (excessive heat of man-made origin) were used as exclusion criteria for HRI, 5.0% of patients with non-work-related deaths, 3.0% of patients with work-related ED visits, and 1.7% of patients with work-related hospitalizations would have been removed.

Conclusions: Using multiple data sources and all diagnosis fields may improve the sensitivity of HRI surveillance. Future studies should evaluate the impact of converting ICD-9-CM to ICD-10-CM codes on HRI surveillance of ED visits and hospitalizations.

Keywords

heat, illness, surveillance

Record-breaking summer temperatures and deadly heat waves in recent years have led to an increased awareness, particularly among public health workers, of adverse heat-related outcomes.^{1,2} As a result, public health surveillance efforts have increased, with the goal of reducing heat-related morbidity and mortality. Such surveillance has been conducted with

- Heat-health warning systems—when a trigger criterion is met (eg, $\geq x$ expected deaths or a priori temperature intensity or duration threshold), jurisdictions activate prevention activities³
- Syndromic surveillance—near real-time surveillance (eg, every 12 hours), often with emergency department (ED) chief complaint keywords to identify heat-related illness (HRI)^{4,5}

- Retrospective analysis—analyzing historical morbidity and mortality data and potentially combining them with environmental data (eg, temperature)^{1,6-10}

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- Active follow-up—contacting patients for additional information^{11,12}

Because high environmental heat may affect multiple body systems, some surveillance systems have measured adverse heat-related outcomes with all-cause morbidity or mortality; others have measured these outcomes with cause-specific morbidity or mortality.^{7,8,13} When used to measure heat-related health outcomes, all-cause morbidity or mortality may have a high sensitivity but a low specificity, whereas cause-specific morbidity or mortality may have a high specificity but a low sensitivity. Neither is ideal. Furthermore, the use of either outcome measure in this setting may be suboptimal because both require the use of a baseline (or low-heat exposure) estimate for comparison and both rely on the assumption that all cases above that baseline are related to exposure to high outdoor heat, which may not be accurate.

Alternately, numerous surveillance systems have used HRI as the preferred outcome to be measured.^{5,13,14} Although HRI may underestimate the incidence of adverse heat-related outcomes,¹³ its use has been supported by cause-specific analyses in which HRI is the outcome with the largest relative increase during a heat wave or when ambient outdoor heat increases.¹⁵⁻¹⁸ A logical assumption is that if the HRI rate or count is increasing, then other heat-related outcomes are also increasing.

HRI has typically been identified by using different coding schemes, such as the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*,¹⁹ or emergency medical services categories,^{18,20} or by using keywords in free-text fields (eg, ED chief complaint notes). Even so, little has been published about the proportion of patients with HRI identified by specific code queries and keyword searches, how results with these methods may vary by data source, or how the proportion of patients with HRI identified by the query components may vary by whether or not the HRI was work related.^{1,5,21-25}

The primary objective of this study was to identify patients with HRI through *ICD* codes for heat-related diagnosis and external cause of injury in 3 large state administrative data sets often used for HRI surveillance: ED visits, hospital discharge records, and death certificates. A secondary objective was to stratify the analysis by whether or not the HRI was work related. Findings could contribute to a discussion about outcome measures used for heat-related morbidity and mortality surveillance and provide a framework by which other jurisdictions could explore their data and refine their HRI surveillance efforts.

Methods

We obtained unpublished data on ED visits and hospital discharges from the Florida Agency for Health Care Administration for 2005 through 2012. The ED data set contained only the visits of patients who were treated and

released, and the hospital discharge data set contained data on all patient hospitalizations, regardless of the admission source (via ED or directly to the hospital). We obtained unpublished data on deaths for the same years from the Florida Department of Health, Office of Vital Statistics. The University of North Carolina Institutional Review Board approved the study. The Florida Department of Health Institutional Review Board determined that the study fell within the purview of public health practice and surveillance activities and waived board review.

By focusing on the warm season, HRI surveillance typically captures data on patients with morbidity and mortality that are most likely related to outdoor environmental heat exposure.²⁶⁻²⁸ Thus, we restricted our investigation to Florida residents with HRI during the Florida warm season (May 1 to October 31).²⁹ For ED patients who were treated and released and for hospitalized patients admitted through the ED, we used the date of the ED visit (rather than the date of hospitalization) as the date of symptom onset. For patients who died, we used the date of injury (instead of the date of death), if available, as the date of symptom onset.

To identify patients with HRI, we used *ICD-9-CM* codes to search ED and hospital discharge data, and we used codes from the *International Classification of Diseases, Tenth Revision (ICD-10)*³⁰ to search mortality data. We defined HRI as occurring when a patient's record showed (1) the presence of an *ICD* injury diagnosis code for the effects of heat and light (*ICD-9-CM* codes 992 or 992.0-992.9 or *ICD-10* codes T67 or T67.0-T67.9) in any of the ED or hospital discharge diagnosis fields (ie, primary or secondary diagnoses) or in the fields for cause of death (ie, underlying, contributing, or immediate) and/or (2) the presence of an *ICD-9-CM* or *ICD-10* code for external cause of injury for excessive heat due to weather conditions (E900.0 or X30, respectively), excessive heat due to man-made conditions (E900.1 or W92, respectively), or excessive heat of unspecified origins (E900.9) or *ICD-9-CM* E900.^{10,25,27}

We stratified our data by work relatedness. We classified HRI as work related in those aged ≥ 16 when the expected primary payer for care was workers' compensation or when the patient's record specified certain work-related *ICD-9-CM* codes for external cause of injury (Table 1).^{25,31} We classified deaths as work related in those aged ≥ 16 when the "injury at work" field on their death certificate was marked yes. All HRI patients and deaths not classified as work related were considered to be non-work related.

The records of patients who died with an injury or poisoning are required to contain free-text information, provided by the medical certifier, explaining how the death occurred (eg, specific activity or situation).³² We reviewed this free-text field in the records of all patients who died with HRI, and we manually summarized the information into the following a posteriori categories: alcohol use, confined in car, exertional, illicit drug use, or other.

Demographic information and descriptive statistics about the study population are published elsewhere.³³ Briefly,

Table 1. ICD-9-CM codes and definitions used to identify whether heat-related illnesses in patients were work related during emergency department visits and hospitalizations, Florida, May 1 through October 31, 2005-2012^a

ICD-9-CM Code	Definition
E000.0	Civilian activity done for income or pay
E000.1	Military activity
E800-E807	Railway accident among railway employees (fourth digit = 0) ^a
E830-E838	Water transport accident among crew, dockers, or stevedores (fourth digit = 2 or 6) ^a
E840-E845	Air and space transport accidents among crew or ground crew (fourth digit = 2 or 8) ^a
E846	Accident involving powered vehicles used solely within the buildings and premises of industrial or commercial establishment
E849.1	Place of occurrence: farm building/land under cultivation
E849.2	Place of occurrence: mine or quarry
E849.3	Place of occurrence: industrial place and premises

Abbreviation: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

^aICD-9-CM E-codes require a fourth digit, which describes the cause, site, or manifestation of the disease or condition. For example, the E843.8 diagnosis code is used for "aircraft fall—ground crew (fall in, on, or from aircraft injuring ground crew, airline employee)."¹⁹

males, those in racial/ethnic minority groups, and rural residents had the highest relative rates of HRI. Among patients treated in the ED, those aged 15-35 had the highest rates of work-related and non-work-related HRI. For patients who were hospitalized or died, non-work-related HRI rates increased with age, whereas work-related HRI rates were stable across all ages.

Results

A total of 32 354 patients with HRI were identified in Florida during the warm seasons of 2005 through 2012 (Table 2). Of those, we classified 28 937 as having non-work-related HRI (23 981 from EDs, 4816 from hospitals, and 140 deaths) and 3417 as having work-related HRI (2979 from EDs, 415 from hospitals, and 23 deaths). We identified 911 patients with non-work-related HRI and 82 patients with work-related HRI who were admitted to the hospital via the ED; the mean latencies between ED visits and hospital admissions of these 2 groups were 0.2 days (SD = 0.5, maximum = 4) and 0.1 days (SD = 0.4, maximum = 2), respectively.

A total of 96 non-work-related HRI and 22 work-related HRI deaths had both the date of injury and the date of death recorded on the death certificate. In these decedents, the mean latency between injury and death was 1.3 days (SD = 3.6, maximum = 22) for those whose HRI deaths were non-work related and 2.5 days (SD = 1.8, maximum = 39) for those whose HRI deaths were work related. There was 1 non-work-related HRI death in which the date of injury

occurred between May 1 and October 31, but the date of death occurred outside of this period.

Most patients and deaths in our study were identified by using ICD-9-CM and ICD-10 injury diagnosis codes for HRI (ICD-9-CM codes 992-992.9, ICD-10 codes T67-T67.9). Although we did not use only primary diagnosis codes to identify patients with HRI, we found a primary diagnosis of HRI in 64.9% (15 554 of 23 981) of patients with ED visits for non-work-related HRI and in 42.5% (2046 of 4816) of patients with hospitalizations for non-work-related HRI. Similarly, we found a primary diagnosis of HRI in 75.4% (2245 of 2979) of patients with ED visits for work-related HRI and in 49.6% (206 of 415) of patients with hospitalizations for work-related HRI.

Among the 140 patients who died with non-work-related HRI, the underlying cause of death was excessive heat due to weather conditions (ICD-10 code X30) in 83 (59.3%), excessive heat due to man-made conditions (ICD-10 code W92) in 6 (4.3%), another code for non-heat-related external cause of injury in 21 (15.0%), or a non-heat-related diagnosis code in 30 (21.4%) deaths. Among the 23 patients who died with work-related HRI, the underlying cause of death was excessive heat due to weather conditions in 22 deaths and chronic heart disease in 1 death.

We considered heatstroke and sunstroke (ICD-9-CM code 992.0 or ICD-10 code T67.0) and heat exhaustion (ICD-9-CM codes 992.3-992.5 or ICD-10 codes T67.3-T67.5) to be the most severe forms of HRI.³⁴ Among patients with non-work-related HRI, 1 of these diagnoses was present in 78.2% (18 751 of 23 981) of ED patients, 86.9% (4183 of 4816) of hospitalized patients, and 82.9% (116 of 140) of those who died. Among patients with work-related HRI, 1 of these diagnoses was present in 81.5% (2429 of 2979) of ED patients, 94.0% (390 of 415) of hospitalized patients, and 91.3% (21 of 23) of those who died (Table 2).

Patients with non-work-related HRI were identified only by an excessive heat code for external cause of injury (ICD-9-CM codes E900, E900.0, E900.1, or E900.9 or ICD-10 codes X30 or W92) in 3.7% (879 of 23 981) of ED visits, 3.5% (169 of 4816) of hospitalizations, and 2.1% (3 of 140) of deaths. Patients with work-related HRI were identified only by a code for an external cause of injury in 2.8% (82 of 2979) of ED visits, 1.2% (5 of 415) of hospitalizations, and no deaths (Table 2).

Among non-work-related HRI patients who were identified by using an ICD-9-CM HRI diagnosis code, 16.7% (3850 of 23 102) of ED patients and 15.0% (699 of 4647) of hospitalized patients had no corresponding heat-related code for external cause of injury in their records (Table 3). Of the 137 non-work-related HRI deaths identified by an ICD-10 HRI diagnosis code, 10 (7.3%) had no heat-related code for external cause of injury listed in their records. Among work-related HRI patients who were identified by ICD-9-CM HRI diagnosis codes, 13.8% (400 of 2897) of ED patients and 11.2% (46 of 410) of hospitalized patients

Table 2. Number of heat-related illnesses^a in Florida residents, by *ICD-9-CM* or *ICD-10* code,^{19,30} data source,^b and whether the illness was work related, May 1 through October 31, 2005-2012

Heat-Related Illness Description (Codes: <i>ICD-9-CM</i> ; <i>ICD-10</i>)	Event, No. (%) ^c		
	ED Visit ^d	Hospitalization ^d	Death ^e
Non-work-related heat-related illness			
Injury diagnosis codes ^f			
Heatstroke and sunstroke (992.0; T67.0)	542 (2.3)	1315 (27.3)	109 (77.9)
Heat exhaustion (992.3-992.5; T67.3-T67.5)	18209 (75.9)	2868 (59.6)	7 (5.0)
Mild heat illness (992.1, 992.2, 992.6, 992.7; T67.1, T67.2, T67.6, T67.7)	2428 (10.1)	280 (5.8)	0
Other specified; unspecified heat effects (992.8, 992.9; T67.8, T67.9)	1923 (8.0)	184 (3.8)	21 (15.0)
External cause of injury (E-codes)			
Excessive heat due to weather conditions (E900.0; X30)	515 (2.1)	112 (2.3)	3 (2.1)
Excessive heat due to man-made conditions (E900.1; W92)	12 (0.1)	7 (0.1)	0
Excessive heat of unspecified origins (E900.9)	349 (1.5)	50 (1.0)	NA
Excessive heat (E900)	3 (0.0)	0	NA
Total	23981 (100.0)	4816 (100.0)	140 (100.0)
Work-related heat-related illness ^g			
Injury diagnosis codes ^f			
Heatstroke and sunstroke (992.0; T67.0)	56 (1.9)	104 (25.1)	21 (91.3)
Heat exhaustion (992.3-992.5; T67.3-T67.5)	2373 (79.7)	286 (68.9)	0
Mild heat illness (992.1, 992.2, 992.6, 992.7; T67.1, T67.2, T67.6, T67.7)	296 (9.9)	10 (2.4)	0
Other specified; unspecified heat effects (992.8, 992.9; T67.8, T67.9)	172 (5.8)	10 (2.4)	2 (8.7)
External cause of injury (E-codes)			
Excessive heat due to weather conditions (E900.0; X30)	60 (2.0)	5 (1.2)	0
Excessive heat due to man-made conditions (E900.1; W92)	4 (0.1)	0	0
Excessive heat of unspecified origins (E900.9)	18 (0.6)	0	NA
Excessive heat (E900)	0	0	NA
Total	2979 (100.0)	415 (100.0)	23 (100.0)

Abbreviations: ED, emergency department; *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification*; *ICD-10*, *International Classification of Diseases, Tenth Revision*; NA, not applicable.

^aEach patient record was counted in only 1 heat-related illness category. If multiple codes were present in the record, the most severe or complete diagnosis was used. The most severe and complete diagnosis was heatstroke and sunstroke (992.0; T67.0), and the least severe and complete diagnosis was excessive heat (E900).

^bData sources: ED visit records and hospital discharge records were obtained from the Florida Agency for Health Care Administration (unpublished). Death certificates were obtained from the Florida Department of Health Office of Vital Statistics (unpublished).

^cPercentages may not total to 100.0 because of rounding.

^d*ICD-9-CM* code used to identify heat-related illness.

^e*ICD-10* code used to identify heat-related illness deaths.

^fInjury diagnosis descriptions and codes are listed from most to least severe.

^gHeat-related illness was considered work related if the patient record specified workers' compensation as the expected payer or work-related *ICD-9-CM* E-code. A heat-related illness death was considered work related if the "injury at work" box on the death certificate was marked yes.

had no corresponding heat-related code for external cause of injury in their records. Of the 23 work-related HRI deaths, all had both an *ICD-10* diagnosis code and the code for heat-related external cause of injury (X30) listed in their records. Finally, of the 7 patients with non-work-related HRI who died and had the code for external cause of injury W92 (excessive heat due to man-made conditions) in their records, the death certificates indicated that 4 were in a car, 2 were in an attic, and 1 occurred where an air conditioner had been set too high.

We also looked at proportion of hospitalizations stratified by admittance (Table 4). The distribution of patients was similar except that among HRI patients admitted via the ED, 65.1% (69 of 106) were work-related heat exhaustion, whereas among HRI patients admitted via another source, 70.2% (217 of 309) were work-related heat exhaustion.

Discussion

HRI surveillance is often conducted through administrative morbidity data sets and death certificates. However, an HRI diagnosis identifies patients with heat exposure, but it does not capture all HRI patients. Records often list the presenting symptom or condition of HRI (eg, myocardial infarction event) or the chronic condition exacerbated by HRI.^{13,35} To improve heat-related surveillance, it is essential to increase the identification of HRI patients.

HRI that was diagnosed in approximately 33% of ED visits, 56% of hospitalizations, and 31% of deaths would have been missed by our analysis if only the primary diagnosis (or underlying cause) field was queried. Furthermore, although administrative data sets (eg, ED or hospital discharge records) often include *ICD* codes in ordered diagnosis

Table 3. Number of heat-related illnesses^a in Florida residents with an *ICD-9-CM* or *ICD-10* diagnosis code for the effects of heat and light,^b by *ICD-9-CM* or *ICD-10* code for external cause of injury,^{19,30} data source,^c and whether the illness was work related, May 1 through October 31, 2005-2012

Heat-Related Illness Description (Codes: <i>ICD-9-CM</i> ; <i>ICD-10</i>)	Event, No. (%)		
	ED Visit ^{d,e}	Hospitalization ^{d,e}	Death ^f
Non-work-related heat-related illness			
Excessive heat due to weather conditions (E900.0; X30)	13 986 (60.5)	3401 (73.2)	120 (87.6)
Excessive heat due to man-made conditions (E900.1; W92)	140 (0.6)	38 (0.8)	7 (5.1)
Excessive heat of unspecified origins (E900.9)	5100 (22.1)	509 (11.0)	NA
Excessive heat (E900)	26 (0.1)	0	NA
No E-code present	3850 (16.7)	699 (15.0)	10 (7.3)
Total	23 102 (100.0)	4647 (100.0)	137 (100.0)
Work-related heat-related illness^g			
Excessive heat due to weather conditions (E900.0; X30)	1817 (62.7)	317 (77.3)	23 (100.0)
Excessive heat due to man-made conditions (E900.1; W92)	87 (3.0)	7 (1.7)	0
Excessive heat of unspecified origins (E900.9)	593 (20.5)	40 (9.8)	NA
Excessive heat (E900)	0	0	NA
No E-code present	400 (13.8)	46 (11.2)	0
Total	2897 (100.0)	410 (100.0)	23 (100.0)

Abbreviations: ED, emergency department; *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification*; *ICD-10*, *International Classification of Diseases, Tenth Revision*; NA, not applicable.

^aEach patient record was counted in only 1 heat-related illness category. If multiple codes were present in the record, the most severe or complete diagnosis was used. The most severe and complete diagnosis was heatstroke and sunstroke (992.0; T67.0), and the least severe and complete diagnosis was excessive heat (E900). The table rows are in order of descending severity and completeness.

^bThe diagnosis codes for effects of heat and light injury: 992-992.9 (*ICD-9-CM*) and T67-T67.9 (*ICD-10*).

^cData sources: ED visit records and hospital discharge records were obtained from the Florida Agency for Health Care Administration (unpublished). Death certificates were obtained from the Florida Department of Health Office of Vital Statistics (unpublished).

^d*ICD-9-CM* code used to identify heat-related illness.

^eIn non-work-related heat-related illness, 1 patient had both codes E900.0 and E900.9. In work-related heat-related illness, 2 patients had both codes E900.0 and E900.1.

^f*ICD-10* code used to identify heat-related illness death.

^gA heat-related illness was considered work related if the patient record specified workers' compensation payer or work-related *ICD-9-CM* E-code. A heat-related death was considered work related if the "injury at work" box on the death certificate was marked yes.

fields, syndromic surveillance system (near real-time surveillance) data sets that include *ICD* codes do not always contain a diagnosis order. Therefore, we agree with others who have noted that to capture data on as many patients with HRI as possible, HRI *ICD* codes should be collected from all fields indicating diagnosis (primary/secondary) and cause of death (underlying, immediate, or contributing).^{21,36,37}

We observed that the severity of HRI varied by data source. For example, heatstroke was identified in the death certificates of most patients who died of HRI (77.9%-91.3%), but it was noted in the records of few HRI-related ED visits (1.9%-2.3%). This finding is consistent with the fact that heatstroke is considered one of the most severe forms of HRI³⁴ and that patients with heatstroke may be more likely to be admitted from the ED to the hospital rather than treated and released.^{21,22}

In addition to the variation in HRI severity by data source, for the morbidity data sets, $\leq 10\%$ of patients were diagnosed with mild HRI. These findings indicate that the full burden of HRI may not be captured and that the data (ie, ED visit and hospital discharge records) most likely include only those patients whose HRI is severe enough to require immediate medical attention. Consequently, when conducting HRI surveillance, public health professionals should consider using

multiple data sources to capture the full spectrum of HRI severity, including nontraditional data sources, such as records from urgent care facilities.

A small but important proportion of patients and deaths (up to 3.7%) with HRI were identified only by their heat-related code for external cause of injury. The number of HRI patients identified by a code for external cause of injury may be due to Florida regulations mandating that codes for external cause of injury be reported by all health care facilities.³⁸ It may also have been related to the high rates of compliance with this regulation in Florida. Between 2007 and 2012, 95% to 98% of all nonfatal injury ED visits and hospital discharge records had a code for external cause of injury.³⁹ Furthermore, the 3 available fields for external cause of injury in the Florida ED and hospital discharge data allowed for separate characterization of the injury mechanism, intent, location, and activity. For injury-related deaths, a code for external cause of injury (rather than an *ICD-10* injury diagnosis code) should be recorded as the underlying cause of death on the death certificate.⁴⁰ However, 7% of death certificates among Florida residents had an HRI diagnosis code but no corresponding heat-related code for external cause of injury. Nevertheless, it may not be possible to generalize our results to

Table 4. Number of heat-related illness hospitalizations^a among Florida residents, by *ICD-9-CM* code,¹⁹ source of admittance, and whether the illness was work related, May 1 through October 31, 2005-2012^b

Heat-Related Illness Description (<i>ICD-9-CM</i> Codes)	Event, No. (%)		
	Admittance via ED	Admittance via Other Source ^c	Total Hospitalizations
Non-work-related heat-related illness			
Injury diagnosis codes ^d			
Heatstroke and sunstroke (992.0)	362 (27.2)	953 (27.3)	1315 (27.3)
Heat exhaustion (992.3-992.5)	820 (61.7)	2048 (58.7)	2868 (59.6)
Mild heat illness (992.1, 992.2, 992.6, 992.7)	61 (4.6)	219 (6.3)	280 (5.8)
Other specified/unspecified heat effects (992.8, 992.9)	43 (3.2)	141 (4.0)	184 (3.8)
External cause of injury (E-codes)			
Excessive heat due to weather conditions (E900.0)	21 (1.6)	91 (2.6)	112 (2.3)
Excessive heat due to man-made conditions (E900.1)	0	7 (0.2)	7 (0.1)
Excessive heat of unspecified origins (E900.9)	22 (1.7)	28 (0.8)	50 (1.0)
Excessive heat (E900)	0	0	0
Total	1329 (100.0)	3487 (100.0)	4816 (100.0)
Work-related heat-related illness^e			
Injury diagnosis codes ^d			
Heatstroke and sunstroke (992.0)	28 (26.4)	76 (24.6)	104 (25.1)
Heat exhaustion (992.3-992.5)	69 (65.1)	217 (70.2)	286 (68.9)
Mild heat illness (992.1, 992.2, 992.6, 992.7)	3 (2.8)	7 (2.3)	10 (2.4)
Other specified/unspecified heat effects (992.8, 992.9)	6 (5.7)	4 (1.3)	10 (2.4)
External cause of injury (E-codes)			
Excessive heat due to weather conditions (E900.0)	0	5 (1.6)	5 (1.2)
Excessive heat due to man-made conditions (E900.1)	0	0	0
Excessive heat of unspecified origins (E900.9)	0	0	0
Excessive heat (E900)	0	0	0
Total	106 (100.0)	309 (100.0)	415 (100.0)

Abbreviations: ED, emergency department; *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification*.

^aEach patient record was counted in only 1 heat-related illness category. If multiple codes were present in the record, the most severe or complete diagnosis was used. The most severe and complete diagnosis was heatstroke and sunstroke (992.0; T67.0), and the least severe and complete diagnosis was excessive heat (E900). The table rows are in order of descending severity and completeness.

^bData source: hospital discharge records from the Florida Agency for Health Care Administration (unpublished).

^cOther sources of admittance may include the direction of a physician or court order or a transfer from a skilled nursing facility, another health care facility, hospice, or an ambulatory surgery center.

^dInjury diagnosis descriptions and codes listed from most to least severe.

^eA heat-related illness was considered work related if the patient record specified workers' compensation payer or a work-related *ICD-9-CM* E-code.

all jurisdictions, because the completeness, accuracy, and specificity of code for external cause of injury reporting vary by state.³⁸ Still, although the magnitude of improvement will vary by jurisdiction, the additional use of *ICD* codes for external cause of injury for HRI surveillance should increase the number of patients identified with HRI. During the assignment of codes in administrative data, the use of specific and multiple codes for external cause of injury should be encouraged.⁴¹

We elected to include the *ICD* code for external cause of injury for excessive heat due to man-made conditions (E900.1 from *ICD-9-CM* and W92 from *ICD-10*) in our analysis. When HRI surveillance is conducted, these codes are not often included or are even used by some jurisdictions as exclusion criteria.^{21,27,28,42} It has been argued that the purpose of HRI surveillance is to track patients affected by or deaths caused by outdoor environmental heat exposure rather than those exposed to indoor heat in areas such as

boiler rooms, kitchens, or factories.^{19,21} However, indoor temperature has been positively correlated with outdoor temperature.⁴³⁻⁴⁵ In addition, previous studies of workers in aluminum smelters or underground mining facilities reported more adverse heat-related outcomes as outdoor temperature increased.⁴⁶⁻⁴⁸ Others have reported that when indoor work environments were not cooled or ventilated properly, the outdoor ambient temperature added considerably to the level of indoor heat.¹ Moreover, according to the *ICD-9-CM* manual, the code for excessive heat due to man-made conditions includes excessive heat generated in transport vehicles.¹⁹ As such, this code might reasonably be applied, for example, to those with an HRI as a result of being trapped in a vehicle during periods of high outdoor temperatures. Finally, when we examined free-text notes associated with the code W92 on death certificates of patients in our study, 6 of the 7 deaths reported the presence of heat exposure exacerbated by outdoor environmental heat.

Table 5. Heat-related illness crosswalk for ICD-9-CM¹⁹ and ICD-10-CM⁵² codes and descriptions

ICD-9-CM Code	Description	ICD-10-CM Code ^a	Description
992.0	Heat stroke and sunstroke	T67.0	Heat stroke and sunstroke
992.1	Heat syncope	T67.1	Heat syncope
992.2	Heat cramps	T67.2	Heat cramps
992.3	Heat exhaustion, anhidrotic	T67.3	Heat exhaustion, anhidrotic
992.4	Heat exhaustion due to salt depletion	T67.4	Heat exhaustion due to salt depletion
992.5	Heat exhaustion, unspecified	T67.5	Heat exhaustion, unspecified
992.6	Heat fatigue, transient	T67.6	Heat fatigue, transient
992.7	Heat edema	T67.7	Heat edema
992.8	Other specified heat effects	T67.8	Other specified heat effects
992.9	Unspecified	T67.9	Unspecified
E838.9	Other and unspecified water transport accident	V93.2	Heat exposure on board watercraft ^b
E900.0	Excessive heat due to weather conditions	X30	Exposure to excessive natural heat
E900.0	Excessive heat due to weather conditions	X32	Exposure to sunlight ^b
E900.1	Excessive heat of man-made origin	W92	Exposure to excessive heat of man-made origin
E900.9	Excessive heat of unspecified origin	X30	Exposure to excessive natural heat

Abbreviations: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification.

^aIncludes all episodes of care. Designated episodes of care for injuries, poisonings, and other consequences of external causes are identified by the ICD-10-CM seventh character: initial encounter (seventh character is A) related to active treatment; subsequent encounter (seventh character is D) related to continuation of care during the recovery/healing phase; and sequela encounter (seventh character is S) related to complications from the injury after the recovery/healing phase. Note that the fifth and sixth characters are placeholders and will always contain an X (eg T67.0XXA, T67.0XXD, T67.0XXS). ICD-10-CM seventh character also crosswalks to: T67 sequela \cong ICD-9-CM 909.4; T67 subsequent encounter \cong ICD-9-CM V58.89; X30, X32, W92 sequela \cong E929.5; V93.2 sequela \cong E929.1.

^bICD-10-CM V93.2 and X32 codes did not exist in ICD-9-CM. However, per the Diagnosis Code General Equivalence Mappings provided by the Centers for Disease Control and Prevention (<https://www.cdc.gov/nchs/icd/icd10.cm.htm>), these codes have been mapped to a specific ICD-9-CM code.

Taken together, the previous arguments support inclusion of the codes E900.1 and W92 for HRI surveillance. Nevertheless, at most, 0.1% of the patients in our study were identified as having HRI solely through the use of 1 of these 2 codes. However, we determined that if we had used these 2 codes instead as exclusion criteria, 5.0% of patients with non-work-related HRI deaths, 3.0% of patients with work-related HRI ED visits, and 1.7% of work-related HRI hospitalizations would have been removed. Because the use of codes for external cause of injury in HRI surveillance varies by jurisdiction, the additional proportion of patients with HRI that would potentially be captured by including these codes (or by not using them as exclusion criteria) may vary.³⁸ Given the findings in this study, we recommend that, at a minimum, codes E900.1 and W92 not be used as exclusion criteria for HRI surveillance. Furthermore, we also suggest that the use of these codes be strongly considered as a way to potentially increase the sensitivity of HRI surveillance.

In our data, as typical of administrative data sets, the exact timing of injury (ie, HRI onset) was unknown, leading to varying degrees of bias in the timing of injury.^{49,50} For data on ED visits and hospitalizations, we inferred that the date closest to symptom onset was the date of the ED visit. Patients admitted to the hospital via the ED may not always be admitted the same day; instead, prior to hospital admission, patients may be placed on observation status.⁵¹ The date with the potential to be furthest from symptom onset is the date of death. An extreme example from our data was

the decedent who was hospitalized for >1 month before death. Although the date of injury is required to be noted on the death certificate for injury-related deaths,³² we found that it was not always done. To reduce the bias in the timing of HRI onset, if available, it is recommended that the ED visit date or the date of injury be used for hospitalizations and deaths, respectively.

Our HRI morbidity surveillance used ICD-9-CM codes, but in October 2015, the US coding system shifted to the *International Classification of Diseases, Tenth Revision, Clinical Modification* (ICD-10-CM). The ICD-9-CM codes used in this analysis all have corresponding ICD-10-CM codes (Table 5).⁵² It is currently unclear how the switch to ICD-10-CM will affect HRI surveillance. In ICD-10-CM, 2 potential HRI codes were not available in ICD-9-CM. Additionally, for each heat-related ICD-10-CM code, the seventh character indicates the encounter: initial, subsequent, sequela.⁵³ In the case of sequela, in ICD-9-CM, a sequela code for external cause of injury (ie, E929.5, late effects of accident due to natural and environmental factors) would have been required in conjunction with the injury diagnosis.¹⁹ However, many morbidity systems may only have 1 external cause of injury field. As a result, HRI diagnoses may not have been coded as sequela. It is recommended that future studies examine (1) how HRI surveillance based on ICD-10-CM codes varies among and within jurisdictions, (2) how the seventh character is being assigned and its impact on HRI surveillance, and (3) how the proportion of patients identified by each ICD-9-CM or ICD-10-CM HRI code may affect HRI time trends.

Limitations

This study had several limitations. First, restricting the study to warmer months (May 1 to October 31) may have underestimated the number of patients who had HRI. Second, our study focused on HRI from outdoor environmental heat exposure. Even by restricting our investigation to the warm season, some patients identified with HRI may not have had this exposure. For example, 2 deaths in our study were in patients who developed HRI from being in saunas. Similarly, a publication from Maricopa County, Arizona, reported on 3 patients during the summers of 2009-2012 who died of HRI from being in excessively hot bath water.⁵³ Third, although using *ICD-9-CM* codes in HRI surveillance is helpful, these codes are designed to be used for billing purposes rather than surveillance purposes. Additionally, the choice of codes is subjective and may vary by medical provider and facility, which could introduce bias or inconsistency. Fourth, we used the identification of payer equal to workers' compensation to determine work-related and non-work-related HRI. However, others have reported that workers' compensation coverage is generally underused²⁵; as such, we may have underestimated the number of patients with work-related HRI. We attempted to minimize this underestimation by using various work-related codes for external cause of injury.

Conclusions

Our results support the use of multiple data sources, all relevant data fields (including primary and secondary diagnoses, as well as underlying and contributing cause of death), and specific *ICD* injury diagnosis and codes for external cause of injury to improve HRI surveillance sensitivity. Our findings also suggest that codes E900.1 and W92 should not be used as exclusion criteria. This study of Florida HRI data could be used to help public health practitioners in other jurisdictions improve their heat-related surveillance systems and make them aware of the components and limitations of their current systems. We recommend evaluating the impact of the recent conversion from *ICD-9-CM* to *ICD-10-CM* codes on HRI surveillance of ED visits and hospitalizations.

Acknowledgments

We thank Kristina Kintziger and Meredith Jagger for their support, technical input, and review of this manuscript and Melissa Jordan for her assistance in obtaining the data.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was funded in part by a training grant from the National Institute of Environmental Health Sciences (T32 ES007018); by the North Carolina Occupational Safety and Health and Education

and Research Center, National Institute for Occupational Safety and Health (5T42OH008673-09); and by the National Center for Environmental Health, Centers for Disease Control and Prevention (project 5UE1EH001047-03).

References

- Gubernot DM, Anderson GB, Hunting KL. The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. *Int J Biometeorol*. 2013;58(8):1779-1788.
- Kovats RS, Hajat S. Heat stress and public health: a critical review. *Annu Rev Public Health*. 2008;29:41-55.
- McGregor G, Bessemoulin P, Ebi K, Menne B, eds. *Heat Waves and Health: Guidance on Warning System Development*. Geneva, Switzerland: World Health Organization; 2015.
- Josseran L, Caillère N, Brun-Ney D, et al. Syndromic surveillance and heat wave morbidity: a pilot study based on emergency departments in France. *BMC Med Inform Decis Mak*. 2009;9:14.
- Perry AG, Korenberg MJ, Hall GG, Moore KM. Modeling and syndromic surveillance for estimating weather-induced heat-related illness. *J Environ Public Health*. 2011;2011:750236.
- Gosling SN, Lowe JA, McGregor GR, Pelling M, Malamud BD. Associations between elevated atmospheric temperature and human mortality: a critical review of the literature. *Clim Change*. 2009;92(3):299-341.
- Ye X, Wolff R, Yu W, Vaneckova P, Pan X, Tong S. Ambient temperature and morbidity: a review of epidemiological evidence. *Environ Health Perspect*. 2012;120(1):19-28.
- Basu R. High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environ Health*. 2009;8:40.
- Knowlton K, Rotkin-Ellman M, King G, et al. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. *Environ Health Perspect*. 2009;117(1):61-67.
- Yip FY, Flanders WD, Wolkin A, et al. The impact of excess heat events in Maricopa County, Arizona: 2000-2005. *Int J Biometeorol*. 2008;52(8):765-772.
- Prudhomme JC. *Memorandum: Cal/OSHA Investigations of Heat Related Illnesses 2005*. Sacramento, CA: State of California; 2006.
- Prudhomme JC. *Memorandum: Cal/OSHA Investigations of Heat Related Illnesses 2006*. Sacramento, CA: State of California; 2007.
- Basu R, Samet JM. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev*. 2002;24(2):190-202.
- Luber G, McGeehin M. Climate change and extreme heat events. *Am J Prev Med*. 2008;35(5):429-435.
- Kaiser R, Le Tertre A, Schwartz J, Gotway CA, Daley WR, Rubin CH. The effect of the 1995 heat wave in Chicago on all-cause and cause-specific mortality. *Am J Public Health*. 2007;97(suppl 1):S158-S162.
- Rey G, Jouglu E, Fouillet A, et al. The impact of major heat waves on all-cause and cause-specific mortality in France from

- 1971 to 2003. *Int Arch Occup Environ Health*. 2007;80(7):615-626.
17. Vaneckova P, Bambrick H. Cause-specific hospital admissions on hot days in Sydney, Australia. *PLoS One*. 2013;8(2):e55459.
 18. Williams S, Nitschke M, Sullivan T, et al. Heat and health in Adelaide, South Australia: assessment of heat thresholds and temperature relationships. *Sci Total Environ*. 2012;414:126-133.
 19. Centers for Disease Control and Prevention. International classification of diseases, ninth revision, clinical modification (ICD-9-CM). <https://www.cdc.gov/nchs/icd/icd9cm.htm>. Accessed February 17, 2017.
 20. Bassil KL, Cole DC, Moineddin R, et al. The relationship between temperature and ambulance response calls for heat-related illness in Toronto, Ontario, 2005. *J Epidemiol Community Health*. 2011;65(9):829-831.
 21. Hess JJ, Saha S, Lubner G. Summertime acute heat illness in US emergency departments from 2006 through 2010: analysis of a nationally representative sample [published correction appears in *Environ Health Perspect*. 2014;122(11):A293]. *Environ Health Perspect*. 2014;122(11):1209-1215.
 22. Pillai SK, Noe RS, Murphy MW, et al. Heat illness: predictors of hospital admissions among emergency department visits—Georgia, 2002-2008. *J Community Health*. 2014;39(1):90-98.
 23. Finch CF, Boufous S. The descriptive epidemiology of sports/leisure-related heat illness hospitalisations in New South Wales, Australia. *J Sci Med Sport*. 2008;11(1):48-51.
 24. Sanchez CA, Thomas KE, Malilay J, Annett JL. Nonfatal natural and environmental injuries treated in emergency departments, United States, 2001-2004. *Fam Community Health*. 2010;33(1):3-10.
 25. Harduar Morano L, Bunn TL, Lackovic M, et al. Occupational heat-related illness emergency department visits and inpatient hospitalizations in the southeast region, 2007-2011. *Am J Ind Med*. 2015;58(10):1114-1125.
 26. Wheeler K, Lane K, Walters S, Matte T. Heat illness and deaths—New York City, 2000-2011. *MMWR Morb Mortal Wkly Rep*. 2013;62(31):617-621.
 27. Fechter-Leggett ED, Vaidyanathan A, Choudhary E. Heat stress illness emergency department visits in national environmental public health tracking states, 2005-2010. *J Community Health*. 2016;41(1):57-69.
 28. Choudhary E, Vaidyanathan A. Heat stress illness hospitalizations—environmental public health tracking program, 20 states, 2001-2010. *MMWR Surveill Summ*. 2014;63(SS13):1-10.
 29. Winsberg MD, Simmons M. An analysis of the beginning, end, length, and strength of Florida's hot season. <http://climatecenter.fsu.edu/topics/specials/floridas-hot-season>. Accessed June 3, 2015.
 30. World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, 10th Revision*. Geneva, Switzerland: World Health Organization; 2011.
 31. Alamgir H, Koehoorn M, Ostry A, Tompa E, Demers P. An evaluation of hospital discharge records as a tool for serious work related injury surveillance. *Occup Environ Med*. 2006;63(4):290-296.
 32. National Center for Health Statistics. *Medical Examiners' and Coroners' Handbook on Death Registration and Fetal Death Reporting*. Hyattsville, MD: US Department of Health and Human Services; 2003. DHHS publication 2003-1110.
 33. Harduar Morano L, Watkins S, Kintziger K. A comprehensive evaluation of the burden of heat-related illness and death within the Florida population. *Int J Environ Res Public Health*. 2016;13(6):E551.
 34. Lugo-Amador NM, Rothenhaus T, Moyer P. Heat-related illness. *Emerg Med Clin North Am*. 2004;22(2):315-327.
 35. Bouchama A, Knochel JP. Heat stroke. *N Engl J Med*. 2002;346(25):1978-1988.
 36. Semenza JC, McCullough JE, Flanders WD, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago. *Am J Prev Med*. 1999;16(4):269-277.
 37. Kilbourne EM. The spectrum of illness during heat waves. *Am J Prev Med*. 1999;16(4):359-360.
 38. Annett JL, Fingerhut LA, Gallagher SS, et al. Strategies to improve external cause-of-injury coding in state-based hospital discharge and emergency department data systems: recommendations of the CDC Workgroup for Improvement of External Cause-of-Injury Coding. *MMWR Recomm Rep*. 2008;57(RR-1):1-15.
 39. Florida Department of Health. Florida Injury Surveillance Data System: state and county profiles. <http://www.floridahealth.gov/statistics-and-data/florida-injury-surveillance-system>. Accessed February 16, 2016.
 40. Miniño AM, Anderson RN, Fingerhut LA, Boudreault MA, Warner M. Deaths: injuries, 2002. *Natl Vital Stat Rep*. 2006;54(10):1-124.
 41. National Center for Injury Prevention and Control. *Recommended Actions to Improve External-Cause-of-Injury Coding in State-Based Hospital Discharge and Emergency Department Data Systems*. Atlanta, GA: Centers for Disease Control and Prevention; 2009.
 42. Fortune MK, Mustard CA, Etches JJ, Chambers AG. Work-attributed illness arising from excess heat exposure in Ontario, 2004-2010. *Can J Public Health*. 2013;104(5):e420-e426.
 43. Smargiassi A, Fournier M, Griot C, Baudouin Y, Kosatsky T. Prediction of the indoor temperatures of an urban area with an in-time regression mapping approach. *J Expo Sci Environ Epidemiol*. 2008;18(3):282-288.
 44. White-Newsome JL, Sánchez BN, Jolliet O, et al. Climate change and health: indoor heat exposure in vulnerable populations. *Environ Res*. 2012;112:20-27.
 45. Schluter PJ, Macey PM, Ford RP. The relationship between inside and outside ambient temperatures in Christchurch, New Zealand. *Paediatr Perinat Epidemiol*. 2000;14(3):275-282.
 46. Fogleman M, Fakhrzadeh L, Bernard TE. The relationship between outdoor thermal conditions and acute injury in an aluminum smelter. *Int J Ind Ergon*. 2005;35(1):47-55.

47. Donoghue AM, Bates GP. The risk of heat exhaustion at a deep underground metalliferous mine in relation to surface temperatures. *Occup Med (Lond)*. 2000;50(5):334-336.
48. Donoghue AM, Sinclair MJ, Bates GP. Heat exhaustion in a deep underground metalliferous mine. *Occup Environ Med*. 2000;57(3):165-174.
49. Wellenius GA, Burger MR, Coull BA, et al. Ambient air pollution and the risk of acute ischemic stroke. *Arch Intern Med*. 2012;172(3):229-234.
50. Watson WL, Ozanne-Smith J. Injury surveillance in Victoria, Australia: developing comprehensive injury incidence estimates. *Accid Anal Prev*. 2000;32(2):277-286.
51. Sheehy AM, Graf B, Gangireddy S, et al. Hospitalized but not admitted: characteristics of patients with "observation status" at an academic medical center. *JAMA Intern Med*. 2013; 173(21):1991-1998.
52. Centers for Disease Control and Prevention. International classification of diseases, 10th revision, clinical modification (ICD-10-CM). <https://www.cdc.gov/nchs/icd/icd10cm.htm>. Accessed February 3, 2017.
53. Bianca Salas S, Berisha V, Mohamed A, Goodin K. Heat-associated death surveillance: what's all the heat about? Comparison of methodologies. Paper presented at: Council of State and Territorial Epidemiologists Annual Conference; June 2014; Nashville, TN.