

Distinctive injury deaths: the role of environment, policy and measurement across states

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ABSTRACT

Background Maps identifying the most distinctive feature of each state have become popular on social media, but may also have important public health applications. A map identifying the most distinctive injury death in each state could be a useful tool for policymakers, enabling them to identify potential gaps in prevention efforts.

Objective To identify the most distinctive cause of injury death in each state and explore potential reasons for the geographical variation.

Methods The Centers for Disease Control Web-based Injury Statistics Query and Reporting System was used to identify the injury death for each state with a rate which was the largest multiple of the national rate. Analyses were conducted with and without inclusion of 'indefinite' codes, which include injury causes of death of undetermined intent, unspecified person killed in a motor vehicle crash (MVC; vehicle occupant, cyclist, pedestrian, etc) or unspecified injury.

Results Noteworthy patterns included seven states in Appalachia and the Southeast with high relative rates of unintentional firearm deaths (2.14–4.06 times the national average) and five states on the West Coast with high relative rates of legal intervention deaths (1.76–3.49 times the national average). Sensitivity analyses indicated that use of 'undetermined intent' classifications and the level of detail in coding MVCs vary substantially by state.

Conclusions These analyses highlight potential areas for prevention, such as promotion of safe storage laws in states with relatively high rates of unintentional firearm deaths and areas where standardisation of cause of death codes could be improved.

INTRODUCTION

Maps have become an increasingly popular medium to convey patterns and trends. Social media, in particular, has embraced this mode of communication. One common type of map shows the most 'distinctive' characteristic of each state. For example, the most distinctive band,¹ cuisine,² or job.³ These maps do not show the most popular item in each state, but rather which items are disproportionately popular—that is, the largest multiple of the national average. Recently, researchers have applied this methodology to public health. Using International Classification of Disease, V.10 (ICD-10) cause of death codes from the Centers for Disease Control and Prevention (CDC) WONDER (Wide-ranging Online Data for Epidemiologic Research) database, Boscoe and Pradhan⁴ analysed the most distinctive cause of death in each state.

A cause of death may be the most distinctive in a state for several reasons. First, and perhaps most intuitively, the most distinctive cause of death may be related to some aspect of the physical environment. For example, one might expect that states with access to large bodies of water would have more deaths from drowning. Second, the most distinctive cause of death may be related to a certain set of policies or cultural attitudes. For example, states may have different policies for, or cultural attitudes towards, impaired driving or firearms, which may in turn lead to geographical variation in these types of deaths. Finally, there is geographical variation in the way in which deaths are classified. Although a standard set of codes are used, there is a substantial grey area in determining cause of death. Boscoe and Pradhan⁴ noted that this is particularly true of codes that start with the word 'other,' indicating that states vary greatly in the level of detail included in their coding.

The primary goal of this analysis is similar to that of Boscoe and Pradhan: to determine the most distinctive cause of death in each state. However, this analysis will focus on injury deaths and use more recent data (2004–2013). A secondary goal is to take preliminary steps to explore the relative contributions of differences in geography and the physical environment, policy and culture and measurement to the distinctiveness of injuries.

METHODS

Data and injury categories

All data for this analysis were obtained from the CDC Web-based Injury Statistics Query and Reporting System (WISQARS).⁵ These data are publicly available at the state and national levels. Ten years of data (2004–2013) were included for all 50 states and the District of Columbia. Cause of death is based on ICD-10 codes recorded on death certificates. All possible, mutually exclusive injury categories were examined, with the exception of the two 'adverse medical events' categories, which were considered to be outside the scope of this study. Injury categories were excluded from the analysis if no state had more than 20 deaths from the injury over the 10-year period, as the associated death rates are considered unstable.⁵ This research was classified as not human subjects research by the Johns Hopkins Bloomberg School of Public Health institutional review board.

Analysis

For each state, the age-adjusted mortality rate per 100 000 population for each injury category was divided by the corresponding age-adjusted national rate. Age-adjusted rates were directly calculated and



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Table 1 Most distinctive* injury death for each state

State	Distinctive injury death (without indefinite injuries)	Rate ratio†	Distinctive injury death (with indefinite injuries)	Rate ratio†
Alaska	Other transportation, unintentional	7.61	Other transportation, unintentional	7.61
Hawaii	Fall, suicide	4.38	Non-drug poisoning	11.86
Mississippi	Struck, homicide	4.26	Struck, homicide	4.26
District of Columbia	Firearm, homicide	4.45	Firearm, homicide	4.06
Louisiana	Firearm, unintentional	4.06	Firearm, unintentional	3.93
Missouri	Drug, homicide	3.65	Drug, homicide	3.65
New Mexico	Firearm, legal intervention	3.49	Firearm, legal intervention	3.49
Montana	MVC, occupant injured, unintentional	3.42	MVC, occupant injured, unintentional	3.42
Iowa	Machinery, unintentional	3.29	Machinery, unintentional	3.29
Alabama	Firearm, unintentional	3.10	Firearm, unintentional	3.10
South Dakota	MVC, occupant injured, unintentional	3.02	MVC, occupant injured, unintentional	3.02
Wyoming	Nature, unintentional	3.01	Nature, unintentional	3.01
West Virginia	Firearm, unintentional	2.98	Fire, undetermined intent	15.03
Kansas	MVC, all, suicide	2.87	MVC, all, suicide	2.87
Delaware	Drowning, suicide	2.84	Drowning, suicide	2.84
Ohio	Non-drug poisoning, homicide	2.79	Non-drug poisoning, homicide	2.79
North Dakota	Machinery, unintentional	2.76	Machinery, unintentional	2.76
Wisconsin	MVC, all, suicide	2.65	MVC, all, suicide	2.65
Indiana	Struck, homicide	2.62	Struck, homicide	2.62
Arizona	Natural/environmental	2.59	Firearm, undetermined intent	2.86
Illinois	Drug, homicide	2.57	Drug, homicide	2.57
Arkansas	Firearm, unintentional	2.51	Non-drug poisoning	3.19
Idaho	Other transportation, unintentional	2.49	Other transportation, unintentional	2.49
Colorado	Non-drug poisoning, suicide	2.30	Non-drug poisoning, suicide	2.30
New York	Fall, suicide	2.26	Fall, undetermined intent	2.31
Nevada	Firearm, legal intervention	2.25	Firearm, legal intervention	2.25
Rhode Island	Drowning, suicide	2.21	Drug poisoning, undetermined intent	2.44
Oklahoma	Nature, unintentional	2.19	Unspecified person in a MVC	2.77
Tennessee	Firearm, unintentional	2.18	Firearm, undetermined intent	2.91
Maine	Drowning, suicide	2.18	Drowning, suicide	2.18
Kentucky	Firearm, unintentional	2.17	Unspecified person in a MVC	2.22
Maryland	Struck, homicide	2.15	Drug poisoning, undetermined intent	9.72
South Carolina	Firearm, unintentional	2.14	Unspecified person in a MVC	2.44
Vermont	Fall, unintentional	2.11	Fall, unintentional	2.11
Oregon	Firearm, legal intervention	2.06	Fall, undetermined intent	2.46
Nebraska	MVC, occupant injured, unintentional	2.01	MVC, occupant injured, unintentional	2.01
Pennsylvania	Drug, homicide	2.01	Drug, homicide	2.01
Utah	Firearm, legal intervention	1.97	Drug poisoning, undetermined intent	8.55
Florida	Bicycle/pedal vehicle, unintentional	1.96	Bicycle/pedal vehicle, unintentional	1.96
Michigan	Fire/hot object, homicide	1.88	Fire, undetermined intent	2.14
Washington	Fall, suicide	1.85	Fall, undetermined intent	2.76
North Carolina	Cut/pierce, unintentional	1.82	Cut/pierce, unintentional	1.82
Georgia	Cut/pierce, unintentional	1.79	Unspecified person in a MVC	1.79
California	Firearm, legal intervention	1.76	Firearm, legal intervention	1.76
Minnesota	Non-drug poisoning, suicide	1.66	Non-drug poisoning, suicide	1.66
New Hampshire	Non-drug poisoning, suicide	1.64	Non-drug poisoning, suicide	1.64
Texas	MVC, all, homicide	1.53	MVC, all, homicide	1.53
New Jersey	Drowning, suicide	1.42	Drowning, suicide	1.42
Massachusetts	Struck, homicide	1.41	Drowning, undetermined intent	2.37
Connecticut	Suffocation, unintentional	1.30	Suffocation, unintentional	1.30
Virginia	Cut/pierce, unintentional	1.30	Unspecified injury	1.41

*Defined as the injury death for which the state death rate is the largest multiple of the national death rate.

†State injury rate/national injury rate for given injury.

MVC, motor vehicle crash.

standardised to the 2000 total US population. All ages, races and ethnicities were included in state and national rates. We used similar methodology to Boscoe and Pradhan,⁴ to identify

the injury category that was the largest multiple of the national rate and had at least 20 deaths over the study period. The most distinctive cause of injury death for each state was then mapped

using ArcGIS software.⁶ States may differ in their classification of 'indefinite' injuries, defined here as any injury cause of death of undetermined intent, unspecified person killed in a motor vehicle crash (MVC; vehicle occupant, cyclist, pedestrian, etc) or unspecified injury. These codes are described in detail in online supplementary table S1. Analyses were performed with and without indefinite injuries to test the sensitivity of the results to their inclusion. The top four leading causes of injury death in the USA were calculated and compared with the most frequently occurring, most distinctive causes of death.

Coding variability

One of the greatest concerns about using cause of death data from death certificates is that the cause of death is not consistently coded by location. The role and qualifications of those who determine and record cause of death differ by state. Depending on the state, either a medical examiner or coroner will determine the cause of death.⁷ Coroners and medical examiners may be appointed or elected, depending on the state and have different training requirements.⁷ Medical examiners typically have more extensive scientific training and are more likely to classify deaths as suicides as compared with coroners.⁸ Research also indicates that states do not consistently use 'undetermined intent' ICD-10 codes, particularly for poisonings.⁹ There may also be variability in use of the unspecified person category in motor vehicle accidents with some states being much less likely to indicate whether the person who died in a MVC was a vehicle occupant, pedestrian, cyclist, etc. Thus, some injury death rates may be distinctive, at least in part, due to differences in classification rather than a real difference in rates of injury death. While we are not able to make this distinction on a case by case basis, we have developed two measures to provide a sense of the relative contribution of potential misclassification to the results. The first measure, called the Suicide Classification Ratio (SCR), is calculated using the following formula:

$$SCR_{ij} = \frac{(\text{State}_i \text{ Rate for Injury}_{ij}, \text{Suicide}) / (\text{State}_i \text{ Rate for Injury}_{ij}, \text{Undetermined Intent})}{(\text{National Rate for Injury}_{ij}, \text{Suicide}) / (\text{National Rate for Injury}_{ij}, \text{Undetermined Intent})}$$

A SCR close to one indicates that the state tends to classify injuries as suicide compared with undetermined intents at approximately the same rate as nationally. A SCR that is substantially greater than one indicates that the state is much more likely to classify the injury as a suicide than expected based on national data. A SCR substantially less than one would indicate that the state is less likely to classify the injury as a suicide than expected based on national data and that the state's injury is distinctive despite potential measurement bias in the opposite direction. Similarly, a Motor Vehicle Classification Ratio (MVCR) was calculated using the formula:

$$MVCR_{ij} = \frac{(\text{State}_i \text{ Rate for Motor Vehicle Injury}_{ij}) / (\text{State}_i \text{ Rate for all Motor Vehicle Injuries})}{(\text{National Rate for Motor Vehicle Injury}_{ij}) / (\text{National Rate for all Motor Vehicle Injuries})}$$

Deaths involving a MVC allow for detailed codes specifying whether the injured person was a vehicle occupant, pedestrian,

cyclist, etc, and whether the intent was unintentional, homicide or suicide, but these specifications are often not given. Thus, for states with a specific category of MVCs as the most distinctive cause of injury death, the MVCR indicates whether use of that code category is higher or lower than expected based on national data. SCR and MVCR are calculated for all states with suicides or MVC categories as their most distinctive cause of injury death.

RESULTS

Injury categories

Thirty-four injury categories met inclusion criteria. The final set of code groupings and descriptions of injuries used for this analysis are provided in online supplementary table S1, together with the additional unspecified injury categories.

Most distinctive injuries

The most distinctive injury deaths for each state are provided in table 1 and mapped in figure 1. The most distinctive cause of injury death with the greatest rate ratio (state injury rate/national injury rate for a given injury) was 'other transportation death, unintentional' in Alaska with those injuries occurring at 7.61 times the national rate. No state's most distinctive cause of injury death was less than the national rate, but Virginia had the smallest rate ratio with 'cut/pierce, unintentional' injury deaths occurring at 1.30 times the national rate. A few geographical patterns are noted. Most strikingly, the seven states for which 'firearm, unintentional' is the most distinctive are clustered in Appalachia and the Southeast (West Virginia, Kentucky, South Carolina, Louisiana, Arkansas, Alabama, Tennessee). The five states for which 'firearm, legal intervention' is the most distinctive are all in the western part of the country and three states on the Southeast Coast had 'cut/pierce, unintentional' as their most distinctive injury death. Rural, Western and Midwestern states tended to have higher rates of motor vehicle, machinery and natural/environmental deaths.

Most frequent distinctive and overall injury deaths

The most frequent injuries, overall (ie, the injuries with the highest national rates) are presented in table 2. The highest rate of injury deaths based on the categorisation system outlined in online supplementary table S1 is for 'drug poisoning, unintentional' at 9.02 deaths per 100 000 people. However, it is important to note that motor vehicle deaths have been subdivided into several categories for this analysis and that the overall rate of all motor vehicle death, regardless of who was killed or intent, is 12.92 deaths per 100 000 people. The injuries that occur most frequently in table 1 (ie, the most frequent most distinctive injuries) are also presented in table 2. A more detailed comparison of the most frequent and distinctive injuries by state is provided in online supplementary table S2. These injuries occur at a much lower rate and have greater variability than the four most frequently occurring injuries, overall. The most distinctive cause of injury death that occurs most frequently in table 1 and has the largest variability is 'firearm, unintentional,' which was the most distinctive injury death for seven states and has an IQR of 0.12–0.38 deaths per 100 000 people. The lowest rate, after excluding states with fewer than 20 unintentional firearm deaths, was for Massachusetts which only had 21 unintentional firearm deaths; an age-adjusted rate of 0.03 deaths per 100 000 people. In contrast, Louisiana had 364 unintentional firearm deaths over the same time period; an age-adjusted rate of 0.8 deaths per 100 000 people. In other words,

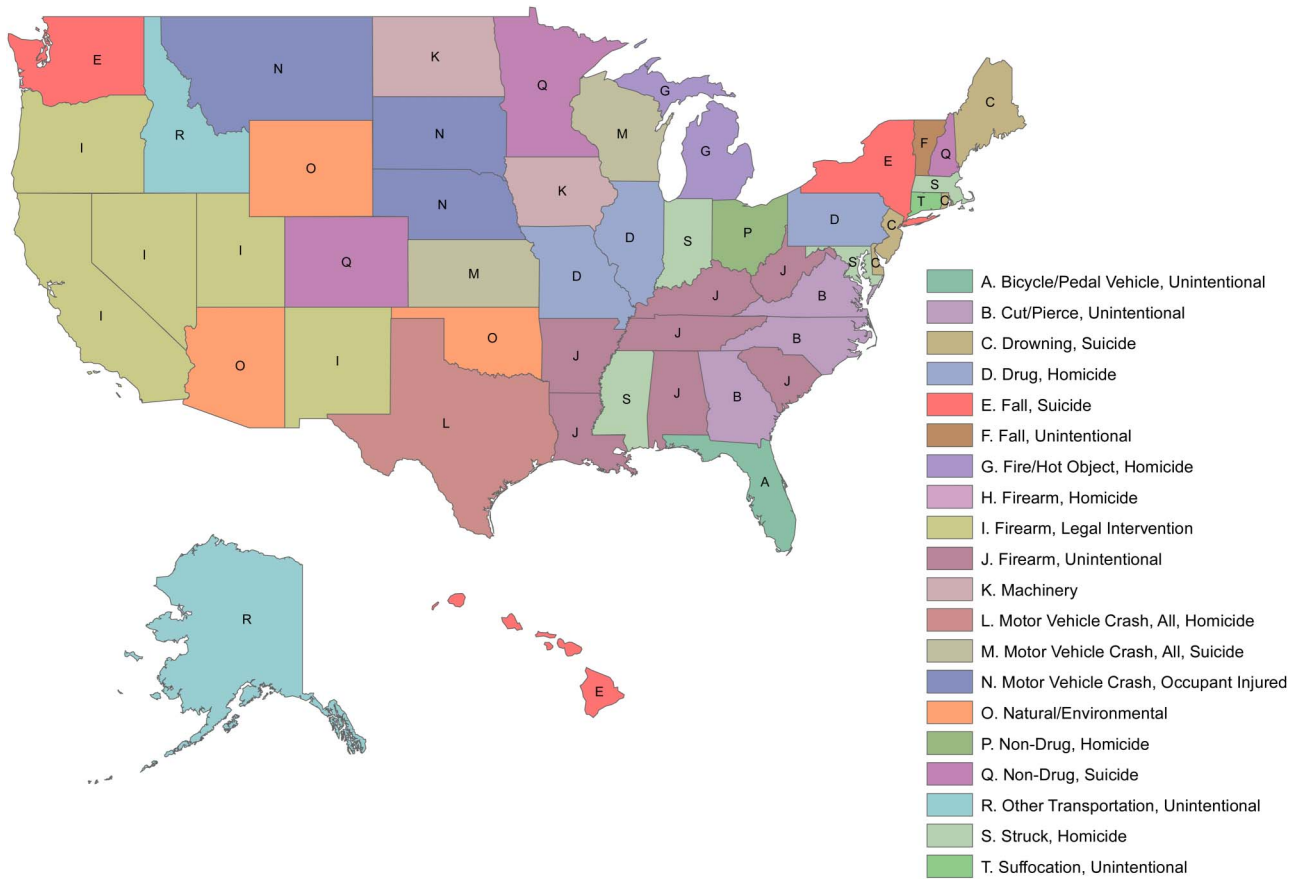


Figure 1 The most distinctive* injury death in each state. *Defined as the injury death for which the state death rate is the largest multiple of the national death rate.

Louisiana had 27 times the rate of unintentional firearm deaths as Massachusetts (data not shown).

Classification of injury intent and MVCs

After adding the indefinite injury categories, the most distinctive injury changed for 18 of the 50 states. These changes are noted in table 1. Interestingly, the only state where ‘unspecified injuries’ was the most distinctive injury death, was Virginia. As shown in table 1, Virginia also had the lowest rate ratio for its most distinctive injury at 1.30. This may indicate that Virginia’s apparently low injury rates relative to the national average are in part due to lack of specificity in

reporting. In general, the maximum ratios after including the indefinite injury categories were less than twice the maximum ratio not including indefinite injuries, with the exceptions being Hawaii (4.4 for fall suicide vs 11.9 for non-drug poisoning, undetermined intent), Maryland (2.2 for struck, homicide vs 9.7 for drug overdose, undetermined intent), Utah (1.97 for firearm, legal intervention vs 8.55 for drug poisoning, undetermined intent) and West Virginia (3.0 for firearm, unintentional vs 15.0 for fire, undetermined intent). This indicates that, in these four states, certain deaths may be classified as being of undetermined intent far more frequently than in other states.

Table 2 Most frequent distinctive* and overall injury deaths

Most frequent overall injury deaths			Most frequent distinctive* injury deaths			
Injury	National rate†	IQR of national rate	Injury	No of states where most distinctive*	National rate‡	IQR of national rate
Drug poisoning, unintentional	9.02	7.6–11.5	Firearm, unintentional	7	0.198	0.12–0.38
Firearm, suicide	8.88	5.4–9.0	Firearm, legal intervention	5	0.124	0.08–0.19
Fall, unintentional	7.49	6.1–10.0	Drowning, suicide	4	0.124	0.08–0.16
Motor vehicle, occupant injured, unintentional	5.79	2.8–7.7	Struck by/against, homicide	4	0.049	0.03–0.07

*Defined as the injury death for which the state death rate is the largest multiple of the national death rate.

†Deaths per 100,000 people, age-adjusted.

‡Deaths per 100,000 people, age-adjusted.

Table 3 Suicide classification ratios

State	Distinctive* injury death	Suicide classification ratio†
Hawaii	Fall, suicide	0.41
Delaware	Drowning, suicide	N/A‡
Colorado	Non-drug poisoning, suicide	0.11
New York	Fall, suicide	0.92
Rhode Island	Drowning, suicide	1.68
Maine	Drowning, suicide	1.56
Washington	Fall, suicide	0.62
Minnesota	Non-drug poisoning, suicide	0.09
New Hampshire	Non-drug poisoning, suicide	0.17
New Jersey	Drowning, suicide	1.41

*Defined as the injury death for which the state death rate is the largest multiple of the national death rate.

†(state suicide rate for injury/state undetermined intent rate for given injury)/(national suicide rate for injury/national undetermined intent rate for given injury).

‡Fewer than 20 drowning deaths of undetermined intent.

The SCR and MVCR are presented in tables 3 and 4, respectively. For both falls and non-drug suicides, the ratios are substantially lower than one. This indicates that these causes of death are not the most distinctive because states are more likely to classify deaths as suicides. It seems that these states may be overcoming a measurement bias in the opposite direction. By contrast, states with drowning suicide as the most distinctive cause of death may be more likely to classify drowning deaths as suicides than as undetermined intent. Similarly, in states where a motor vehicle cause of death is listed, those states are much more likely to have given a specific cause of death than nationally. This indicates that the high rate of certain types of motor vehicle deaths relative to the national average may be due, at least in part, to the lower use of unspecified codes.

DISCUSSION

This study provides insight into the most distinctive causes of injury death for each state and the District of Columbia. An important finding from this study is that unintentional firearm deaths were the most distinctive for seven states: Alabama, Arkansas, Kentucky, Louisiana, South Carolina, Tennessee and West Virginia. These states are clustered in Appalachia and the Southeast where owning firearms may be more of a social norm. Furthermore, all these states lack safe storage laws, also referred to as child access prevention laws. Only 18 states have laws that require guns to be stored in a safe manner; laws that require

Table 4 Motor vehicle classification ratios

State	Distinctive* injury death	Motor vehicle classification ratio†
Montana	MVC, occupant injured, unintentional	1.88
South Dakota	MVC, occupant injured, unintentional	2.09
Kansas	MVC, all, suicide	2.57
Wisconsin	MVC, all, suicide	3.06
Nebraska	MVC, occupant injured, unintentional	1.89
Texas	MVC, all, homicide	1.91

*Defined as the injury death for which the state death rate is the largest multiple of the national death rate.

†(state rate for given injury/state rate for all motor vehicles)/(national rate for given injury/national rate for all motor vehicles).

MVC, motor vehicle crash.

storing a gun locked, unloaded and separate from ammunition have been associated with protective effects against unintentional firearm discharge resulting in a fatality and firearm suicide among youth.¹⁰

As these data are aggregated across each state's population, it is unknown which age groups are represented in these unintentional firearm deaths across the study period. However, of the 505 unintentional firearm deaths that occurred nationally in 2013, nearly 25% of victims were aged ≤ 19 years.¹¹ A 2005 study of gun storage practices found that only 0.3% of households with children in Massachusetts had loaded, unlocked firearms in the house, the lowest of any state, whereas the percentage for Alabama was 7%. This is consistent with our findings that unintentional firearm injury deaths were Alabama's most distinctive cause of injury at more than three times the national rate and that Massachusetts had the lowest calculated rate ratio for unintentional firearm injury deaths.¹⁰ Restricting access for unauthorised individuals through safe storage of firearms might help to reduce the large disparity of unintentional firearm deaths occurring in these states.

Legal intervention, defined as any injury sustained as a result of an encounter with any law enforcement official, serving in any capacity, whether on or off duty, including injuries to the law enforcement official, suspect and bystander, was the most distinctive injury for five states clustered in the West USA: California, Oregon, Nevada, New Mexico and Utah. However, there are a number of problems with the reporting of 'legal intervention' on death certificates and these data may not be indicative of the true level.¹² It is likely that legal intervention deaths may occur more frequently across the USA than is shown on death certificates. Deaths involving law enforcement may be coded as firearm deaths instead of legal intervention and this under-reporting may differ by state, though the reasons for these differences are not well understood.¹² Efforts are being made to collect better data by both federal agencies and non-profit organisations such as Fatal Encounters which uses crowd-sourced information to keep track of citizens killed by law enforcement,¹³ which is just one aspect of the legal intervention ICD-10 code. Of the 3112 people killed during interactions with law enforcement between 2010 and 2014 that have been captured by Fatal Encounters, nearly 32% occurred in the five states for which legal intervention was the most distinctive injury death, though these states represent just under 16% of the US population. This suggests that even though there are problems with the classification of legal intervention deaths on death certificates, these five states may still experience legal intervention deaths disproportionately more often than would be expected nationally.

Three states—Montana, South Dakota and Nebraska—had 'MVC, occupant injured, unintentional' as their most distinctive injury. Trust for America's Health (TFAH) recently released a report on the top 10 indicators for best injury prevention practices and assessed compliance by state. Four of these indicators—presence of primary seatbelt law, mandatory ignition interlocks for convicted drunk drivers, required booster seats and night-time driving restrictions for teens—were related to motor vehicle safety. While states had an average of two of these indicators, Montana had none and South Dakota and Nebraska have only one each.¹⁴

Similarly, natural/environmental, motor vehicle and machinery deaths were often the most distinctive deaths in rural, mid-western and western states. This is probably related to the characteristics of these states such as larger wilderness area, rural areas which require more driving time, and increased

occupational injury risks from agricultural machinery.¹⁵ Alaska, which had the highest rate ratio of any state, had ‘other transportation, unintentional’ as its most distinctive injury. This category includes fatal injuries involving animal-drawn vehicles, trains and streetcars which, while not very common in Alaska, happen at a much higher rate there than nationally. Although it may not be possible to change these underlying geographical characteristics, the most distinctive injuries in these states could help inform behavioural interventions targeted at those most at risk.

This study has several limitations. First, ICD-10 cause of death codes may be used inconsistently by states, particularly in their use of unspecified injury and unspecified intent codes. Although we conducted analyses to explore the extent of differences in classification, these analyses cannot show for individual cases whether a death was misclassified. Second, while this analysis highlights injuries with a disproportionately high burden in some states, it does not provide any sense of the magnitude of the burden in that state. An injury may have a very high rate ratio, but only a small number of total deaths. A high rate ratio could highlight areas where prevention efforts are relatively lacking, but the magnitude of the burden of injury may be too small to devote resources to that area. Third, for some types of injuries, WISQARS does not differentiate between meaningful subcategories. For example, given the recent attention to prescription drug overdose deaths, it would be useful to distinguish deaths from legal and illegal drugs. However, both these categories fall under the ‘unintentional drug poisoning’ code. Finally, states with fewer than 20 deaths from a cause over the 10-year period were not included because results based on fewer than 20 deaths are considered unstable, but some important information might have been missed through these exclusions. For example, a small number of deaths in a state with a low population could still have a very high rate ratio, which would not be included in the analysis.

What is already known on this subject

- ▶ Maps identifying the most distinctive feature of each state are a popular way to convey information and may also have important public health applications.
- ▶ Previous work identifying the most typical cause of death in each state highlights potential geographical variation.

What this study adds

- ▶ This study identifies the most distinctive cause of death from injury in each US state using recent data.
- ▶ This study goes further than previous analyses to explore the relative contributions of differences in geography and the physical environment, differences in policy and culture and differences in measurement, to the geographical variation in states’ most distinctive deaths from injury.

This study is the first to our knowledge that applies the ‘most distinctive’ map methodology to injury epidemiology and prevention. Mapping the results allowed us to identify clusters of most distinctive injury deaths. Moreover, this study goes further in examining the reasons for the most distinctive designations than has been done previously. We used data over a 10-year period, which avoided classifying a cause of injury death as most distinctive that could be the result of a 1-year spike rather than a trend. These findings can help policymakers and public health practitioners identify injuries that, while not necessarily the most burdensome, warrant attention as the most distinctive injury death in their states. In states where injuries are distinctive due to differences in policy or culture, the results could also be a useful tool for advocates who could assert, “Not only is this injury a problem, it is a problem that we as a state are distinctively bad at addressing.”

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Contributors SEH conceived the study; SEH and CKC developed the analysis plan; SEH analysed the data; SEH and CKC carried out the literature review, drafted the manuscript and provided critical revisions to the manuscript.

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Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The original data for the study are publicly available. Intermediary datasets are available from the corresponding author upon request.

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INJURY PREVENTION

State clustering of fatal unintentional firearm injuries and those involving police officers

Distinctive geographical patterns linked to differences in measurement, environment, and policy

Unintentional fatal firearm injuries and those involving a police officer currently cluster in distinct geographical areas of the USA, reveals research published in the journal ***Injury Prevention***.

In states where injuries are disproportionately common due to differences in policy or culture, a map identifying the most distinctive injury death in each state could help policymakers and advocates to push for change, say the researchers.

In an effort to find out the most distinctive cause of injury death in each state, the researchers mined data from the Centers for Disease Control and Prevention, focusing in particular on rates that were higher than the national average.

The data were further analysed to find out whether differences in measurement might account for any distinctive patterns.

Two particularly striking geographical patterns emerged. A cluster of seven states in Appalachia and the Southeast had high relative rates of unintentional firearm deaths—around two to four times the national average.

These states were Alabama, Arkansas, Kentucky, Louisiana, South Carolina, Tennessee and West Virginia. None of them is among the 18 states that has legislation on the safe storage of firearms, also referred to as child access prevention laws, the researchers point out.

And five states on the West coast had high relative rates of 'legal intervention' deaths—whereby a suspect or bystander is killed by a police officer or when a police officer is killed in the line of duty—of around two to three-and-a-half times the national average.

These states were California, Oregon, Nevada, New Mexico and Utah.

Legal intervention deaths are not always accurately recorded and classified, say the researchers. But data from Fatal Encounters, an organization that tracks citizens killed by law enforcement, shows that between 2010 and 2014, almost a third of these deaths occurred in the five states even though these states make up just 16% of the population.

This suggests that these states may still have disproportionately high rates of legal intervention deaths, say the researchers.

Elsewhere, rural, Western, and Midwestern states tended to have higher rates of vehicle, machinery and natural/environmental injury deaths, which are probably related to the larger areas of wilderness and agricultural land in these states, suggest the researchers.

An unintentional passenger injury sustained during a car crash was the most distinctive injury death in Montana, South Dakota, and Nebraska.

Four recognized indicators of motor vehicle safety—primary seatbelt law, mandatory ignition key locks for convicted drunk drivers, booster seats, and night time driving restrictions for teens—are completely absent in Montana while South Dakota and Nebraska only have one each. This compares with an average of two per state nationally.

Further analyses of the way in which injury deaths were coded and measured indicated that use of “undetermined intent” classifications and the level of detail used in coding motor vehicle crashes varied substantially by state.

“This study is the first to our knowledge that applies the ‘most distinctive’ map methodology to injury epidemiology and prevention,” write the researchers.

“These findings can help policymakers and public health practitioners identify injuries that, while not necessarily the most burdensome, warrant attention as the most distinctive injury death in their states,” they say.

They add: “In states where injuries are distinctive due to differences in policy or culture, the results could also be a useful tool for advocates who could assert ‘Not only is this injury a problem, it is a problem that we as a state are distinctively bad at addressing’.”

Notes for editors:

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Online Resource 1. Injury Codes and Descriptions

Categories for Main Analysis		
Category	ICD10 Codes	Description
Cut/Pierce, Unintentional	W25-W29, W45	Includes unintentional cuts from contact with sharp glass, knives, sharp tools, household machinery, or other sharp household objects.
Cut/Pierce, Suicide	X78	Intentional self-harm by a sharp object.
Cut/Pierce, Homicide	X99	Assault by a sharp object.
Drowning, Unintentional	W65-W74	Unintentional drowning in pool, bathtub, or other body of water.
Drowning, Suicide	X71	Intentional self-harm by drowning in pool, bathtub, or other body of water.
Drowning, Homicide	X92	Assault by drowning and submersion.
Fall, Unintentional	W00-W19	Includes slipping on ice or other slippery surface, tripping, falls due to non-transport collisions (colliding with a person or object), being unintentionally dropped by another person, falling from furniture (ex: bed, chair), playground equipment, a building, a bridge, a tree, a cliff, falling down stairs or a ladder, or any other fall from one level to another.
Fall, Suicide	X80	Intentional self-harm by jumping from a high place.
Fire, hot object or substance, Unintentional	X00-X19	Exposure to fire, melting of clothes, contact with hot substances (ex: hot drinks, hot food, steam, heating appliances).
Fire, hot object or substance, Suicide	X76-X77	Intentional self-harm by smoke, fire and flames, steam, or other hot objects.

Fire, hot object or substance, Homicide	X97-X98,U01.3	Assault by smoke, fire, and flames, steam, or other hot objects (includes arson). Terrorism from fire, petrol bomb, or hot objects.
Firearm, Unintentional	W32-W34	Unintentional discharge or malfunction from a gun or other firearm.
Firearm, Suicide	X72-X74	Intentional self-harm from gun or other firearm.
Firearm, Homicide	X93-X95, U01.4	Assault or terrorism from gun or other firearm.
Firearm, Legal Intervention	Y35.0	Any injury sustained as a result of an encounter with any law enforcement official, serving in any capacity at the time of the encounter, whether on-duty or off-duty. Includes: injury to law enforcement official, suspect and bystander
Machinery (Unintentional)	W24, W30-W31	Injury from contact with agriculture, construction, or other machinery.
Natural, Environmental	W42,W43,W53-W64,W92-W99,X20-X39,X51-X57	Exposure to noise, animal attacks, injury by plant contact, exposure to extreme temperatures or air pressures, lack of food, lack of water
Motor vehicle, homicide	Y03, U01.1	Assault of crashing by a motor vehicle, being run over by a motor vehicle, or other assault by a motor vehicle, destruction or intentional crashing of an aircraft.
Motor vehicle, suicide	X82	Intentional self-harm by crashing a motor vehicle.
Motor vehicle, occupant, unintentional	V30-V86	Injured occupant of a three-wheeled motor vehicle, car, truck, van, heavy transport vehicle, bus, or industrial transport vehicle in crash.
Motorcyclist, unintentional	V20-V29	Injured motorcyclist in crash.
Pedal cyclist, unintentional	V10-V11, V12-V14 (.0-.2) V15-V18, V19 (.0-.3, .8, .9)	Injured pedal cyclist in crash.

Pedestrian, unintentional	V01, V02-V04 (.0), V05, V06, V09 (.0,.1,.3,.9)	Pedestrian injured in any type of crash
Drug Poisoning, Unintentional	X40-X44	Unintentional poisoning from medical and illicit drugs.
Drug Poisoning, Homicide	X85	Homicidal poisoning by any drug.
Drug Poisoning, Suicide	X60-X64	Intentional self-poisoning by any drug.
Non-drug Poisoning, Unintentional	X45-X49	Unintentional poisoning by alcohol, gasses, pesticides, or other noxious substances.
Non-drug Poisoning, Homicide	X86-X90, U01(.6,.7)	Assault by pesticides, bioweapons or other noxious substances.
Non-drug Poisoning, Suicide	X65-X69	Intentional self-poisoning by alcohol, gasses, pesticides, or other noxious substances.
Other Transportation, Unintentional	V80 (.3-.5),V81.1 V82.1	Fatal injury involving transportation by riding an animal, an animal pulled vehicle, a train, or a streetcar.
Struck by/against, homicide	Y00, Y04	Struck with a blunt object or bodily force
Struck by/again, unintentional	W20-W22,W50-W52	Struck by a thrown or flying object, non-fire building collapse, struck against an object, unintentionally hit, struck, or crushed by another person or people.
Suffocation, unintentional	W75-W84	Accidental suffocation, hanging, strangulation, choking, prolonged exposure to a low-oxygen environment, or other threat to breathing.
Suffocation, homicide	X91	Assault by hanging, strangulation, and suffocation
Suffocation, suicide	X70	Intentional self-harm by hanging, strangulation and suffocation.
Additional Indefinite Injury Categories		
Other specified injuries	X58,Y86,X83,Y87.0,Y08,Y87.1,Y33, Y87.2,Y35.6,Y89(.0,.1), U01.8, U02	Exposure to other specified factors, sequelae from other specified injuries.
Unspecified Injuries	X59,X84,Y09,Y34,Y89.9,Y35.7,Y36.9, U01.9, U03.9	Exposure to other unspecified factors, other unspecified injuries.

Drowning, Undetermined Intent	Y21	Drowning of undetermined intent.
Drug Poisoning, Undetermined Intent	Y10-Y14	Drug poisoning of unspecified intent.
Non-drug Poisoning, Unspecified Intent	Y15-19	Non-drug poisoning of undetermined intent.
Fire/Hot Object, Undetermined Intent	Y26-Y27	Fire/hot object death of undetermined intent.
Fall, Undetermined Intent	Y30	Fall of undetermined intent.
Firearm, Undetermined Intent	Y22-Y24	Firearm of undetermined intent.
Suffocation, Undetermined Intent	Y20	Suffocation of undetermined intent.
Motor Vehicle, Unspecified	V87(.0-.8),V89.2	Motor vehicle crash with unspecified person killed (unspecified if the person killed was a vehicle occupant, pedestrian, cyclist, etc.)

State	Most Distinctive Injury (excluding indefinite categories)	Most Distinctive Injury Rate per 100,000 people (excluding indefinite categories)	Most Distinctive Injury Rate Ratio (state rate divided by national rate, excluding indefinite categories)	Most Distinctive Injury (including indefinite categories)	Most Distinctive Injury Rate per 100,000 people (including indefinite categories)	Most Distinctive Injury Rate Ratio (state rate divided by national rate, including indefinite categories)	Most Frequent Injury (excluding indefinite categories)	Most Frequent Injury Rate (excluding indefinite categories)	Most Frequent Injury (including indefinite categories)	Most Frequent Injury Rate (including indefinite categories)
Alabama	Firearm, Unintentional	0.6137	3.0971	Firearm, Unintentional	0.6137	3.0971	Drug poisoning, Unintentional	9.0228	Motor vehicle, Unspecified Passenger, Unintentional	12.4016
Alaska	Other Transportation, Unintentional	3.4636	7.60523	Other Transportation, Unintentional	3.4636	7.6052	Firearm, Suicide	14.1515	Firearm, Suicide	14.1515
Arizona	Natural/Environmental, Unintentional	1.3218	2.59115	Firearm, Undetermined Intent	0.2293	2.864	Drug poisoning, Unintentional	12.1204	Drug poisoning, Unintentional	12.1204
Arkansas	Firearm, Unintentional	0.4969	2.50756	Non-drug poisoning, Undetermined Intent	0.2044	3.1899	Firearm, Suicide	9.3502	Motor vehicle, Unspecified Passenger, Unintentional	10.984
California	Firearm, Legal Intervention	0.2186	1.75751	Firearm, Legal Intervention	0.2186	1.7575	Drug poisoning, Unintentional	8.113	Drug poisoning, Unintentional	8.113
Colorado	Non-drug poisoning, Suicide	1.0327	2.29872	Non-drug poisoning, Suicide	1.0327	2.2987	Fall, Unintentional	12.7508	Fall, Unintentional	12.7508
Connecticut	Suffocation, Unintentional	2.5174	1.30276	Suffocation, Unintentional	2.5174	1.3028	Drug poisoning, Unintentional	9.674	Drug poisoning, Unintentional	9.674
Delaware	Drown, Suicide	0.3528	2.83783	Drown, Suicide	0.3528	2.8378	Drug poisoning, Unintentional	10.3895	Drug poisoning, Unintentional	10.3895
District of Columbia	Cutting/piercing, Homicide	2.4685	3.92556	Cutting/piercing, Homicide	2.4685	3.9256	Firearm, Homicide	14.7023	Firearm, Homicide	14.7023
Florida	Bicycle/Pedal Vehicle, Unintentional	0.5492	1.96146	Bicycle/Pedal Vehicle, Unintentional	0.5492	1.9615	Drug poisoning, Unintentional	12.1254	Drug poisoning, Unintentional	12.1254

Georgia	Cutting/piercing, Unintentional	0.0634	1.79039	Motor vehicle, Unspecified Passenger, Unintentional	8.333	1.7922	Drug poisoning, Unintentional	8.3443	Drug poisoning, Unintentional	8.3443
Hawaii	Fall, Suicide	1.0867	4.37625	Non-drug poisoning, Undetermined Intent	0.76	11.8627	Fall, Unintentional	6.7103	Fall, Unintentional	6.7103
Idaho	Other Transportation, Unintentional	1.1346	2.49119	Other Transportation, Unintentional	1.1346	2.4912	Motor Vehicle, Occupant Injured, Unintentional	11.1971	Motor Vehicle, Occupant Injured, Unintentional	11.1971
Illinois	Drug poisoning, Homicide	0.0609	2.56679	Drug poisoning, Homicide	0.0609	2.5668	Drug poisoning, Unintentional	8.8175	Drug poisoning, Unintentional	8.8175
Indiana	Struck by/against, Homicide	0.1273	2.61743	Struck by/against, Homicide	0.1273	2.6174	Drug poisoning, Unintentional	9.3134	Drug poisoning, Unintentional	9.3134
Iowa	Machinery, Unintentional	0.6942	3.29095	Machinery, Unintentional	0.6942	3.2909	Fall, Unintentional	9.8684	Fall, Unintentional	9.8684
Kansas	Motor vehicle, Suicide	0.1255	2.86975	Motor vehicle, Suicide	0.1255	2.8698	Motor Vehicle, Occupant Injured, Unintentional	10.0155	Motor Vehicle, Occupant Injured, Unintentional	10.0155
Kentucky	Firearm, Unintentional	0.4299	2.16949	Motor vehicle, Unspecified Passenger, Unintentional	10.3134	2.2181	Drug poisoning, Unintentional	16.7599	Drug poisoning, Unintentional	16.7599
Louisiana	Firearm, Unintentional	0.8043	4.059	Firearm, Unintentional	0.8043	4.059	Drug poisoning, Unintentional	11.9517	Drug poisoning, Unintentional	11.9517
Maine	Drown, Suicide	0.271	2.17988	Drown, Suicide	0.271	2.1799	Drug poisoning, Unintentional	9.7094	Drug poisoning, Unintentional	9.7094
Maryland	Struck by/against, Homicide	0.1044	2.14661	Drug poisoning, Undetermined Intent	9.868	9.7218	Fall, Unintentional	7.5305	Drug poisoning, Undetermined Intent	9.868
Massachusetts	Struck by/against, Homicide	0.0686	1.4104	Drown, Undetermined Intent	0.1931	2.3671	Drug poisoning, Unintentional	10.1014	Drug poisoning, Unintentional	10.1014

Michigan	Fire, Homicide	0.0703	1.87526	Fire, Undetermined Intent	0.0819	2.1352	Drug poisoning, Unintentional	8.9037	Drug poisoning, Unintentional	8.9037
Minnesota	Non-drug poisoning, Suicide	0.7462	1.66098	Non-drug poisoning, Suicide	0.7462	1.661	Fall, Unintentional	12.4025	Fall, Unintentional	12.4025
Mississippi	Struck by/against, Homicide	0.2072	4.25988	Struck by/against, Homicide	0.2072	4.2599	Motor Vehicle, Occupant Injured, Unintentional	19.2403	Motor Vehicle, Occupant Injured, Unintentional	19.2403
Missouri	Drug poisoning, Homicide	0.0867	3.65264	Drug poisoning, Homicide	0.0867	3.6526	Drug poisoning, Unintentional	11.358	Drug poisoning, Unintentional	11.358
Montana	Motor Vehicle, Occupant Injured, Unintentional	15.4631	3.42286	Motor Vehicle, Occupant Injured, Unintentional	15.4631	3.4229	Motor Vehicle, Occupant Injured, Unintentional	15.4631	Motor Vehicle, Occupant Injured, Unintentional	15.4631
Nebraska	Motor Vehicle, Occupant Injured, Unintentional	9.1016	2.01471	Motor Vehicle, Occupant Injured, Unintentional	9.1016	2.0147	Motor Vehicle, Occupant Injured, Unintentional	9.1016	Motor Vehicle, Occupant Injured, Unintentional	9.1016
Nevada	Firearm, Legal Intervention	0.2797	2.24854	Firearm, Legal Intervention	0.2797	2.2485	Drug poisoning, Unintentional	15.7707	Drug poisoning, Unintentional	15.7707
New Hampshire	Non-drug poisoning, Suicide	0.7347	1.63532	Non-drug poisoning, Suicide	0.7347	1.6353	Fall, Unintentional	10.2109	Fall, Unintentional	10.2109
New Jersey	Drown, Suicide	0.1761	1.41675	Drown, Suicide	0.1761	1.4167	Drug poisoning, Unintentional	8.2447	Drug poisoning, Unintentional	8.2447
New Mexico	Firearm, Legal Intervention	0.4336	3.48606	Firearm, Legal Intervention	0.4336	3.4861	Drug poisoning, Unintentional	18.8072	Drug poisoning, Unintentional	18.8072
New York	Fall, Suicide	0.5608	2.25826	Fall, Undetermined Intent	0.0489	2.3102	Drug poisoning, Unintentional	6.5609	Drug poisoning, Unintentional	6.5609
North Carolina	Cutting/piercing, Unintentional	0.0645	1.82161	Cutting/piercing, Unintentional	0.0645	1.8216	Drug poisoning, Unintentional	9.9296	Drug poisoning, Unintentional	9.9296
North Dakota	Machinery, Unintentional	0.5824	2.76083	Machinery, Unintentional	0.5824	2.7608	Fall, Unintentional	8.6671	Fall, Unintentional	8.6671

Ohio	Non-drug poisoning, Homicide	0.0223	2.78801	Non-drug poisoning, Homicide	0.0223	2.788	Drug poisoning, Unintentional	12.7629	Drug poisoning, Unintentional	12.7629
Oklahoma	Natural/Environmental, Unintentional	1.1163	2.1884	Motor vehicle, Unspecified Passenger, Unintentional	12.8645	2.7668	Drug poisoning, Unintentional	14.9143	Drug poisoning, Unintentional	14.9143
Oregon	Firearm, Legal Intervention	0.2557	2.05548	Fall, Undetermined Intent	0.0522	2.4644	Fall, Unintentional	10.9074	Fall, Unintentional	10.9074
Pennsylvania	Drug poisoning, Homicide	0.0477	2.00909	Drug poisoning, Homicide	0.0477	2.0091	Drug poisoning, Unintentional	13.3216	Drug poisoning, Unintentional	13.3216
Rhode Island	Drown, Suicide	0.2743	2.20649	Drug poisoning, Undetermined Intent	2.4787	2.442	Drug poisoning, Unintentional	11.7932	Drug poisoning, Unintentional	11.7932
South Carolina	Firearm, Unintentional	0.4248	2.14388	Motor vehicle, Unspecified Passenger, Unintentional	11.3346	2.4378	Drug poisoning, Unintentional	10.4805	Motor vehicle, Unspecified Passenger, Unintentional	11.3346
South Dakota	Motor Vehicle, Occupant Injured, Unintentional	13.6466	3.02078	Motor Vehicle, Occupant Injured, Unintentional	13.6466	3.0208	Motor Vehicle, Occupant Injured, Unintentional	13.6466	Motor Vehicle, Occupant Injured, Unintentional	13.6466
Tennessee	Firearm, Unintentional	0.432	2.18015	Firearm, Undetermined Intent	0.2331	2.9115	Drug poisoning, Unintentional	12.7641	Drug poisoning, Unintentional	12.7641
Texas	Motor vehicle, Homicide	0.0224	1.52949	Motor vehicle, Homicide	0.0224	1.5295	Drug poisoning, Unintentional	7.5955	Drug poisoning, Unintentional	7.5955
Utah	Firearm, Legal Intervention	0.2448	1.96784	Drug poisoning, Undetermined Intent	8.6816	8.553	Firearm, Suicide	9.4432	Firearm, Suicide	9.4432
Vermont	Fall, Unintentional	15.8253	2.11219	Fall, Unintentional	15.8253	2.1122	Fall, Unintentional	15.8253	Fall, Unintentional	15.8253
Virginia	Cutting/piercing, Unintentional	0.046	1.2994	unspecified2, Undetermined Intent	3.682	1.4109	Fall, Unintentional	6.7546	Fall, Unintentional	6.7546
Washington	Fall, Suicide	0.4585	1.84654	Fall, Undetermined Intent	0.0585	2.764	Drug poisoning, Unintentional	10.8486	Drug poisoning, Unintentional	10.8486

West Virginia	Firearm, Unintentional	0.5902	2.97817	Fire, Undetermined Intent	0.5765	15.0271	Drug poisoning, Unintentional	20.9842	Drug poisoning, Unintentional	20.9842
Wisconsin	Motor vehicle, Suicide	0.116	2.65206	Motor vehicle, Suicide	0.116	2.6521	Fall, Unintentional	14.2111	Fall, Unintentional	14.2111
Wyoming	Natural/Environmental, Unintentional	1.5354	3.00989	Natural/Environmental, Unintentional	1.5354	3.0099	Firearm, Suicide	13.7605	Firearm, Suicide	13.7605