Spinal Injury Associated With Firearm Use

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Abstract

Objective

Injuries associated with firearms are a significant health burden. However, there is no comprehensive study of firearm spinal injuries over a large population. It was the purpose of this study to analyze the demographics of spinal firearm injuries across the entire United States for all ages using a national database.

Methods

A retrospective review of prospectively collected data using the Inter-University Consortium for Political and Social Research Firearm Injury Surveillance Study 1993-2015 (ICPSR 37276) was performed. The demographic variables of patients with spinal injuries due to firearms were analyzed with statistical analyses accounting for the weighted, stratified nature of the data, using SUDAAN 11.0.01™ software (RTI International, Research Triangle Park, North Carolina, 2013). A p-value of < 0.05 was considered statistically significant.

Results

For the years 1993 through 2015, there were an estimated 2,667,896 emergency department (ED) visits for injuries due to firearms; 10,296 of these injuries (0.4%) involved the spine. The vast majority (98.2%) were due to powder firearm gunshot wounds. Those with a spine injury were more likely to have been injured in an assault (83.7% vs. 60.2%), involved a handgun (83.5% vs. 60.2%), were male (90.8% vs. 86.4%), were admitted to the hospital (86.8% vs. 50.9%), and were seen in urban hospitals (86.7 vs. 64.6%). The average age was 28 years with very few on those < 14 years of age. Illicit drug involvement was over four times as frequent in those with a spine injury (34.7% vs. 8.0%). The cervical spine was involved in 30%, thoracic in 32%, lumbar in 32%, and sacrum in 6%. A fracture occurred in 91.8% and neurologic injury in 33%. Injuries to the thoracic spine had the highest percentage of neurologic involvement (50.4%). There was an annual percentage decrease for patients with and without spine involvement in the 1990s, followed by increases through 2015. The average percentage increase for patients with a spine injury was 10.3% per year from 1997 onwards (p < 10^{-6}), significantly greater than the 1.5% for those without spinal involvement (p = 0.0001) from 1999 onwards.

Conclusions

This nation-wide study of spinal injuries associated with firearms covering all ages can be used as baseline data for future firearm studies. A reduction in the incidence of such injuries can be guided by our findings but may be difficult due to sociopolitical barriers (e.g. socioeconomic status of the injured patients, differences in political opinion regarding gun control in the US, and geospatial patterns of firearm injury).

Introduction

Injuries associated with firearms are a significant health burden [1-3]. While firearm injuries represent only 4% of injuries seen at major trauma centers (National Trauma Databank information), deaths attributed to firearms in the population are equivalent to those from motor vehicle crashes and falls [2]. They also result in significant costs to society, both financially and in loss of human life/work [3-5]. Firearm injuries account for more than an annual $70 billion in costs [3] to the US health care system. Ranney [4] noted that in the six months after a firearm injury, patient-level health care visits and costs increased three to 20 times when compared to the six months prior. They also account for the sizeable human loss of life [5]; for those with a gunshot spinal cord injury due, the life expectancy loss for each person with quadriplegia is 17 years and with paraplegia 11.4 years. This equates to 25,647 years of life lost each year due to new spinal cord gunshot injuries.

There is some literature regarding firearm injuries to the spine, however many focus on only one anatomic area (e.g., cervical), multiple mechanisms of injury, including firearms, specific age groups, war injuries,
Results

significant. For all analyses, a p < 0.05 was considered statistically

4.8.0.1, April 2020; Statistical Research and Applications Branch, National Cancer Institute

analysis was used to analyze for percentage changes over time (Joinpoint Regression Program, Version

should be interpreted with caution; thus both n and N were reported. Analyses between groups of

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BDYPT (body part) code of 31 (upper trunk), 79 (lower trunk), and 89 (neck) and using the diagnosis codes

of fracture (57), internal organ injury (62), and nerve damage (61). Next, all the narrative comments were

searched using the FIND command in Microsoft Excel™ (Microsoft® Office 365, Microsoft Corporation,

Redmond, WA)) using the keywords: vert, sacr, cocc, thor, lumbar, cerv, axis, quad, para, as well as

each individual vertebra (ie. C1, 2, . . . , L5). A neurologic injury was considered present when the diagnosis

code was 61 (nerve damage) and/or when the search of the narrative comments was positive for paraplegia,

quadriplegia, or paralyzed/paralysis and when the diagnosis code 62 (internal organ injury) was associated

with a neurologic injury in the narrative comments. The NEISS does not report an American Spinal Injury

Association Impairment Scale or Injury Severity Score.

We also wished to analyze the prevalence of sexual assault and alcohol involvement with these events. Sexual

assault was determined by searching for the keywords of rape, sex, sexual assault, incest, sodomy,

intercourse, ejaculate, penetration, vagin, oral, and anal. Alcohol involvement was determined by searching

for the keywords alcohol, EtOH, intoxicated, drinking, drank, drunk, club, ethanol, saloon, tavern, liqueur,

booze, beer, whiskey, brandy, rum, vodka, scotch, tequila, wine, sake, champagne, cognac, and BAC (an
arbony for blood alcohol involvement).

Statistical analysis

Statistical analyses were performed with SUDAAN 11.0.01™ software (RTI International, Research Triangle

Park, North Carolina, 2013) to account for the stratified and weighted nature of the data. The estimated

number of ED-visits was calculated, along with 95% confidence intervals (CIs) of the estimate. (Throughout

the remainder of the manuscript when numbers are denoted as [x, y], these represent the 95% CIs of the

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groups). Differences between groups of categorical data were analyzed by the c2 test. Joinpoint regression

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significant.

Results

www.icpsr.umich.edu, NEISS -www.cpsc.gov/library/neiss.html).

The data for 1993 through 2015 due to firearms were downloaded from the ICPSR website. This data set

includes age/age groups, injury diagnosis, gender, race, marital status, type of firearm, the perpetrator of

injury, intent of injury (unintentional, assault, suicide, law enforcement), anatomic location of the injury,

method of transportation to the ED, disposition from the ED, the involvement of
drugs/crimes/fights/arguments in the incident, and whether or not the patient was shot. The race was
classified as White, Black, Amerindian (Hispanic and Native American), and Indo-Malay (Asian origin) [8].
This study was considered exempt by our local institutional review board.

Materials And Methods

The data for this study were obtained from the Inter-University Consortium for Political and Social Research
Firearm Injury Surveillance Study 1993-2015 (ICPSR 37276) [7] collected by the National Electronic Injury
Surveillance System (NEISS). The NEISS, a branch of the US Consumer Product Safety Commission, collects
data from a probability sample of hospitals in the United States and its territories that have at least six beds
and an emergency department (ED). The sample contains five strata: four based on size (the total number of
emergency room visits reported by the hospital and are small, medium, large, and very large) and one
consisting of children’s hospitals. The NEISS is composed of ~100 hospitals, as this number varies slightly
from year to year. Patient information is collected daily from each NEISS hospital for every patient treated
in the ED due to an injury associated with consumer products. For this particular study, the ICPSR data set
consists of any patient seeking care in the ED for any firearm-related injury, regardless of activity involved
during the injury (e.g. hunting, committing a crime, suicide, assault), and whether or not the patient
sustained a gunshot wound ( coded as GSW by NEISS) or injured in some other way (coded as NGSW by
NEISS). Examples of an NGSW are a laceration while cleaning a firearm, head trauma from being pistol-
whipped, a clavicle fracture from a rifle recoil, etc. Further details regarding the acquisition of ICPSR/NEISS
data and guidelines for use of such data can be accessed from their respective websites (ICPSR -
www.icpsr.umich.edu, NEISS -www.cpsc.gov/library/neiss.html).

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estimate). When the actual number of patients (n) is < 20, the estimated number (N) becomes unstable and
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continuous data were performed with the t-test (two groups) or analysis of variance (ANOVA) (three or more
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[https://surveillance.cancer.gov/joinpoint/]). For all analyses, a p < 0.05 was considered statistically

significant.
Analyses between patients and without a spine injury

Patients with a spine injury (Table 1) were more likely to have been injured during an assault (83.7% vs. 60.2%; p = 0.0009), involved a handgun (83.5% vs. 60.2%; p = 0.0001), male sex (90.8% vs. 86.4%; p = 0.003), admitted to the hospital (86.8% vs. 50.9%; p = 0.0006), and seen in larger hospitals (86.7 vs. 64.6%; p = 0.006). The injury was less commonly self-inflicted (9.9% vs. 25.9%; p = 0.028). Although there was no overall difference in the average age between the patients with a spinal injury compared to those without (28.1 vs. 27.8 years; p = 0.67), there was a marked difference when broken down by age groups, with very few spinal injuries in patients < 14 years of age (Figure 1). Illicit drug involvement was over four times as frequent in patients with a spine injury (34.7% vs. 8.0%; p = 0.0052), and involvement in a crime was 1.5 times as frequent (40.6% vs. 27.6%; p = 0.046) in patients with a spine injury. There were no sexual assaults in the spinal injury group.

| Spine involvement | No spine involvement |  |
|-------------------|----------------------|--|
|                  | n    | N     | L95% | U95% | %     | n    | N     | L95% | U95% | %     | p value |
| All               | 420  | 10,296| 7,205| 14,944| 0.4   | 90,720| 2,658,361| 2,653,713| 2,661,452| 99.6  |         |
| Age (years)       |      |       |      |       |       |      |       |       |       |       | 0.67    |
| Mean [95% CI]     | 28.1 | [26.6, 29.5] | 27.8 | [27.1, 28.4] | 99.6  |         |
| Median [interquartile] | 23.5 | [19.3, 33.2] | 23.5 | [17.7, 34.1] |         |
| Injury intent     |      |       |      |       |       |      |       |       |       |       |         |
| Unintentional     | 22   | 776   | 426  | 1,372 | 7.9   | 19,998| 790,532| 638,015| 959,658| 33.0  | 0.0009  |
| Assault           | 349  | 8,192 | 7,433| 8,742 | 83.7  | 56,317| 1,441,298| 1,259,506| 1,612,043| 60.2  |         |
| Suicide           | 18   | 580   | 318  | 1,035 | 5.9   | 3,774 | 131,815| 95,559| 180,579| 5.5   |         |
| Law enforcement   | 11   | 241   | 144  | 401   | 2.5   | 932   | 31,308| 22,992| 42,630| 1.3   |         |
| Firearm type      |      |       |      |       |       |      |       |       |       |       |         |
| Handgun           | 104  | 2,617 | 2,278| 2,839 | 83.5  | 24,781| 701,369| 587,132| 816,930| 48.3  | 0.0001  |
| Rifle             | 8    | 287   | 145  | 541   | 9.2   | 3,796 | 145,263| 110,105| 189,997| 10.0  |         |
| Shotgun           | 5    | 224   | 60   | 732   | 7.1   | 3,256 | 131,436| 112,865| 152,666| 9.0   |         |
| BB                | 1    | 6     | 1    | 47    | 0.2   | 12,680| 474,511| 391,615| 565,634| 32.7  |         |
| Hospital size     |      |       |      |       |       |      |       |       |       |       |         |
| Small             | 7    | 589   | 228  | 1,441 | 5.7   | 6,476 | 507,349| 363,664| 690,642| 19.1  | 0.0061  |
| Medium            | 15   | 690   | 257  | 1,727 | 6.7   | 7,430 | 406,425| 275,406| 584,308| 15.3  |         |
| Large             | 69   | 3,988 | 1,511| 7,198 | 38.7  | 13,608| 758,313| 404,071| 1,251,025| 28.5  |         |
| Very large        | 313  | 4,937 | 2,426| 7,553 | 48.0  | 58,525| 958,628| 643,589| 1,326,522| 36.1  |         |
| Children's        | 16   | 92    | 38   | 222   | 0.9   | 4,681 | 27,646| 18,077| 42,534| 1.0   |         |
| Sex               |      |       |      |       |       |      |       |       |       |       |         |
| Male              | 379  | 9,332 | 8,950| 9,612 | 90.8  | 78,802| 2,295,005| 2,267,481| 2,320,634| 86.4  | 0.0033  |
| Female            | 39   | 944   | 664  | 1,326 | 9.2   | 11,888| 362,615| 336,986| 390,139| 13.6  |         |
| Race              |      |       |      |       |       |      |       |       |       |       |         |
| White             | 80   | 2,830 | 2,241| 3,481 | 35.1  | 23,843| 931,455| 740,477| 1,133,254| 42.6  | 0.059   |
| Black             | 146  | 3,053 | 1,803| 4,540 | 37.9  | 38,409| 872,340| 626,255| 1,144,195| 39.9  |         |
| Amerindian        | 64   | 2,072 | 1,193| 3,287 | 25.7  | 9,368 | 363,148| 203,062| 610,719| 16.6  |         |
| Asian             | 6    | 98    | 35   | 271   | 1.2   | 866   | 21,228| 11,378| 39,606| 1.0   |         |
| Incident locale   |      |       |      |       |       |      |       |       |       |       |         |
| Home              | 68   | 1,969 | 1,510| 2,461 | 41.6  | 20,327| 732,937| 631,178| 836,432| 47.1  | 0.011   |
| Category                      | Yes | No | %  | 1000s | 10000s | 100000s | 1000000s |
|-------------------------------|-----|----|-----|-------|--------|----------|----------|
| School/recreation             | 14  | 354| 7.5 | 1,986 | 78,502 | 64,005  | 96,242   |
| Street/highway                | 53  | 1,265| 26.7| 18,310| 434,890| 316,601 | 576,828  |
| Other property                | 47  | 1,144| 24.2| 10,250| 304,040| 252,129 | 363,632  |
| Farm                          | 0   | 0   | 0   | 0     | 127    | 6,942   | 4,360    |
| Transportation to ED          |     |     |     | 0     | 11,057 | 10.4    | 0.4      |
| Emergency medical service     | 349 | 8,414| 84.4| 49,921| 1,255,959| 1,049,318| 1,458,588|
| Air                           | 27  | 808 | 8.1 | 1,917 | 58,535 | 34,462  | 98,396   |
| Private vehicle               | 13  | 521 | 5.2 | 17,930| 698,677| 545,218 | 874,630  |
| Walk-in                       | 5   | 144 | 1.4 | 8,161 | 283,043| 203,446 | 388,355  |
| Police                        | 5   | 79  | 0.8 | 2,977 | 72,219 | 35,413  | 145,217  |
| Other                         | 0   | 0   | 0   | 0     | 237    | 8,278   | 4,040    |
| Anatomic location of injury   |     |     |     | 0     | 16,399 | 3.0     | 0.3      |
| Head/neck                     | 126 | 3,015| 29.6| 25,521| 793,383| 740,891 | 847,663  |
| Upper trunk                   | 138 | 3,605| 35.4| 14,266| 381,696| 334,378 | 434,639  |
| Lower trunk                   | 148 | 3,427| 33.7| 11,123| 289,804| 257,815 | 325,003  |
| Upper extremity               | 1   | 82  | 0.8 | 14,783| 491,967| 442,972 | 545,057  |
| Lower extremity               | 4   | 44  | 0.4 | 23,075| 647,338| 615,109 | 680,735  |
| Diagnosis                     |     |     |     | 0     | 24.9   | 0.3     | 0.3      |
| Contusion/abrasion            | 0   | 0   | 0   | 0     | 142,625| 194,201 | 6.3      |
| Foreign body                  | 23  | 576 | 5.6 | 9,135 | 323,836| 248,409 | 417,875  |
| Fracture                      | 163 | 3,752| 36.4| 6,523 | 188,859| 157,624 | 225,779  |
| Laceration                    | 34  | 839 | 8.1 | 9,807 | 335,217| 263,935 | 422,348  |
| Internal organ injury         | 61  | 1,093| 10.3| 26,026| 648,574| 497,345 | 827,855  |
| Puncture                      | 54  | 2,974| 28.9| 28,777| 840,801| 671,810 | 1,029,951|
| Not stated                    | 45  | 1,062| 10.3| 26,026| 648,574| 497,345 | 827,855  |
| ED Disposition                |     |     |     | 0     | 24.6   | 0.3     | 0.3      |
| Treated and released          | 35  | 1,309| 12.8| 51,326| 1,686,619| 1,503,591| 1,855,563|
| Admit                         | 382 | 8,873| 86.8| 33,742| 813,584| 664,132 | 979,964  |
| Fatal                         | 2   | 37  | 145 | 0.4   | 4,910  | 136,289 | 115,742  |
| Marital Status                |     |     |     | 0     | 5.2    | 0.3     | 0.3      |
| Never married                 | 150 | 4,017| 74.0| 33,207| 927,325| 810,059 | 1,029,794|
| Married                       | 26  | 910 | 16.8| 7,619 | 308,953| 244,696 | 384,365  |
| Divorced/separated            | 7   | 173 | 3.2 | 1,564 | 60,117 | 44,329  | 81,156   |
| Other                         | 6   | 327 | 6.0 | 1,239 | 67,661 | 24,961  | 173,906  |
| Argument                      |     |     |     | 0     | 5.0    | 0.3     | 0.3      |
| Yes                           | 30  | 515 | 19.6| 5,440 | 165,558| 136,973 | 198,871  |
| No                            | 69  | 2,115| 80.4| 25,064| 941,741| 908,428 | 970,326  |
| Crime                         |     |     |     | 0     | 85.0   | 0.54    | 0.46     |
|                     | n   | N             | L95%   | U95% | %   | n   | N             | L95%   | U95% | %   | p value |
|---------------------|-----|---------------|--------|------|-----|-----|---------------|--------|------|-----|---------|
| **Spine involvement** |     |               |        |      |     |     |               |        |      |     |         |
| No spine involvement|     |               |        |      |     |     |               |        |      |     |         |
| All                 | 420 | 10,296        | 7,205  | 14,944 | 0.4 | 90,720 | 2,658,361 | 2,653,713 | 2,661,452 | 99.6 |         |
| **Age (years)**      |     |               |        |      |     |     |               |        |      |     |         |
| Mean [95% CI]        | 28.1 | [26.6, 29.5]  | 27.8   | [27.1, 28.4] | 0.67 |        |               |        |      |     |         |
| Median [interquartile]| 23.5 | [19.3, 33.2]  | 23.5   | [17.7, 34.1] |        |        |               |        |      |     |         |
| **Injury intent**    |     |               |        |      |     |     |               |        |      |     |         |
| Unintentional        | 22  | 776           | 426    | 1,372 | 7.9 | 19,998 | 790,532 | 638,015 | 959,568 | 33.0 | 0.0009 |
| Assault              | 349 | 8,192         | 7,433  | 8,742 | 83.7 | 56,317 | 1,441,298 | 1,259,506 | 1,612,043 | 60.2 |         |
| Suicide              | 18  | 580           | 318    | 1,035 | 5.9 | 3,774  | 131,815  | 95,559  | 180,579  | 5.5  |         |
| Law enforcement      | 11  | 241           | 401    | 2.5   | 932  | 31,308 | 22,992   | 42,630  |         | 1.3  |         |
| **Firearm type**     |     |               |        |      |     |     |               |        |      |     |         |
| Handgun              | 104 | 2,617         | 2,278  | 2,839 | 83.5 | 24,781 | 701,369  | 587,132 | 816,930  | 48.3 | 0.0001 |
| Rifle                | 8   | 287           | 145    | 541   | 9.2  | 3,796  | 145,263  | 110,105 | 189,997  | 10.0 |         |
| Shotgun              | 5   | 224           | 60     | 732   | 7.1  | 3,256  | 131,436  | 112,865 | 152,666  | 9.0  |         |
| BB                   | 1   | 6             | 1      | 47    | 0.2  | 12,680 | 474,511  | 391,615 | 565,634  | 32.7 |         |
| **Hospital size**    |     |               |        |      |     |     |               |        |      |     |         |
| Small                | 7   | 589           | 228    | 1,441 | 5.7  | 6,476  | 507,349  | 363,664 | 690,642  | 19.1 | 0.0061 |
| Medium               | 15  | 690           | 257    | 1,727 | 6.7  | 7,430  | 406,425  | 275,406 | 584,308  | 15.3 |         |
| Anatomic location of injury | Males | Females | Total | Males | Females | Total |
|----------------------------|-------|---------|-------|-------|---------|-------|
| Head/neck                  | 126   | 3,015   | 3,141 | 25,521| 793,383 | 818,904|
| Upper trunk                | 138   | 3,605   | 3,743 | 3,666,737| 381,696 | 4,048,433|
| Lower trunk                | 148   | 3,427   | 3,575 | 348,629| 289,804 | 638,433|
| Upper extremity            | 1     | 82      | 83    | 8,342 | 491,967 | 500,309|
| Lower extremity            | 4     | 44      | 48    | 4,476 | 647,338 | 651,814|

**Diagnosis**

| Diagnosis                   | Males | Females | Total | Males | Females | Total |
|-----------------------------|-------|---------|-------|-------|---------|-------|
| Contusion/abrasion          | 0     | 0       | 0     | 0     | 0       | 0     |
| Foreign body                | 23    | 576     | 599    | 9,135 | 323,836 | 333,971|
| Fracture                    | 163   | 3,752   | 3,915  | 6,523 | 188,859 | 195,382|
| Laceration                  | 34    | 839     | 873    | 9,807 | 335,217 | 345,024|
| Internal organ injury       | 61    | 1,093   | 1,154  | 112,535| 127,629 | 239,164|
| Puncture                    | 54    | 2,974   | 3,028  | 28,977| 840,801 | 869,778|
| Not stated                  | 45    | 1,062   | 1,107  | 26,026| 648,574 | 674,600|

**ED Disposition**

| Disposition | Males | Females | Total | Males | Females | Total |
|-------------|-------|---------|-------|-------|---------|-------|
| Large       | 69    | 3,988   | 4,057 | 13,608| 758,313 | 871,921|
| Very large  | 313   | 4,937   | 5,250 | 58,525| 958,628 | 1,017,153|
| Children's  | 16    | 92      | 108   | 4,681 | 27,646  | 32,327 |
| Sex         |       |         |       |       |         |       |
| Male        | 379   | 9,332   | 9,711 | 78,802| 2,295,005| 2,373,807|
| Female      | 39    | 944     | 983   | 11,888| 362,615 | 374,503|
| Race        |       |         |       |       |         |       |
| White       | 80    | 2,830   | 2,910 | 23,643| 931,455 | 955,098|
| Black       | 146   | 3,053   | 3,199 | 38,409| 872,340 | 810,749|
| Amerindian  | 64    | 2,072   | 2,136 | 9,368 | 363,148 | 372,516|
| Asian       | 6     | 98      | 104   | 866   | 21,228  | 22,094 |
| Incident locale |  |        |       |       |         |       |
| Home        | 68    | 1,969   | 2,037 | 20,327| 732,937 | 753,264|
| School/recreation | 14  | 354      | 368   | 64,005| 96,242  | 160,247|
| Street/highway | 53  | 1,265    | 1,318 | 18,310| 434,890 | 453,200|
| Other property | 47  | 1,144    | 1,291 | 304,040| 363,632 | 667,672|
| Farm        | 0     | 0       | 0     | 127   | 6,942   | 7,069  |
| Transportation to ED |     |         |       |       |         |       |
| Emergency medical service | 349 | 8,414   | 8,763 | 49,921| 1,255,969| 1,265,890|
| Air         | 27    | 808     | 835   | 1,917 | 58,535  | 60,452 |
| Private vehicle | 13  | 521      | 534   | 78,502| 64,005  | 142,507|
| Walk-in      | 5     | 144     | 149   | 8,161 | 283,043 | 291,204|
| Police       | 5     | 79      | 84    | 2,977 | 72,219  | 75,196 |
| Other        | 0     | 0       | 0     | 127   | 6,942   | 7,069  |

**Emergency Medical Services**

| Diagnosis | Males | Females | Total | Males | Females | Total |
|-----------|-------|---------|-------|-------|---------|-------|
| Contusion/abrasion | 0     | 0       | 0     | 0     | 0       | 0     |
| Foreign body | 23    | 576     | 599    | 9,135 | 323,836 | 333,971|
| Fracture | 163   | 3,752   | 3,915  | 6,523 | 188,859 | 195,382|
| Laceration | 34    | 839     | 873    | 9,807 | 335,217 | 345,024|
| Internal organ injury | 61    | 1,093   | 1,154  | 112,535| 127,629 | 239,164|
| Puncture | 54    | 2,974   | 3,028  | 28,977| 840,801 | 869,778|
| Not stated | 45    | 1,062   | 1,107  | 26,026| 648,574 | 674,600|
TABLE 1: Demographics of those with and without a spine injury and firearm use

n = actual number of ED visits, N = estimated number of ED visits, L95% = lower 95% CI, U95% = upper 95% CI

ED: emergency department
Patients with spinal injury

The anatomic location within the spine was identified in 10,197 (99.0%) of the injuries. The spinal level was 32% thoracic (3,325), 32% lumbar (3,213), 30% cervical (3,050), and 6% sacrococcygeal (609). The majority (91.8%) (9,438 - 8,863 - 9,793) of the patients sustained a fracture. There were no differences between patients with and without a fracture by any of the variables in Table 1 or by spine level. We also compared those with and without a neurologic injury. Patients without a fracture were more likely to have sustained a neurologic injury (97.9 vs. 79.1% - p = 0.0037), and there was a significant difference in neurologic injury by spine level (Figure 2). Patients with injuries to the thoracic area had the highest percentage of neurologic involvement (50.4%), followed by the lumbar spine (28.6%) and the cervical spine (24.7%).

Non-powder firearm gunshot wound injuries

Although the majority (97.0%) of patients with spinal injuries associated with firearms involved a powder firearm gunshot wound, 2.9% involved a powder firearm without a gunshot wound. There was one case involving an air-powered firearm, indicating that air-powered weapons can also result in injury. To further explore this issue, the narrative comments of the actual (not estimated) 420 spine injury cases were reviewed to obtain an idea of the types of powder firearm non-gunshot wound injuries. There were 16 actual cases involving powder firearms without a gunshot wound. Four of these were due to falls from hunting stands.
resulting in spine fractures. The others were due to various assaults resulting in various injuries such as "the patient was assaulted with the handle of a 38-caliber handgun resulting in a closed head injury and C1 fracture." Another example is "the patient was assaulted by multiple people and pistol-whipped, resulting in L2, 3, 4 fractures, and hemopneumothorax with rib fractures." The single air-powered firearm wound occurred when a 12-year-old child was shot in the posterior thoracic area by his brother with a pellet gun, with the pellet lodged in the T11 neural foramen.

Changes over time

Joinpoint regression demonstrated an annual percentage decrease for both those patients with and without spine involvement in the 1990s, followed by increases through 2015. The average percentage increase for patients with a spine injury was 10.3% per year from 1997 onwards (p < 10-6) (Figure 3), significantly greater than the 1.5% for those without spinal involvement (p = 0.0001) from 1999 onward (Figure 4).

![FIGURE 3: Joinpoint regression analyses or those with a spine injury](image)

There was an annual decrease of 24.3% from 1993 through 1997 (p = 0.016), and then an annual increase of 10.3% from 1997 through 2015 (p < 10-6).
FIGURE 4: Joinpoint analyses for those without a spine injury

There was an average annual decrease of 7.9% from 1993 to 1999 (p = 0.0002), and then an average annual increase of 1.5% from 1999 through 2015 (p = 0.0001).

Discussion

There are few studies that allow us to compare the results of our present study. A compilation of the literature regarding civilian firearm injuries to the spine finds similar findings to those in this study (Table 2). Excluding those studies of only children, the average age was similar: 28 years in this study and 25 to 27 in the others [9-12]. The vast majority of the patients were male: 91% in this study and 80% to 94% in the literature [9-13]. The anatomic location of the injury was also similar (Figure 5).
| Present Study | Turgut [9] | Rukovansjki [14] | Carillo [13]^ | de Amoreira Gepp [15]^$ | Fife [16]$ | Rhee [10] | Trahan [11] | Waters [12]$ |
|--------------|------------|------------------|--------------|--------------------------|-----------|----------|-----------|-----------|
| n*           | 10,296     | 17               | 20           | 19                       | 11        | 73       | 168       | 147       | 135       |
| GSW alone    | N          | Y                | Y            | Y                        | Y         | N        | N         | Y         | Y         |
| SCI alone    | N          | Y                | Y            | Y                        | Y         | Y        | N         | N         | Y         |
| Geographic location | All USA | Turkey | Croatia | Miami | Brazil | California | LA, Wash DC | New Orleans | California |
| Years studied | 1993-2015 | 1968-1990 | 1991-1993 | 1992-1995 | 1996-2009 | 1970-1971 | 1993-2000 | 2007-2011 | NA         |
| Age (yrs)    |            |                  |              |              |          |          |          |          |
| Average      | 28         | 25               | 17           | -            | 26        | 27       | 25        |
| Range        | <1 to 112  | 16-40            | 12 to 57     | 14-19        | 0-10      | -        | 14-66     | 17-59     |
| % Male       | 91         | 82               | 80           | 95           | -         | -        | 92        | 92        | 94        |
| Injury intent|            |                  |              |              |          |          |          |          |
| Unintentional| 8          | 6                | -            | -            | -         | -        | -         | -         |
| Assault      | 84         | 82               | 100          | -            | -         | -        | -         | -         |
| Self         | 6          | 12               | -            | -            | -         | -        | -         | -         |
| Spine level (%) |          |                  |              |              |          |          |          |          |
| Cervical     | 30         | 47               | 40           | 16           | 18        | 37       | 100       | 27        | 19        |
| Thoracic     | 32         | 18               | 40           | 21           | 73        | 48       | 0         | 36        | 52        |
| Lumbosacral  | 38         | 35               | 35           | 63           | 9         | 15       | 0         | 36        | 29        |
| Race (%)     |            |                  |              |              |          |          |          |          |
| White        | 35.1       | -                | -            | -            | -         | -        | -         | 9.0       | 4.4       |
| Black        | 37.9       | -                | -            | -            | -         | -        | -         | 84.0      | 46.7      |
| Amerindian   | 25.7       | -                | -            | -            | -         | -        | -         | 45.2      |           |
| Asian        | 1.2        | -                | -            | -            | -         | -        | -         |
| Drug involvement | 35       | -                | 37           | -            | -         | -        | -         | 39        |
| Alcohol involvement | 0       | -                | 26           | -            | -         | -        | -         | 16        |

**TABLE 2: Literature comparison of spinal injuries due to firearms**

N = no, Y = yes, GSW = gunshot injury, SCI = spinal cord injury

* the n is for only those with GSW’s in each study

^ only children

$ only those with spinal cord injuries; the others include both those with and without spinal cord injuries
FIGURE 5: Location of spine injury due to firearms: present study and those in the literature

The actual number of cases is shown in each cell.

The vast majority (86.7%) of the patients with a spine injury were seen in large or very large hospitals (Table 1). This pattern likely indicates firearm injury due to urban violence [17-21], supported by the fact that 83.7% of the patients with a spine injury were injured during an assault. Although the number of spinal firearm injuries initially decreased in the 1990s, there was an annual 10.3% increase from 1997 through 2015. This likely reflects the epidemic of increasing firearm violence [4,22-23].

Non-powder weapons can result in serious injury [24-26], especially in children and adolescents. These injuries include blindness and paralysis [25], subarachnoid hemorrhage; lung, liver, and kidney lacerations; pulmonary artery injury; and tracheal injury [24], with 50% requiring an operative procedure [26]. One case in this study involved a 12-year-old child having a pellet gun missile becoming lodged in the T11 neural foramen, which is a significant injury and required hospital admission.

A neurologic injury was most frequent when the firearm injury involved the thoracic spine. This is likely due to the fact that cervical spine injuries, especially those involving the upper cervical spine (e.g. C1–4) can easily result in immediate/rapid death. It is possible that such a patient was never taken to an ED but was rather pronounced dead at the scene and transferred to the morgue. The proportion of spinal injuries between the cervical, thoracic, and lumbar areas was very similar. This is surprising because the available anatomic height differs among the different spinal regions, with the cervical spine having a smaller height than the thoracic or lumbar spine. The reason that the cervical spine had relatively equal numbers is unknown. One hypothesis is that perhaps the perpetrator was firing towards the head, but the bullet hit the cervical spine instead.

The demographics of firearm injuries point to potential prevention strategies for such injuries. In this study, 90.8% involved males, 83.7% an assault, 83.5% a handgun, 73.2% were 15 to 34 years, with many also involving a crime (40.6%) or drug activity (34.7%). Focusing interventions on these high-risk demographic groups is one prevention approach. Handgun control has certain efficacy [27] but is presently a very politically charged issue in the United States; how gun control laws may change in the future is unknown. Also, illegal handgun use is difficult to control [28]. In Philadelphia, reclaiming blighted vacant urban land significantly reduced shootings that resulted in serious injury or death between the years 2013 to 2015 [19]. Events involving a crime or drug activity are likely codependent; reducing illicit drug activity would hopefully result in less criminal activity as well.

The limitations of this study must be acknowledged. First is the accuracy of the NEISS data. However, previous studies [29-30], including those involving firearms, have demonstrated an over 90% accuracy of NEISS data. Next, the NEISS only identifies individuals who sought care in an ED. It does not include those who might have been treated in urgent care centers, physician offices, other venues, or those who did not seek any medical care. However, any person sustaining a spinal injury due to a firearm would likely present to an ED. Thus, the data presented in this study are likely very accurate. The NEISS does not allow for analyses by the socioeconomic status of the injured patient, nor detailed geographic regions (i.e. exactly which city and where in a particular city) but does allow for analyses by hospital size, which is a proxy of rural versus urban locations. Finally, the NEISS does not give details regarding treatment and outcomes except for disposition from the ED (release, admit, death). Acknowledging these limitations, the data led to the many interesting results noted above.
Conclusions
The vast majority (98.2%) of spine injuries from firearms were due to powder firearm gunshot wounds. The average age was 28 years with very few < 14 years of age. The cervical spine was involved in 30%, thoracic in 32%, lumbar in 32%, and sacrum in 6%. A fracture occurred in 91.8% and neurologic injury in 33%. Injuries to the thoracic spine had the highest percentage of neurologic involvement (50.4%). This very large US-wide study of spinal injuries associated with firearms covering all ages can be used as baseline data for future firearm studies. The need for firearm injury research has been recently noted. A reduction in the incidence of such injuries can be guided by our findings, although it may be difficult. The relentless rise of 10.3% per year in firearm spine injuries is certainly a cause for concern.

Additional Information
Disclosures
Human subjects: Consent was obtained or waived by all participants in this study. Indiana University issued approval NA. This study uses publicly de-identified data collected by the National Electronic Injury Surveillance System. This study was considered to be exempt by our local Institutional Review Board.
Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue. Consent was obtained or waived by all participants in this study. Indiana University issued approval NA. This study uses publicly de-identified data collected by the National Electronic Injury Surveillance System. This study was considered to be exempt by our local Institutional Review Board.
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