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Demographic and Geographic Trends in Gunshot Wound-Associated Orthopedic Injuries among Children, Adolescents, and Young Adults in New York State from 2016–2020

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Abstract: Background: The purpose of this study was to investigate temporal trends in gunshot wound (GSW)-associated orthopedic injuries among children, adolescents, and young adults in New York State, and to determine the impact of the onset of the COVID-19 pandemic on the incidence of these injuries. Methods: The New York Statewide Planning and Research Cooperative System (SPARCS) inpatient database was reviewed to identify patients ≤ 21 years of age who presented to a hospital with GSW-associated injuries from January 2016 to December 2020. Patient diagnosis codes were cross-referenced with the list of the International Classification of Diseases Version 10 Clinical Modification (ICD-10-CM) codes for orthopedic injuries to determine the incidence of GSW-associated orthopedic injuries among this cohort. The number of cases was cross-referenced with New York State census population estimates to calculate incidence per million. The geographic incidence was plotted over a map of New York State with sub-division based on facility Zone Improvement Plan (ZIP) codes. Poisson regression was used to compare the injury incidence in 2020 (pandemic onset) versus the preceding years (pre-pandemic). Results: Between 2016 and 2020, there were 548 inpatient admissions for GSW-associated orthopedic injuries, representing an incidence of 5.6 cases per million. Injury incidence decreased from 2016 to 2019, with an increase in 2020 representing almost 28% of the total cases identified. There was a statistically significant difference in the incidence rate ratio for 2020 compared to 2016–2019 ($p < 0.001$). The majority of patients were male (94%), African–American (73%), and covered by either Medicare (49%) or Managed Care (47%). Most cases were clustered around large metropolitan areas with low incidence in suburban and rural regions of the state. Conclusions: There was a two-fold increase in the incidence of GSW-associated orthopedic injuries among patients ≤ 21 years old in New York State during the onset of the COVID-19 pandemic.

Keywords: gunshot wound; COVID-19; New York State; firearm injury; fracture; pediatric; children; adolescents; young adults

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1. Introduction

Gunshot wounds (GSWs) are one of the leading preventable causes of morbidity and mortality among children, adolescents, and young adults of age 21 years or less in the United States [1–3]. In 2016, GSWs were the second leading cause of death among children and adolescents after motor vehicle accidents [4]. However, by 2019, fatalities among youth related to GSWs had surpassed those associated with motor vehicle accidents [5]. The following year, which was marked by the onset of the SARS-CoV-2 (COVID-19) pandemic in the U.S., saw patients less than 21 years old make up almost 12% of all firearm deaths [3]. In addition to the immense toll on human lives and health, GSW injuries among youth impose a significant cost burden on the U.S. healthcare system. The total cost of hospitalizations associated with pediatric GSWs from 2010–2014 has been estimated at USD 382 million, or roughly USD 28,100 per patient [6]. While GSWs are often associated with injuries to

multiple body systems, GSW-associated orthopedic injuries (e.g., fractures, dislocations, tendinous and ligamentous injuries) are particularly concerning given their debilitating impact on physical function and the potential risk of life-long disability, despite being otherwise survivable injuries [7–9]. In addition, musculoskeletal firearm injuries among youth have been associated with high rates of orthopedic complications, increased hospital length of stay and excessive healthcare costs [10]. Therefore, tracking the incidence of these injuries in the pediatric and young adult population over time is essential from a public health standpoint.

Trends in the incidence of GSW-associated orthopedic injuries among youth may vary from state to state based on the differences in socioeconomic characteristics, ease of acquiring firearms and gun control legislation. In New York State (NYS), non-fatal firearm-related injuries among patients aged 15 years and above were reported to have declined from 2005 to 2016, yet an increasing incidence was observed in 29 of 62 NYS counties (46.8%) from 2010 to 2015 [11]. This raises the question of whether there are geographic disparities that may contribute to different trends in GSW incidence among youth across the state. Furthermore, the COVID-19 pandemic in 2020 imposed new socioeconomic stressors upon the population of NYS and may have further exacerbated existing disparities in GSW-associated orthopedic injury incidence among youth [3,12]. At least one study has identified a national surge in firearm injuries among young children during the first 6 months of the pandemic [12], but it is unclear whether this same trend played out across NYS.

The aims of our study were to (1) characterize temporal trends in GSW-associated orthopedic injuries among patients aged $\leq$ 21 years old across NYS, (2) characterize geographic trends in the incidence of these injuries, and (3) determine whether the incidence of these injuries significantly changed following the outbreak of the COVID-19 pandemic.

2. Methods

2.1. Study Design and Setting

A time trend ecologic study was conducted using existing population data derived from a large database.

2.2. Ethical Approval

This study was exempted from a review by the New York University Langone Health institutional review board as only de-identified data was accessed from a large national database (reviewed on 15 March 2022).

2.3. Data Source and Patient Population

The patient sample was identified using the New York Statewide Planning and Research Cooperative System (SPARCS) inpatient database. The database, established in 1979, collects patient-level data on inpatient and outpatient stays, diagnoses, and treatments/services from all registered healthcare facilities located in NYS [13]. In 2020, the SPARCS database collected data from 427 healthcare facilities, including hospitals, diagnostic and treatment centers, and extension clinics licensed for ambulatory surgery services; nine of these facilities were Level 1 trauma centers [14,15]. It has been previously determined from SPARCS data that the mean annual incidence of non-fatal GSWs in NYS from 2005 to 2016 among patients aged 15 years and older was 18.4 per 100,000 population, with this population being predominantly male (90.6%) and non-Hispanic Black (62.0%) [11].

2.4. Inclusion and Exclusion Criteria

The SPARCS database was queried for patients that met the study inclusion and exclusion criteria. Inclusion criteria were: age $\leq$ 21 years old, presented to a hospital with GSW injuries between 1 January 2016 and 31 December 2020, and had at least one orthopedic or musculoskeletal injury associated with a GSW. GSWs were identified using International Classification of Diseases, 10th Revision (ICD-10) codes associated with firearm injuries (see Supplementary Materials, Section S1). GSWs associated with orthopedic injuries

(e.g., fractures) were identified by cross-referencing the aforementioned patient diagnosis codes against a list of ICD-10 codes for orthopedic injuries (see Supplementary Materials, Section S2). Exclusion criteria were: age > 21 years old and GSWs without any associated orthopedic or musculoskeletal injuries (ex. abdominal GSWs resulting in internal organ injuries).

2.5. Variables Measured

Demographic variables, including age, gender, race and insurance status, were obtained from the SPARCS database for each patient. The incidence of pediatric and young adult GSWs per million for each year between 2016 and 2020 was determined by dividing the total number of GSW cases by the state population in each year. Annual state population counts were obtained from the U.S. Census Bureau [16]. The geographic incidence of GSWs was measured as the total number of cases associated with each unique healthcare facility ZIP code. The geographic incidence was then plotted on a choropleth map of NYS to identify geographic variations in the volume of GSW cases. For each facility ZIP code, we defined low volume as 0–5 cases, medium volume as 6–20 cases, and high volume as >20 cases.

2.6. Statistical Analysis

All statistical analyses were performed in R version 4.3.0 (The R Foundation, Vienna, Austria). The incidence of GSW cases after the outbreak of the COVID-19 pandemic (i.e., during 2020) was compared to the incidence prior to the outbreak (i.e., during 2016–2019) using Poisson regression. Incidence rate ratios (IRRs) with 95% confidence intervals were calculated. p-values < 0.05 were considered significant.

3. Results

3.1. Demographic Characteristics

We identified 637 inpatient admissions for GSW-associated orthopedic injuries in NYS from 2016 to 2020. Demographic characteristics of this cohort are summarized in Table 1. Patient ages ranged from 0 to 21 years old, with an average of 18 $\pm$ 3 years. The majority of patients were male (583 patients; 92%), African–American (446 patients; 70.0%), and covered by either Medicaid (309 patients; 49.0%) or managed care (297 patients; 46.5%).

Table 1. Demographic information.

Variable	Mean $\pm$ SD or Count (%)
N	637
Age (years)	18 $\pm$ 3
Sex	Male: 583 (91.5%) Female: 54 (8.5%)
Race	Black: 446 (70.0%) Hispanic: 96 (15.0%) Other: 55 (8.6%) White: 37 (5.8%) Asian: 3 (0.5%)
Insurance	Medicaid: 309 (49.0%) Managed care: 297 (46.5%) Self-pay: 24 (3.8%) Other: 7 (1.1%)
Year	2016: 140 (22%), incidence 7.13 PMP 2017: 105 (16%), incidence 5.36 PMP 2018: 95 (15%), incidence 4.86 PMP 2019: 106 (17%), incidence 5.45 PMP 2020: 191 (30%), incidence 9.88 PMP

Abbreviations: SD—standard deviation, PMP—per million people.

3.2. Incidence from 2016 to 2020

The annual incidence of GSW-associated orthopedic injuries among patients ≤ 21 years old decreased between 2016 and 2019 but increased in 2020 (Figure 1). Poisson regression (Table 2) identified a statistically significant difference in the IRR of GSW-associated orthopedic injuries in 2020 compared to 2016–2019 ($p \leq 0.005$).

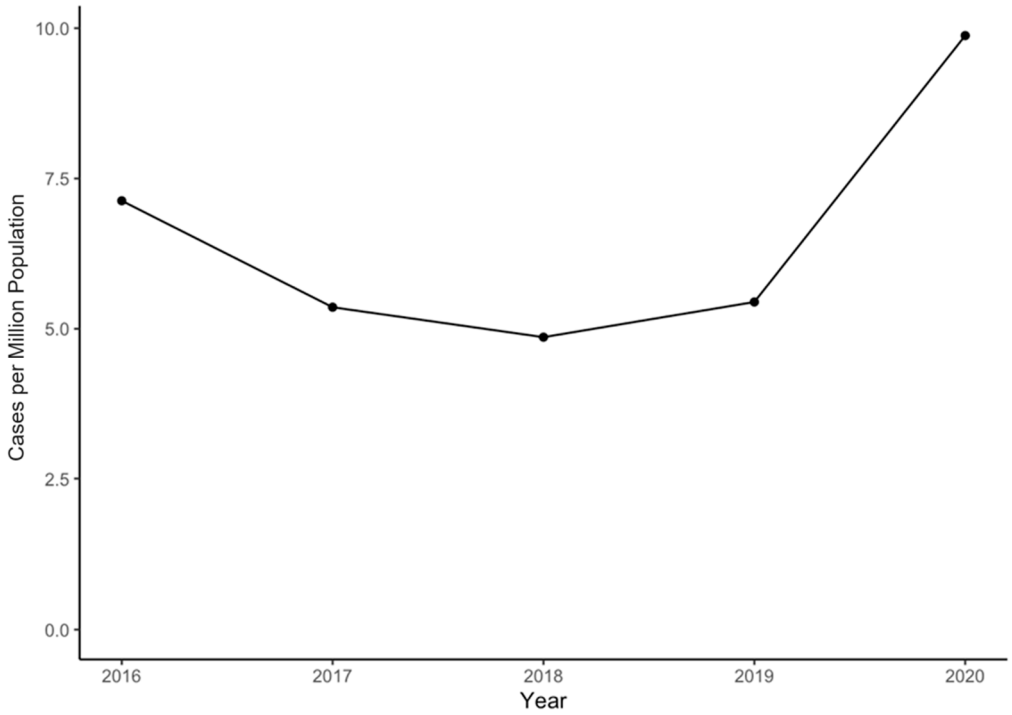


Figure 1. Incidence of gunshot-wound-associated orthopedic injuries among patients ≤ 21 years old in New York State by year from 2016 to 2020.

Table 2. Poisson regression model of the incidence of gunshot-wound-associated orthopedic injuries among patients ≤ 21 years old in 2020 compared to 2016–2019.

Year	IRR with 95% CI	Coefficient *p*-Value	Pearson Chi-Square *p*-Value
2020	—	—	<0.001
2019	0.55 [0.44, 0.70]	<0.001	
2018	0.5 [0.39, 0.63]	<0.001	
2017	0.55 [0.43, 0.70]	<0.001	
2016	0.73 [0.59, 0.91]	0.005	

Abbreviations: GSW—gunshot wound, IRR—incidence rate ratio, CI—confidence interval.

3.3. Geographic Incidence

There was considerable geographic variation in GSW-associated orthopedic injury incidence across NYS (Figure 2). Most high-volume ZIP codes were clustered around the metropolitan area of New York City, including sections of Bronx County (The Bronx), Queens County (Queens) and Kings County (Brooklyn). In contrast, a low incidence of cases was observed in most suburban and rural regions of the state (e.g., upstate New York).

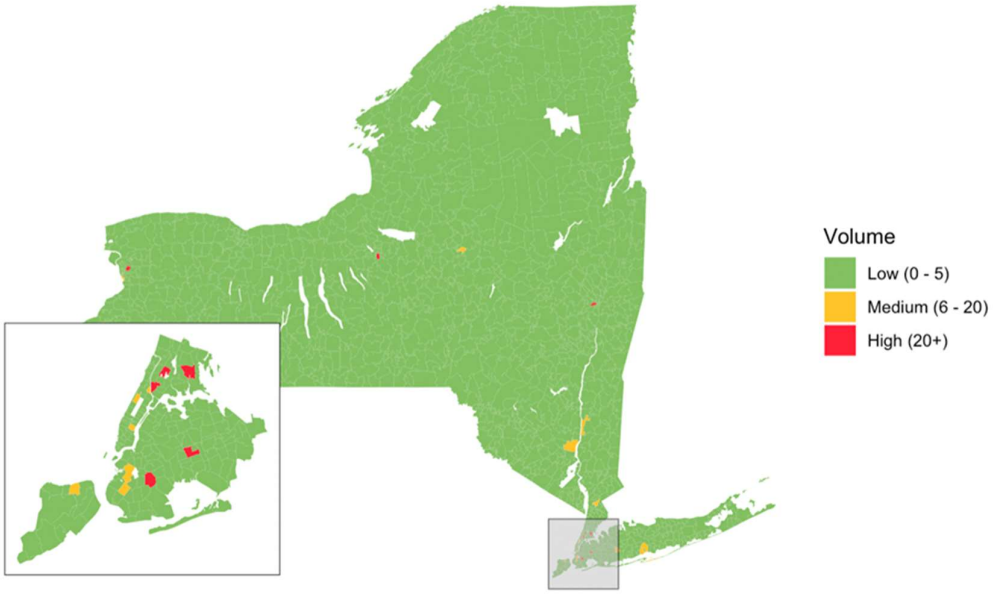


Figure 2. Geographic distribution by ZIP code of the total number of GSW-associated orthopedic injuries among patients ≤ 21 years old in New York State from 2016 to 2020.

4. Discussion

Our analysis found that the incidence of GSW-associated orthopedic injuries among patients ≤ 21 years old in NYS increased significantly in 2020 compared to the preceding four years. A disproportionate number of those injured were male and/or African–American. Healthcare facilities with the highest volumes of GSW-associated orthopedic injuries were clustered around densely populated metropolitan centers.

Firearm injuries among youth below age 21 years have been regarded as a public health crisis in the U.S., with an estimated mortality rate of 6.32 deaths per 100,000 in 2020 [3]. Even among those who suffer non-fatal injuries, GSWs are associated with devastating musculoskeletal injuries that may impact normal growth and development. GSWs frequently impact the musculoskeletal system with the extremities (48–76%), pelvis (31%) and hands (31%) among the most commonly involved sites [17]. Firearm-associated fractures are associated with 50–78% of GSWs [10,17] and may be further complicated by short- and long-term sequelae such as neurovascular injuries, non-union, deep wound infections and growth disturbances [7,18,19]. Boschert et al. found that over one-fourth of pediatric patients who survive a musculoskeletal GSW would have at least one long-term adverse outcome (e.g., functional impairment, growth disturbance) and that this risk was more pronounced in children less than 10 years of age [7]. In addition to their detrimental impact on health, firearm-associated fractures and other GSW-associated orthopedic injuries among youth impose a significant cost burden on the U.S. healthcare system. Sidhu et al. conducted a retrospective analysis of the National Inpatient Sample (NIS) database and found that median hospitalization costs for pediatric patients presenting with GSWs rose significantly from USD 10,749 in 2005 to USD 16,157 in 2017, with costs significantly higher among patients undergoing operative treatment [20]. Evans et al. conducted a single-center economic analysis of pediatric musculoskeletal firearm injuries and found that only privately insured patients produced a positive median net revenue for the hospital system [10]. As a result, the financial burden of these injuries disproportionately affects hospital systems with a predominantly public payer mix.

Though national trends suggest that GSW-related mortality has overtaken some other preventable causes of death among youth, such as motor vehicle collisions, over the past two decades [5,21], trends in incidence over this same period have varied considerably at the city and state level [22–24]. These variations may be attributable to inter-regional differences in socioeconomic factors linked to gun violence [25,26], as well as local ordinances

governing access to firearms [27–29]. Regarding socioeconomic factors, racial disparities in pediatric and young adult GSW incidence have been noted in the literature. Kalesan et al. previously reported that African–American youth were at a higher risk of firearm-related hospitalizations than their White counterparts, independent of the neighborhood economic status [25]. Intentionality of injury may also differ between racial groups. Hughes et al. noted that White pediatric patients were more likely to sustain GSWs unintentionally or due to suicidal intent, whereas Black pediatric patients were more likely to sustain GSWs due to homicidal intent [26]. While the present study did not assess racial disparities, it should be noted that most GSW patients in the cohort were either African–American or of non-White race.

The state of New York is noted to have some of the most stringent gun control laws in the U.S., with legislation such as the New York Secure Ammunition and Firearms Enforcement Act of 2013 (NY SAFE Act) mandating background checks and restricting access to assault weapons [30]. Perhaps for this reason, the overall annual incidence of hospitalization for non-fatal GSWs was noted to have declined in NYS from 2005 to 2016 [11]. Hsu et al., who conducted one of the most recent analyses of GSW incidence in NYS using the SPARCS database, noted a nine-fold higher annual incidence of non-fatal firearm-related injuries among men compared to women [11], and a similar gender disparity was observed in the present cohort. This disparity may be partially attributable to gender norms surrounding gun ownership in the U.S., with higher rates of gun possession among men and the socialization of young males in "gun culture" [31]. Hsu et al. also identified significant geographic disparities in non-fatal GSW incidence, with the highest number of cases observed in major metropolitan areas, including Rochester (Monroe County), Syracuse (Onondaga County) and the Bronx borough of New York City (Bronx County) in 2015 [11]. Likewise, the present study identified the highest volumes of GSW-associated orthopedic injuries among patients $\leq$ 21 years old to be located near high-density population centers in upstate and downstate New York. It should be noted that while similar trends were observed in both the present study and the Hsu et al. study, the latter is not inclusive of all pediatric and young adult patients, as the authors used an age cutoff of 15 years [11].

Despite the incidence of GSW-associated injuries and deaths among youth remaining stable or declining in much of NYS prior to 2020, there is strong evidence that the COVID-19 pandemic may have played a key role in driving up these rates again. Donnelly et al. noted an 87.6% increase in firearm purchases in NYS during the first month of the pandemic (February to March 2020), accompanied by a 110.1% increase in firearm-related incidents and 57.1% increase in firearm-related deaths [32]. Kim and Phillips analyzed the impact of stay-at-home orders in Buffalo, NY and noted a short-term increase in fatal shootings and long-term increase in all non-fatal shootings following the implementation of these restrictions [33]. Other studies have also identified a connection between the onset of the COVID-19 pandemic and higher rates of firearm-related injuries [34–36]. It can be surmised that new stressors and uncertainties related to the pandemic, the surge in firearm acquisition in the early months of the crisis, and the implementation of stay-at-home orders across the state gave rise to an environment in which children, adolescents, and young adults were more readily able to access firearms either intentionally or unintentionally. The role of social and structural factors in driving this "epidemic within a pandemic" is paramount and effective strategies for reducing the incidence of GSWs among youth should include firearm safety education, improved access to mental health resources and community-based violence interventions [37].

Limitations

There are several limitations of the present study's methodology. First, the authors were unable to obtain SPARCS data for 2021 and beyond, which would have allowed for additional analyses to determine whether the higher incidence of GSW-associated orthopedic injuries among youth in 2020 represented a transient spike or a sustained

increase in the incidence of these injuries. Second, the analysis is unable to account for patients who may have sustained GSWs but were not admitted to a hospital for treatment. Given the geographical disparities in access to healthcare throughout NYS, particularly in rural areas, it is likely that the study underestimates the incidence of pediatric and young adult GSWs in these areas. Third, the analysis is unable to provide a breakdown of specific orthopedic injuries, treatments offered and mortality rates as these data were not queried during the initial study period. Fourth, the study did not incorporate regional socioeconomic status measures such as the Area Deprivation Index [38,39] or the Social Vulnerability Index [40] which may have elucidated the role of socioeconomic stressors prior to and during the pandemic in driving the increase in GSW-associated orthopedic injury incidence in 2020.

5. Conclusions

There was a two-fold increase in the incidence of GSW-associated orthopedic injuries among patients $\leq$ 21 years old in New York State during the COVID-19 pandemic.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/traumacare4020015/s1, Section S1: Firearm Injury ICD-10 Codes; Section S2: Orthopedic Injury ICD-10 Codes.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and was deemed to be exempt from a review by the Institutional Review Board of New York University Langone Health (on 15 March 2022).

Informed Consent Statement: Patient consent was waived as only de-identified human subjects data was accessed from a large database for this study.

Data Availability Statement: The datasets used in this study are not publicly available, except on special request to the New York State Department of Health (https://www.health.ny.gov/statistics/sparcs/access/).

Conflicts of Interest: C.W.C. is a board/committee member for the Pediatric Orthopaedic Society of North America (POSNA) and the Pediatric Research in Sports Medicine Society (PRiSM). The remaining authors have no financial or non-financial conflicts of interest to disclose.

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