

Trends in Pediatric Firearm Injuries: 2016–2023

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abstract

BACKGROUND/OBJECTIVES: Firearm injuries (FIs) are the leading cause of death for children and adolescents in the United States. Prior studies noted increases in pediatric FI emergency department (ED) visits early in the pandemic, but long-term trends are unclear.

METHODS: We conducted a retrospective observational study using the Pediatric Health Information System including patients aged younger than 18 years with an FI-related ED visit from 2016 to 2023. Encounters were identified by *International Classification of Diseases, Tenth Revision* discharge diagnosis codes for FI. Time series analysis with segmented Poisson regression with hospital-level clustering was used to identify change points and estimate annualized trends in FI encounters (ED visits, hospitalizations, and mortality).

RESULTS: A total of 6358 pediatric FI ED visits were identified. Most patients were male (79.0%), aged 12 through 17 (69.8%), Black (60.4%), and publicly insured (76%). FI ED visits increased from an average of 44.1 per month in 2016 to 83.3 in 2023. Change points in March and June 2020 marked an early pandemic surge, with ED visits rising at an annualized rate of 496% before demonstrating no statistically significant linear change thereafter, although volumes remained higher than pre-pandemic levels. Hospitalizations and in-hospital death encounters rose in number, but the proportions remained stable (50.7%-55.5% hospitalized; 5.7%-8.1% mortality).

CONCLUSIONS: Pediatric FI ED visits rose early in the COVID-19 pandemic and have remained elevated through 2023, establishing a concerning new baseline. The stable proportions of hospitalizations and in-hospital mortality suggest that increases in absolute counts were driven primarily by rising injury incidence not accompanied by increased severity. Findings underscore the need for sustained prevention and cross-sector collaboration to reduce pediatric FI burden.



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G Pandya carried out the initial and secondary analyses, drafted the initial manuscript, and critically reviewed and revised the manuscript. P Walsh designed the data collection instruments, collected data, and critically reviewed and revised the manuscript. S Tarima coordinated and supervised data collection and analyses, and critically reviewed and revised the manuscript. K Flynn-O'Brien critically reviewed and revised the manuscript for important intellectual content. M Levas conceptualized and designed the study and critically reviewed and revised the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: Pediatric firearm injury emergency department visits increased during the early COVID-19 pandemic, but long-term national trends in visits, hospitalizations, and mortality remain poorly characterized.

WHAT THIS STUDY ADDS: This multicenter study demonstrates a sustained post-pandemic elevation in pediatric firearm injury encounters, with stable hospitalization and mortality proportions.

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INTRODUCTION

Gun violence remains a critical public health crisis for children and adolescents in the United States. Firearm injuries (FIs) surpassed motor vehicle crashes in 2019 as the leading cause of death in this age group, underscoring the urgent need for continued surveillance and prevention strategies.^{1,2} Although these injuries are shaped by multiple individual, household, and community factors, their increasing frequency highlights the need for timely, data-driven approaches to prevention.

Previous studies have documented increases in pediatric FI-related emergency department (ED) visits during the early months of the COVID-19 pandemic, but most were limited to short observation periods, single centers, or small data sets, restricting their ability to assess long-term trends.^{3–5} Few investigations have evaluated both ED visit volumes and outcomes across multiple years spanning the pre-pandemic, pandemic, and post-pandemic periods.^{4,6} This leaves a gap in understanding the sustained impact of the pandemic on pediatric FI burden and outcomes.

To address this gap, we used a large, multicenter administrative database to describe temporal trends in pediatric FI-related ED visits, hospitalizations, and in-hospital mortality from 2016 to 2023. Our objective was to identify periods of significant change and assess whether the early pandemic surge in pediatric FI encounters persisted in subsequent years.

METHODS

Study Design and Data Source

This was a retrospective observational study using data from the Pediatric Health Information System (PHIS), an administrative database of encounter-level data from approximately 50 tertiary pediatric hospitals in the United States affiliated with the Children's Hospital Association (Lenexa, KS). PHIS includes inpatient, ED, ambulatory surgery, and observation encounters, along with associated demographic, diagnostic, procedural, and resource use information. Data are deidentified at submission and undergo standardized validity and reliability checks prior to inclusion.⁷

Study Population

The study included children aged younger than 18 years with a FI-related ED visit between January 1, 2016, and December 31, 2023. Visits were classified as FI-related if any discharge diagnosis field contained the *International Classification of Diseases, Tenth Revision (ICD-10)* code for FI (Supplemental Table 1). These codes were selected based on prior epidemiological work related to pediatric FIs.^{4,8} Encounters involving non-gunpowder projectile weapons, including pellet, BB, and airsoft guns, were excluded. PHIS links encounters for individual patients over time;

only the first FI encounter per patient was included in the analysis. Only encounters that included a billing charge from the ED were included in the study population.

Outcomes and Demographics

The primary outcomes of this study were the rate and temporal trends of pediatric FI ED visits from 2016 to 2023. Temporal trends were modeled by the number of encounters per 30-day period. Secondary outcomes included rate and temporal trends of hospitalization and in-hospital mortality (including ED mortality and post-admission mortality). Demographic variables, including age, sex, race, ethnicity, insurance status, and Child Opportunity Index (COI) 2.0, were obtained to describe the study population. COI is a comprehensive metric of neighborhood resources organized into quintiles from “very low” to “very high.”⁹ Race and ethnicity were collected because of the previously described disproportionate impacts of FI on various racial and ethnic groups, and these variables were collected per individual hospital protocols and then standardized for use in PHIS. Race categories Asian, Native American, Pacific Islander, or multiple races were included in the “other” race category because of small encounter counts.

Statistical Analysis

Frequencies and proportions were used to summarize the demographic and clinical characteristics of the sample. Segmented Poisson regression models were fitted to estimate changes in encounter counts over time. Models included a continuous time variable representing global trends, indicator variables for calendar month to account for seasonality, and statistically derived change points to identify temporal inflection points. Change points were selected by comparing candidate segmented regression models and choosing the model that minimized the Akaike Information Criterion. Regression coefficients were exponentiated and expressed as relative annual percent change using the transformation $\exp(\beta \times 365) - 1$, where β represents the daily slope. In addition, to visually assess patterns of time trends, Poisson regressions with nonparametric global trends were also fitted.

Because encounters were drawn from multiple hospitals within the PHIS network, generalized estimating equations were used to account for clustering of observations within hospitals in Poisson regressions. An exchangeable working correlation structure was specified to account for within-hospital correlation over time. This approach yields population-averaged estimates while providing conservative variance estimates.

Subgroup analyses were conducted refitting the segmented Poisson models to evaluate temporal trends across race, age group, ethnicity, insurance status, and COI categories.

All analyses were performed using R version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria). This study was approved by the Medical College of Wisconsin Institutional Review Board with a waiver of informed consent.

RESULTS

Study Population and Clinical Outcomes

We identified 6358 pediatric FI ED visits from 2016 to 2023. Most patients were male (79.0%), aged 12 to 17 years (69.8%), Black (60.4%), and publicly insured (76.0%); 53.0% resided in very low COI neighborhoods (Table 1). Among encounters, 53.0% resulted in hospitalization, 15.6% required intensive care unit admission, and 6.4% resulted in death; 50.5% of deaths occurred in the ED (Table 2).

Trends in Firearm Injury ED Visits

In 2016, the average number of monthly encounters was 44.1, rising to 83.3 by the end of 2023. Segmented regression identified 2 change points, 1 in March 2020 and 1 in June 2020, which corresponded to the onset of the COVID-19 pandemic and defined 3 temporal phases: pre-pandemic growth, early pandemic surge, and post-surge stabilization (Figure 1, Supplementary Table 2). FI

encounter rates increased during the pre-pandemic period at an annual rate of 6.5% ($P < 0.001$). Between March and May 2020, encounter rates increased sharply at an annualized rate of 496.0% ($P < 0.001$). From June 2020 to December 2023, encounter rates demonstrated a modest, nonsignificant annual decline of -2.1% ($P = 0.50$).

Trends in In-Hospital Mortality

The total number of in-hospital deaths due to pediatric firearm injuries increased over the study period. In 2016, there were 43 firearm-related in-hospital deaths, compared with 59 in 2023—a 37% absolute increase. Segmented regression identified 2 change points, in March and June 2020 (Figure 2, Supplementary Table 3). In-hospital mortality counts did not significantly change during the pre-pandemic period (-4.2% annually, $P = 0.57$). A dramatic surge occurred between March and May 2020, with mortality increasing at an annualized rate of 3067.7% ($P < 0.001$). From June 2020 through 2023, mortality demonstrated a nonsignificant annual decline of -13.2% ($P = 0.11$). The proportion of ED visits resulting in hospitalization remained stable (50.7% to 55.5%, $P = 0.31$).

Trends in Hospitalizations

Hospitalizations increased from 285 in 2016 to 544 in 2021 and then declined to 507 in 2023. Hospitalization fre-

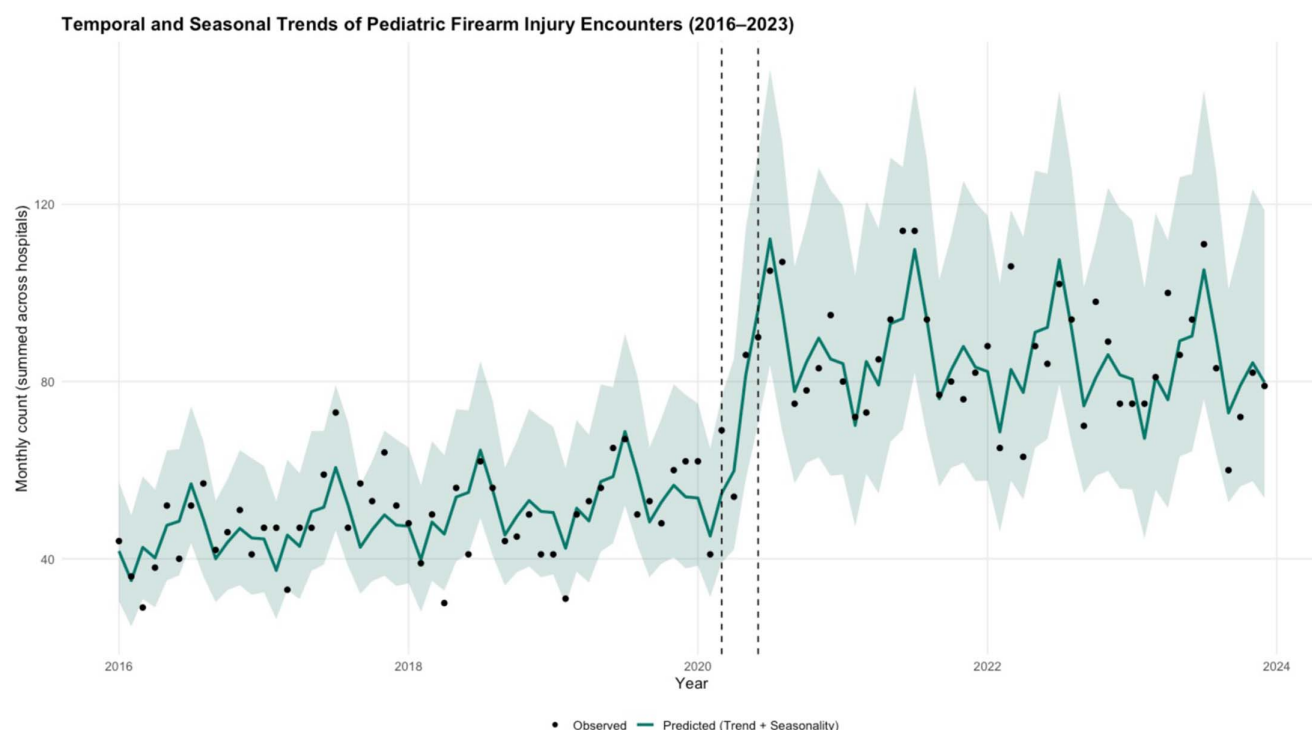


FIGURE 1. Temporal and seasonal trends in pediatric FI encounters (2016–2023). Abbreviation: FI, firearm injury.

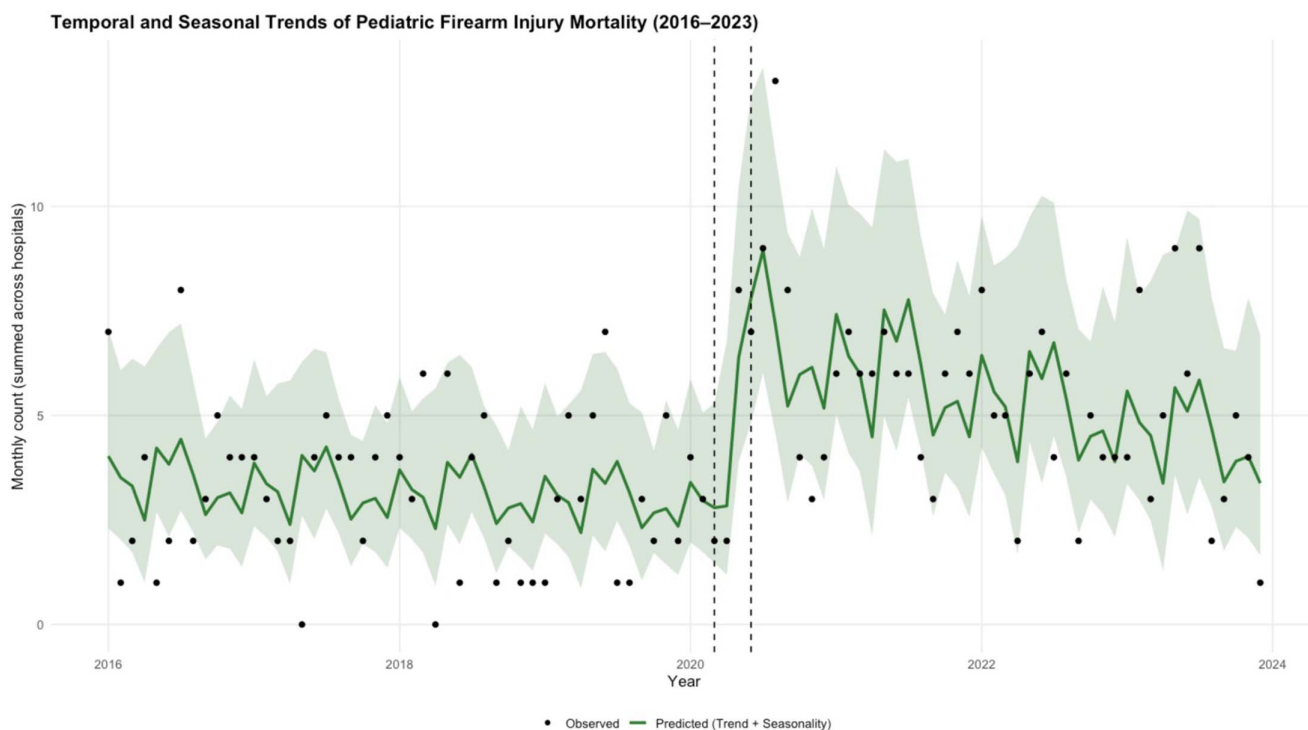


FIGURE 2. Temporal and seasonal trends in pediatric FI mortality (2016–2023). Abbreviation: FI, firearm injury.

quency increased during the pre-pandemic period (prior to March 2020) at an annual rate of 6.1% ($P = 0.008$) (Figure 3, Supplementary Table 4). Between March and May 2020, hospitalizations increased sharply at an annualized rate of 561.8% ($P < 0.001$). From June 2020 through 2023, hospitalization rates showed a nonsignificant annual decline of -5.2% ($P = 0.13$). Despite these changes in hospitalization counts, the proportion of FI ED visits resulting in hospitalization remained stable, ranging from 50.7% to 55.5% annually across the study period ($P = 0.31$).

Subgroup Analysis

Race

From January 2016 to February 2020, FI encounters increased significantly among Black children (6.8%, $P = 0.02$) and children categorized as “other” race (18.5%, $P = 0.002$) (Figure 4, Supplementary Table 5). Trends among white children were not statistically significant (1.7%, $P = 0.63$). Between March 2020 and May 2020, significant increases were observed among Black children (894.4%, $P < 0.001$) and white children (156.9%, $P = 0.01$). From June 2020 through December 2023, trends were not statistically significant among Black or white children.

Age Group

From January 2016 to February 2020, adolescents (aged 12–18 years) experienced a significant annual increase in

FI encounters (7.5%, $P < 0.001$) (Figure 5, Supplementary Table 6). Children aged 3 to 5 years also demonstrated significant growth (9.6%, $P = 0.02$), whereas trends among children aged 0 to 2 and 6 to 11 years were not statistically significant. Between March 2020 and May 2020, all age groups experienced statistically significant increases: 0 to 2 years (2628.4%, $P < 0.001$), 3 to 5 years (724.8%, $P < 0.001$), 6 to 11 years (607.5%, $P < 0.001$), and 12 to 18 years (388.9%, $P < 0.001$). From June 2020 through December 2023, significant declines were observed among children aged 0 to 2 years (-14.3% , $P = 0.04$), 3 to 5 years (-11.1% , $P = 0.03$), and 6 to 11 years (-11.9% , $P = 0.003$). Trends among adolescents were not statistically significant (2.2%, $P = 0.51$).

Ethnicity

From January 2016 to February 2020, FI encounters increased significantly among children identified as not Hispanic or Latino (7.6%, $P = 0.005$), whereas trends among Hispanic or Latino children were not statistically significant (7.7%, $P = 0.26$) (Figure 6, Supplementary Table 7). Between March 2020 and May 2020, significant increases were observed among both not Hispanic or Latino children (491.9%, $P < 0.001$) and Hispanic or Latino children (325.9%, $P = 0.002$). From June 2020 to December 2023, FI encounters continued to increase significantly among Hispanic or Latino children (11.1%,

Temporal and Seasonal Trends of Pediatric Firearm Injury Hospitalizations (2016–2023)

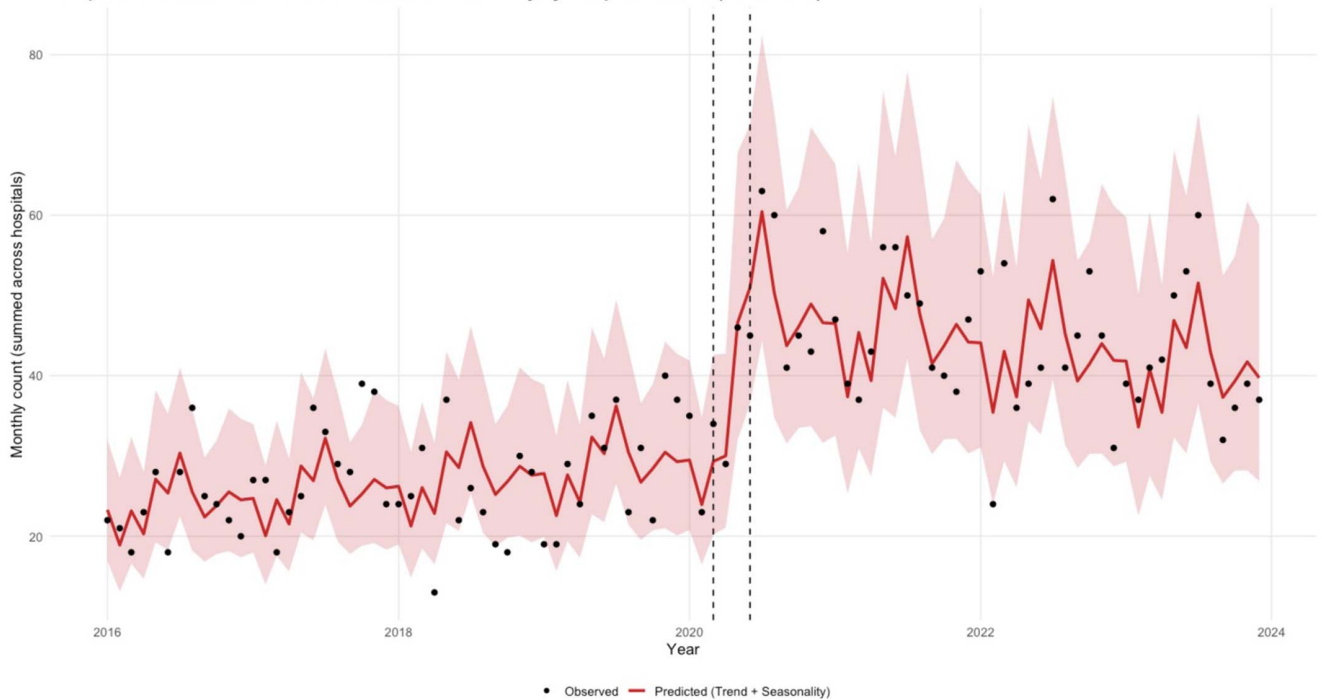


FIGURE 3. Temporal and seasonal trends in pediatric FI hospitalization (2016–2023). Abbreviation: FI, firearm injury.

Observed and Model-Predicted Encounters by Race

Hospital-month clustered segmented Poisson ITS (Mar/Jun 2020 breakpoints) with calendar-month fixed effects

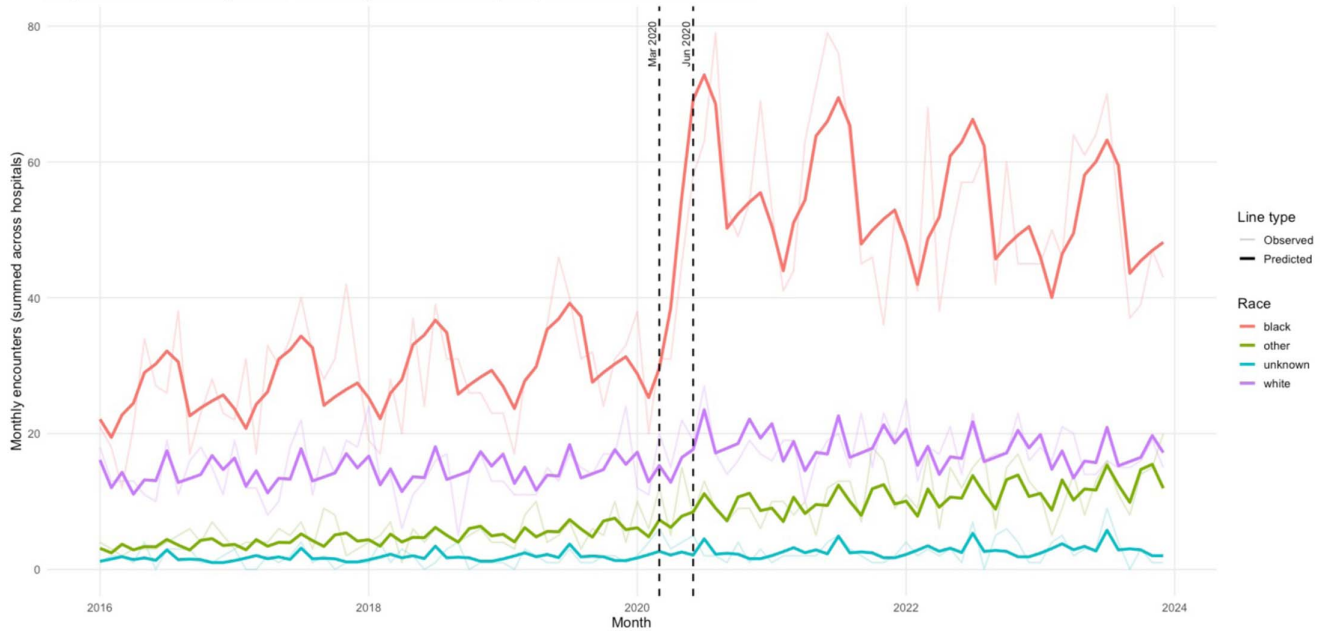


FIGURE 4. Temporal and seasonal trends in pediatric FI ED visits by race (2016–2023). Abbreviations: ED, emergency department; FI, firearm injury.

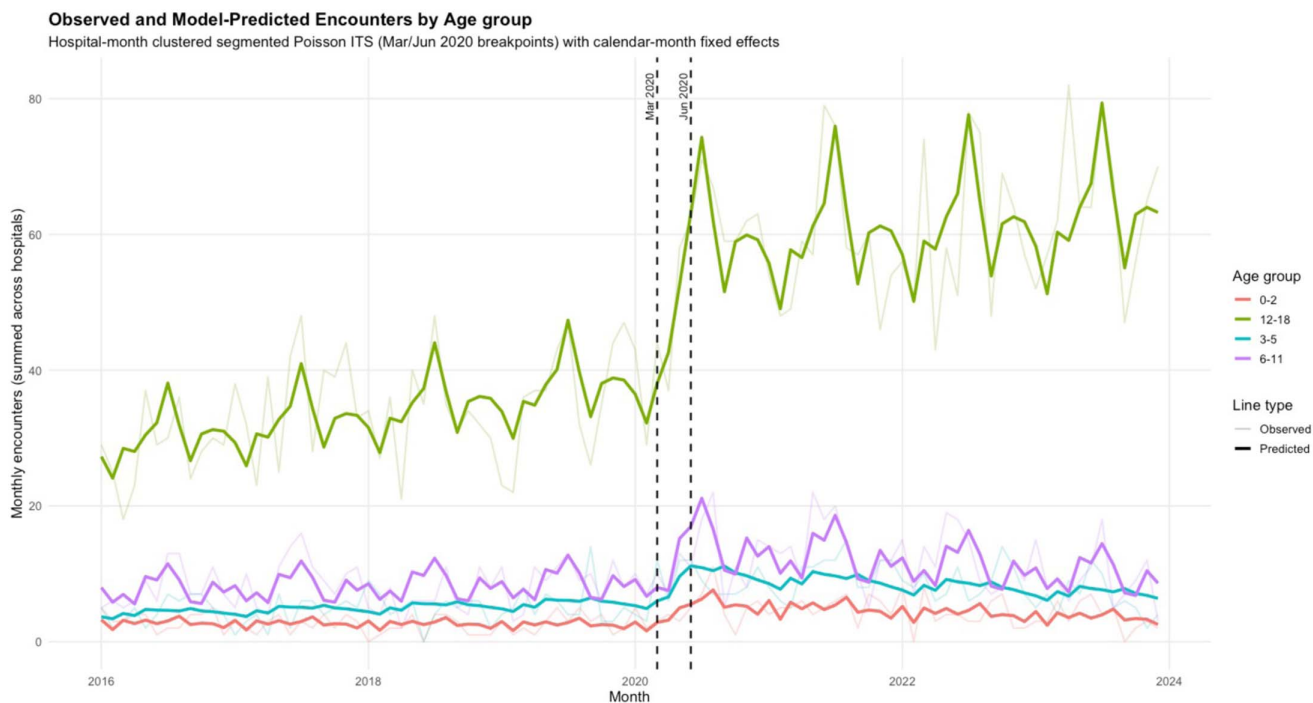


FIGURE 5. Temporal and seasonal trends in pediatric FI ED visits by age group (2016–2023). Abbreviations: ED, emergency department; FI, firearm injury.

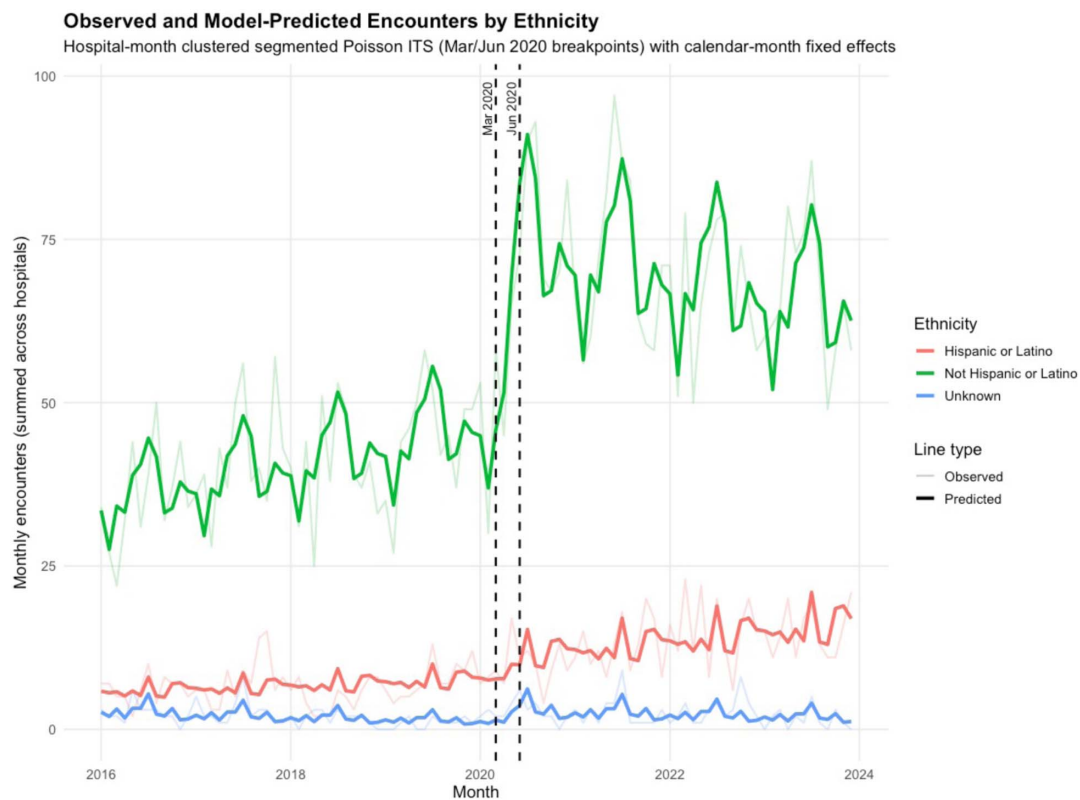


FIGURE 6. Temporal and seasonal trends in pediatric FI ED visits by ethnicity (2016–2023). Abbreviations: ED, emergency department; FI, firearm injury.

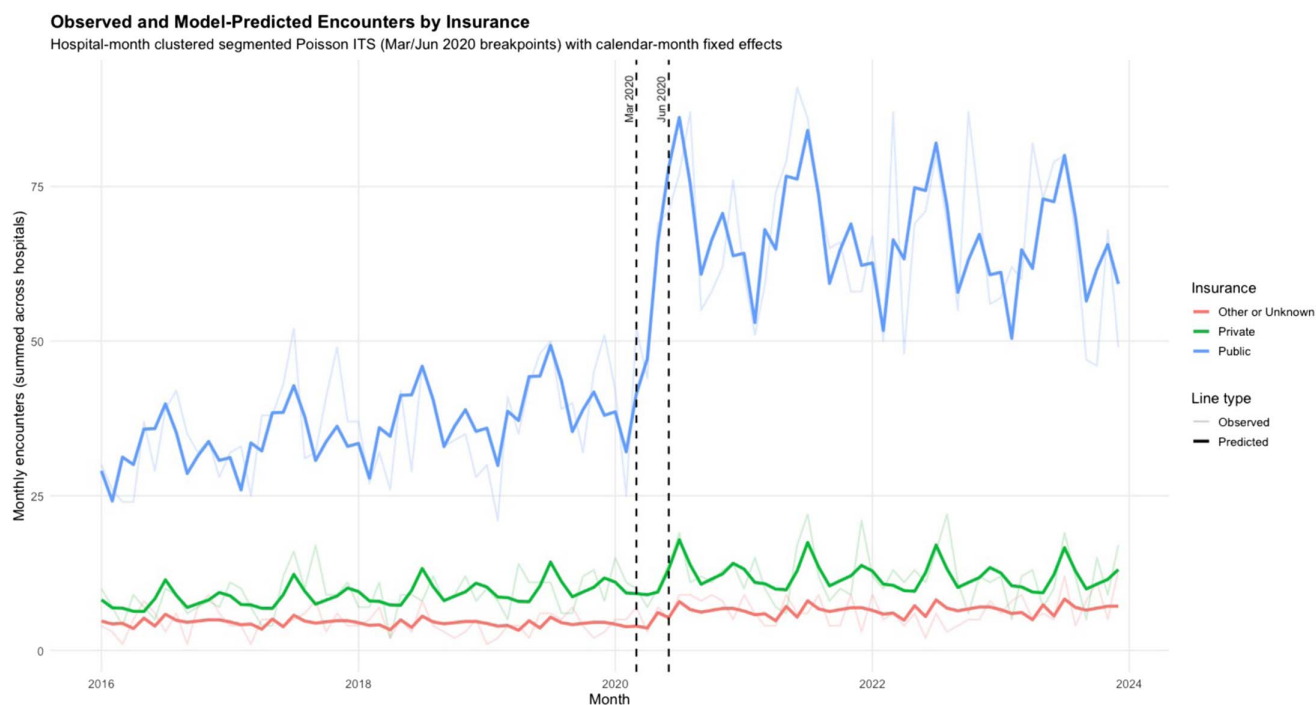


FIGURE 7. Temporal and seasonal trends in pediatric FI ED visits by insurance status (2016–2023). Abbreviations: ED, emergency department; FI, firearm injury.

$P < 0.001$), whereas trends among not Hispanic or Latino children were not statistically significant (-4.1% , $P = 0.22$).

Insurance Status

From January 2016 to February 2020, FI encounters increased significantly among publicly insured children (7.4% , $P < 0.001$), whereas trends among privately insured children were not statistically significant (7.7% , $P = 0.09$) (Figure 7, Supplementary Table 8). Between March 2020 and May 2020, publicly insured children experienced a significant increase (663.2% , $P < 0.001$). The increase among privately insured children (102.7%) was not statistically significant ($P = 0.11$). From June 2020 to December 2023, trends were not statistically significant for either insurance group.

COI

From January 2016 to February 2020, significant increases were observed among children residing in low COI neighborhoods (11.8% , $P = 0.002$) and very high COI neighborhoods (21.7% , $P = 0.01$) (Figure 8, Supplementary Table 9). Between March 2020 and May 2020, significant increases were observed across multiple COI strata, including very low COI (576.2% , $P < 0.001$), high COI (507.5% , $P < 0.001$), and low COI neighborhoods (345.8% , $P < 0.001$). From

June 2020 to December 2023, trends were not statistically significant across all COI quintiles.

DISCUSSION

In this multicenter analysis of pediatric FI ED visits from 2016 to 2023, we observed a sustained increase in encounter volume beginning in the pre-pandemic period, followed by a marked acceleration between March and May 2020. Beginning in June 2020, encounter volumes stabilized at a substantially higher level, with no statistically significant ongoing linear increase through the end of 2023, suggesting persistence at a new, elevated baseline. Although the total numbers of hospitalizations and in-hospital deaths increased, the proportions of FI ED visits resulting in hospitalization or death remained relatively stable over time.

Our finding of a significant increase in pediatric FI ED visits between March and June 2020 is consistent with prior reports describing a surge in FIs among children during this early 2020 period.⁴ Although some national survey data suggest that the proportion of firearm owners reporting safe storage practices has increased in recent years, the total number of firearms in circulation has also risen substantially.^{10–12} The rapid expansion in firearm purchasing during the 2020 firearm purchasing surge may therefore have contributed to increased exposure risk for children, independent of changes in storage practices.^{10,13}

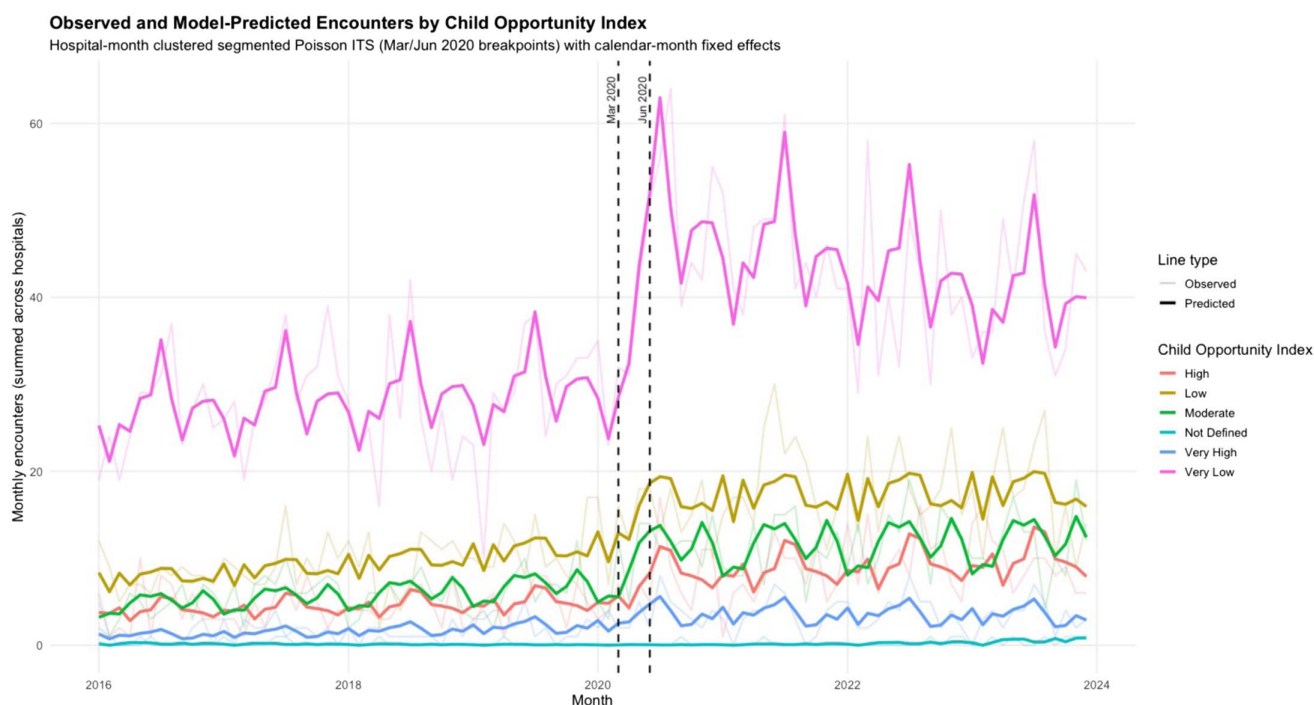


FIGURE 8. Temporal and seasonal trends in pediatric FI ED visits by COI (2016–2023). Abbreviations: ED, emergency department; FI, firearm injury.

In addition, broader societal disruptions, including changes in daily structure and supervision, economic stressors, and worsening youth mental health, may have contributed to increased pediatric injury risk.^{14–22} Importantly, these trends should not be attributed to a single factor, but rather likely reflect the convergence of multiple overlapping societal changes occurring during this period. Although we cannot directly assess these exposures in our data, the observed increase in firearm-related ED visits aligns temporally with these broader societal changes.

The June 2020 inflection point may represent the transition from an initial period of acute societal adaptation, characterized by abrupt changes in daily routines, economic contraction, and social instability, to a more prolonged period of societal adaptation. During this time, national attention expanded beyond the immediate public health crisis to include additional stressors, including widespread civil unrest.²³ Firearm purchasing increased sharply in March 2020 following the World Health Organization's declaration of COVID-19 as a global pandemic and rose again in June 2020 after the murder of George Floyd and subsequent unrest.²³ Rather than representing a purely pandemic-driven phenomenon, this inflection point likely reflects the cumulative effects of multiple concurrent societal changes, including increased firearm availability and community-level stressors. As communities adjusted to these overlapping disruptions and firearm availability expanded,

pediatric firearm injury volumes stabilized at a higher baseline rather than continuing to accelerate.

The stabilization observed beginning in June 2020 suggests that the early pandemic period was followed not by continued acceleration but by establishment of a higher baseline level of pediatric firearm injury. Notably, this persistence continued even after many initial disruptions had long since ended, suggesting that the factors contributing to sustaining higher FI rates may be more deeply rooted. This persistence suggests a structural shift in pediatric firearm injury risk rather than a transient increase. This pattern points to a new landscape for pediatric firearm injury risk, underscoring the need for sustained, long-term prevention strategies rather than short-term pandemic-focused responses.

Hospitalizations and in-hospital deaths followed similar temporal patterns. Both outcomes increased sharply between March and May 2020; however, post-June 2020 slopes were not statistically significant. Notably, the proportion of FI ED visits resulting in hospitalization or in-hospital death remained relatively stable over time, suggesting that the observed increases in absolute hospitalization and mortality volume were driven primarily by a rise in overall injury incidence, rather than a substantial shift in the severity of FIs treated in these pediatric EDs.

Subgroup analyses revealed important heterogeneity. Pre-pandemic increases were most pronounced among

TABLE 1. Demographics of ED Visits for Children With FIs (2016–2023)	
Characteristic	N = 6358, n (%)
Age group	
0–2	337 (5.3)
3–5	633 (10.0)
6–11	947 (14.9)
12–17	4441 (69.8)
Sex	
Female	1261 (19.8)
Male	5022 (79.0)
Unknown	75 (1.2)
Race category	
Black	3839 (60.4)
Other	770 (12.1)
Unknown	217 (3.4)
White	1532 (24.1)
Ethnicity	
Hispanic or Latino	947 (14.9)
Not Hispanic or Latino	5200 (81.8)
Unknown	211 (3.3)
Insurance type	
Other or unknown	519 (8.2)
Private	1004 (15.8)
Public	4835 (76.0)
COI	
Very high	247 (3.9)
High	630 (9.9)
Moderate	816 (12.8)
Low	1277 (20.1)
Very low	3371 (53.0)
Not defined	17 (0.3)
Clinical outcomes	
Hospitalizations	3369 (53.0)
ICU admissions	991 (15.6)
In-hospital mortality	408 (6.40)
Abbreviations: COI, Child Opportunity Index; ICU, intensive care unit.	

adolescents, Black children, publicly insured children, and children residing in lower-opportunity neighborhoods. Between March and May 2020, significant increases were observed across multiple demographic groups, including Black and white children, adolescents, publicly insured children, children residing in lower-opportunity neighborhoods, and both Hispanic and non-Hispanic populations. From June 2020 through December 2023, most subgroups did not demonstrate statistically significant linear change; however, adolescents showed no evidence of decline, and FI encounters among Hispanic or Latino children continued

TABLE 2. Annual Trends in Pediatric Firearm Injury Encounters, Hospitalizations, and In-Hospital Mortality (2016–2023)				
Year	Total Encounters, N	ED Visits, n (% of Total)	Hospitalizations, n (% of Total)	Deaths, n (% of Total)
2016	529	244 (46.1)	285 (53.9)	43 (8.1)
2017	627	279 (44.5)	348 (55.5)	39 (6.2)
2018	563	266 (47.2)	297 (52.8)	34 (6.0)
2019	636	288 (45.3)	348 (54.7)	38 (6.0)
2020	947	423 (44.7)	524 (55.3)	67 (7.1)
2021	1041	497 (47.7)	544 (52.3)	70 (6.7)
2022	1022	499 (48.8)	523 (51.2)	58 (5.7)
2023	1000	493 (49.3)	507 (50.7)	59 (5.9)

to increase significantly during this interval. The proportion of US children who are Hispanic increased modestly from 24.8% in 2016 to 25.9% in 2023, which may partially contribute to rising FI encounters.²⁴ However, the observed 11.1% annual increase in ED visit rates among Hispanic children post-pandemic suggests a disproportionate increase in injury burden beyond demographic shifts alone. Taken together, these findings suggest that prevention efforts should prioritize adolescents, Black children, Hispanic children, publicly insured children, and children living in lower-opportunity neighborhoods, as these groups demonstrated the highest burden and/or most persistent increases over time.

More than half of all FI ED visits in our cohort involved Black children, consistent with previous research.^{2,4,5} Previous work has suggested that these disparities reflect the effects of structural racism, community disinvestment, and historical inequities.^{25,26} Communities with “low” or “very low” COI scores also accounted for a disproportionate share of visits during and following the pandemic, underscoring the importance of considering neighborhood-level factors when designing interventions. The persistence of elevated burden in these groups over time suggests that underlying structural inequities continue to shape and amplify risk beyond short-term societal disruptions.

Addressing this elevated burden of pediatric FIs will require a multifaceted approach. From a policy and public health perspective, the populations identified in our subgroup analyses represent key targets for intervention. FI prevention strategies should integrate ED-based interventions in addition to upstream strategies that address the root causes of violence and injury. This includes investment in community-based violence prevention programs, neighborhood infrastructure, and access to social and mental health services. Programs such as Cure Violence and Advance Peace have demonstrated success in reducing gun violence,^{27,28} and broader policies—such as safe firearm storage laws—have also shown benefit.^{29,30} Hospitals and EDs can play a pivotal role by identifying at-risk youth,

connecting them to hospital-based violence intervention programs, other community-based resources, and promoting safe firearm storage through counseling and device distribution; these strategies may be particularly impactful when targeted toward high-risk groups identified in this study.³¹ These recommendations are consistent with position statements from pediatric surgical and pediatric professional organizations,^{22,32} as well as recent reviews underscoring the need for both community and hospital-based prevention strategies.^{33,34} Given the persistent elevation in pediatric firearm-related ED visits following the COVID-19 pandemic, these efforts must be sustained over the long term and coordinated across health care, public health, education, and social services to support both prevention and ongoing risk reduction. Without targeted, evidence-based interventions that address both immediate risks and systemic contributors to violence, the elevated burden of pediatric FI is likely to persist. The sustained elevation observed after 2020 suggest that this burden is unlikely to resolve without deliberate, population-focused prevention efforts.

LIMITATIONS

This study has several important limitations that should be considered when interpreting the findings. PHIS is an administrative database and is subject to coding misclassification; it includes tertiary pediatric hospitals only, limiting generalizability and excluding children treated elsewhere or dying before hospital arrival.^{8,35} Subgroup analyses were exploratory, and PHIS lacks detailed severity and contextual

data needed to assess mechanism, intent, and social drivers of injury. Local-level policy changes, shifts in community violence dynamics, and pandemic-related disruptions in health care access and resource allocation may have influenced observed trends in ways that were not fully captured by our models. Large relative percentage changes in small subgroups should therefore be interpreted cautiously.

CONCLUSIONS

This analysis demonstrates a significant increase in pediatric firearm injury ED encounters following the onset of the COVID-19 pandemic. Although subsequent slopes did not demonstrate statistically significant linear change, encounter volumes remained higher than pre-pandemic levels through 2023, suggesting the emergence of a concerning new baseline. These findings highlight the long-lasting impact of pandemic-related changes in firearm access, economic hardship, and social disruption on child safety. Continued surveillance, cross-sector collaboration, and evidence-informed policy are critical to reversing this trend and reducing preventable harm and protecting the well-being of children.

ABBREVIATIONS

COI: Child Opportunity Index
ED: emergency department
FI: firearm injury

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