

State Gun Laws and Pediatric Firearm-Related Mortality

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abstract

BACKGROUND: Firearms are the second leading cause of pediatric death in the United States. There is significant variation in firearm legislation at the state level. Recently, 3 state laws were associated with a reduction in overall deaths from firearms: universal background checks for firearm purchases, universal background checks for ammunition purchases, and identification requirement for firearms. We sought to determine if stricter firearm legislation at the state level is associated with lower pediatric firearm-related mortality.

METHODS: This was a cross-sectional study in which we used 2011–2015 Web-based Injury Statistics Query and Reporting System and Census data. We measured the association of the (1) strictness of firearm legislation (gun law score) and (2) presence of the 3 aforementioned gun laws with pediatric firearm-related mortality. We performed negative binomial regression accounting for differences in state-level characteristics (population-based race and ethnicity, education, income, and gun ownership) to derive mortality rate ratios associated with a 10-point change in each predictor and predicted mortality rates.

RESULTS: A total of 21 241 children died of firearm-related injuries during the 5-year period. States with stricter gun laws had lower rates of firearm-related pediatric mortality (adjusted incident rate ratio 0.96 [0.93–0.99]). States with laws requiring universal background checks for firearm purchase in effect for ≥ 5 years had lower pediatric firearm-related mortality rates (adjusted incident rate ratio 0.65 [0.46–0.90]).

CONCLUSIONS: In this 5-year analysis, states with stricter gun laws and laws requiring universal background checks for firearm purchase had lower firearm-related pediatric mortality rates. These findings support the need for further investigation to understand the impact of firearm legislation on pediatric mortality.



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WHAT'S KNOWN ON THIS SUBJECT: Firearm-related injuries are the second leading cause of pediatric death in the United States, yet there is significant variation in firearm legislation at the state level.

WHAT THIS STUDY ADDS: States with stricter firearm legislation, specifically legislation regarding universal background checks for firearms, had lower firearm-related mortality rates in children.

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Firearm injury is the second leading cause of traumatic death and the third leading cause of death overall among children in the United States.¹ The United States has the highest rate of firearm-related injuries in children relative to other industrialized countries.^{1,2} Of note, ~7 US children die of firearm-related injuries daily.³

When compared with other high-income countries, the United States has the highest rate of gun ownership, the weakest gun laws, and the highest rate of firearm-related deaths in children.^{4–6} Firearm legislation varies at the state level and regulations differ with respect to the presence or absence of laws for firearm purchase, ownership, and carriage.⁷ Each year, the Brady Campaign to Prevent Gun Violence gathers an expert panel to objectively assess and rate state firearm legislation on the basis of a series of 33 different gun policies.⁸ Additionally, authors of a recent study found 3 state laws in particular to be strongly associated with a reduction in firearm-related deaths among children and adults combined: universal background checks for firearm purchase, universal background checks for ammunition purchase, and identification requirement for firearms.⁹

Authors of several previous studies have described lower rates of pediatric suicide, homicide, firearm carriage, and firearm-related morbidity in states with strict gun laws.^{10–15} We performed this study to test the hypothesis that stricter firearm legislation at the state level is associated with lower pediatric firearm-related mortality rates.

METHODS

Study Design and Data Source

This was a repeated cross-sectional study using the 2011–2015 Web-based Injury Statistics Query and Reporting System (WISQARS). WISQARS is a publicly available,

interactive, online, de-identified database that provides fatal injury data in the United States from the Centers for Disease Control and Prevention by broad demographic characteristics and cause of injury.³ These data were used to select firearm-related deaths per year for those aged ≤ 21 years by state, except in states with < 10 annual firearm-related deaths where the counts were suppressed. These data were matched to comparable state population data for all children aged ≤ 21 years. Although the intent of injury may differ across the pediatric age group, we chose to focus this study across the entire pediatric age spectrum because the primary purpose of this analysis was to measure the relationship between a comprehensive score of state-based firearm legislation (which may impact children from infancy through young adulthood) and firearm-related mortality. This study was exempt from institutional review board approval because of the use of publicly available de-identified data.

Outcome Variable

The primary outcome was firearm-related mortality rate in children. Deaths were identified by using *International Classification of Diseases, 10th Revision* codes W32–W34, X72–X74, X93–X95, Y22–Y24, Y35.0, and *U01.4 to specify firearm-related mortality. State-specific firearm-related mortality rates were calculated by using respective US 2011–2015 census data.

Exposure Variables

The primary exposure variable was gun law score based on the 2011–2015 Gun Law Scorecards from the Brady Campaign to Prevent Gun Violence. States can receive a maximum of 100 points, based on points awarded for having consistently strong laws. The higher the state gun law score, the stricter the firearm legislation. In 2013, states

began losing points for laws considered to weaken public safety. Because states could lose points, negative scores were possible.⁸ To facilitate statistical modeling, scores were inflated by a constant of 40 to prevent negative values while preserving the original scale.

Secondary exposure variables included individual laws previously associated with lower mortality rates in the total population of adults and children. These included the following 3 laws: (1) universal background checks for firearm purchase, (2) universal background checks for ammunition purchase, and (3) identification requirement for firearms (microstamping, ballistic fingerprinting).⁹ States were categorized into the following groups on the basis of 2015 laws: states having no law, law in effect for < 5 years, or law in effect for ≥ 5 years.^{16,17}

Confounding Variables

We used the following state-level data from the 2011–2015 US Census to adjust for characteristics previously associated with firearm-related mortality: population-based race and ethnicity proportions, percent of the population with college education, and percent of the population living below the poverty threshold.^{2,4,18–20} We adjusted for gun ownership using 2013 data from YouGov, an Internet-based market research company, as reported in a study by Kalesan et al.²¹ States were dichotomized as having low or high gun ownership on the basis of the median value of the percentage of gun ownership.

Data Analysis

We used standard descriptive statistics to summarize the characteristics of the study population and calculate the overall and state-level firearm-related mortality per 100 000 US children. After determining that the data were

too dispersed for Poisson modeling, we used negative binomial multiple regression models to measure the associations of state gun law scores (primary exposure variable) and the presence of the 3 aforementioned laws (secondary exposure variables) with firearm-related mortality rates among children. Four separate models incorporated population-level adjustments for state-level proportions by race and ethnicity, education level, household income, and gun ownership. Variance estimates were adjusted to account for clustering by state across the study years.

Because states with <10 firearm-related deaths among children had suppressed mortality rates, we performed a sensitivity analysis using the mean number of firearm-related deaths over the 5-year study period to estimate an annual mortality rate for states with suppressed data. We compared these results with our primary analysis to assess the robustness of our results. We report incident (mortality) rate ratios (IRRs) and predicted mortality rates with 95% confidence intervals (CIs). We used the “margins” command in Stata version 12.0 (Stata Corp, College Station, TX) to derive predicted mortality rates associated with a 10-point change in the gun law score or in the proportion by race and ethnicity, education level, poverty level, and gun ownership. Similarly, when measuring the impact of the 3 aforementioned laws, we separately calculated predicted mortality rates for states that did not have the law present, states that had the law in effect for <5 years, and states that had the law in effect for ≥5 years.

RESULTS

From 2011 through 2015, there were 21 241 firearm-related deaths among US children reported in WISQARS (~4250 deaths per year). This translates to an annual

firearm-related mortality rate of 4.65 per 100 000 US children. The majority of firearm-related deaths were assault related (61.6%) and occurred among males (87.3%) and 18- to 21-year-old individuals (68.7%) (Table 1).

State-specific mortality rates ranged from 1.1 to 18.1 per 100 000 children. State gun law scores ranged from -39 to +81, and after scaling, 1 to 121, with higher scores indicating stricter gun laws. Gun ownership ranged from 5.2% to 61.7% (median value: 32.2%).

In unadjusted analysis, the association between the gun law score and pediatric firearm-related mortality demonstrated that for every 10-point increase in the gun law score (eg, stricter firearm legislation), the firearm-related mortality rate among children decreased by 8% (IRR 0.92 [95% CI 0.89–0.96]). Sensitivity analysis, in which we used the mean mortality rate over the 5-year period as the annual mortality rate for states that had suppressed mortality data (DE, HI, ME, NH, RI, SD, VT, and WY), revealed similar results (IRR 0.92 [95% CI 0.88–0.96]).

Table 2 reveals the results of the fully adjusted model. In this fully adjusted model, every 10-point increase in gun law score decreases the firearm-related mortality rate in children by 4% (adjusted incident rate ratio [aIRR] 0.96 [95% CI 0.93–0.99]). Figure 1 illustrates the relationship between the gun law score and firearm-related mortality in children after population-level adjustments by race and ethnicity, education level, household income, and gun ownership. As illustrated in Fig 1, predicted firearm-related mortality decreases as firearm laws get stronger.

Table 3 reveals the relationship between specific laws and firearm-related mortality in children. A summary of the presence of these laws by state can be found in the Supplemental Information. In 2015, 7 states had laws requiring universal background checks for firearm purchases that had been in effect for ≥5 years, 5 states had these laws for <5 years, and 38 states did not have such laws. After population-level adjustments, states that had these laws in effect for ≥5 years had

TABLE 1 Characteristics of Study Population, 2011–2015

Demographic	N (%) (Total N = 21 241)	Rate of Firearm-Related Mortality per 100 000 US Children
Age group, y		
≤12	1141 (5.4)	0.4
13–17	5517 (26.0)	5.3
18–21	14 583 (68.7)	16.5
Sex		
Male	18 544 (87.3)	7.9
Female	2697 (12.7)	1.2
Race		
White	11 133 (52.4)	3.2
African American	9471 (44.6)	12.4
Other	637 (3.0)	1.8
Hispanic ethnicity		
Yes	3407 (16.0)	3.2
No	17 786 (83.7)	5.1
Unknown	48 (0.2)	—
Intent		
Assault	13 082 (61.6)	2.9
Suicide	7217 (40.0)	1.6
Unintentional	696 (3.3)	0.2
Undetermined	251 (1.2)	0.1

—, not applicable.

TABLE 2 Association of State Gun Law Scores With Firearm-Related Mortality Rates, 2011–2015

	aIRR (95% CI) ^a
Gun law score	0.96 (0.93–0.99) ^b
High gun ownership (referent = low gun ownership)	0.96 (0.83–1.12)
Percent of population with African American race	1.16 (1.07–1.25) ^b
Percent of population with Hispanic ethnicity	0.98 (0.91–1.05)
Percent of population with a college education	0.72 (0.57–0.90) ^b
Percent of population living below the poverty level	0.79 (0.51–1.22)

^a For every 10-point increase in the gun law score (eg, stricter firearm legislation), the firearm-related mortality rate among children decreases by 4%.

^b Statistical significance at *P* value <.05; adjusted for year and clustered by state.

a predicted mortality rate of 3.80 (2.67–4.94) per 100 000 children compared with 5.88 (5.25–6.52) per 100 000 children in states that did not have such laws (aIRR 0.65 [95% CI 0.46–0.90]). The majority of states (*n* = 47) did not have laws requiring universal background checks for ammunition purchases in 2015. After population-level adjustment, the 1 state that had laws regarding universal background checks for ammunition purchase in effect for <5 years had a lower firearm-related mortality rate than states that did not have such laws (aIRR 2.18 [CI 0.52–3.84] per 100 000 children compared with aIRR 5.69 [CI 5.17–6.22] per 100 000 children;

aIRR 0.38 [CI 0.19–0.82]); however, this association was not significant when compared with the 2 states that had such laws for ≥5 years. Only 2 states had laws requiring firearm identification in 2015, and there was no statistically significant difference in mortality rates between the 2 states that had these laws versus the states that did not.

DISCUSSION

This study supports the hypothesis that states with stricter firearm-related legislation have lower rates of pediatric firearm-related deaths compared with states with less strict firearm legislation. This association

persists after adjustment for gun ownership and other sociodemographic variables. We found that of the 21 241 children who died of firearm-related injuries from 2011 through 2015, rates of firearm-related death were lower in states that had higher (more strict) gun law scores and in states that had laws requiring universal background checks for firearm purchases.

Our findings reveal an important association between firearm legislation and pediatric firearm-related mortality. This association was strong even after adjustment for rates of gun ownership. These data suggest that strict firearm legislation may be protective of children even in areas of high gun ownership.

Our results are consistent with previous studies that revealed lower rates of firearm-related injury in states with stricter firearm laws in a hospitalized population.^{13,18} Safavi et al¹³ found lower pediatric hospitalization rates in states with stricter firearm legislation. Simonetti et al¹⁸ demonstrated that stricter firearm legislation is associated with lower hospital discharge rates for firearm-related injuries in a combined adult and pediatric population in 18 states. Similarly, authors of other studies have observed an association between firearm-related mortality and strictness of firearm legislation or specific firearms laws across 50 states.^{9,19,22} For instance, Fleegler et al²² demonstrated that states with more firearm laws had lower rates of firearm fatalities in a population of adults and children. In an exhaustive review of the literature, Lee et al¹⁹ found that stronger gun policies were associated with lower rates of firearm homicide in the United States. Furthermore, authors of a 2015 international review of 130 studies concluded that the implementation of firearm restrictions is associated with reductions in firearm deaths in the combined population of adults and children.²³

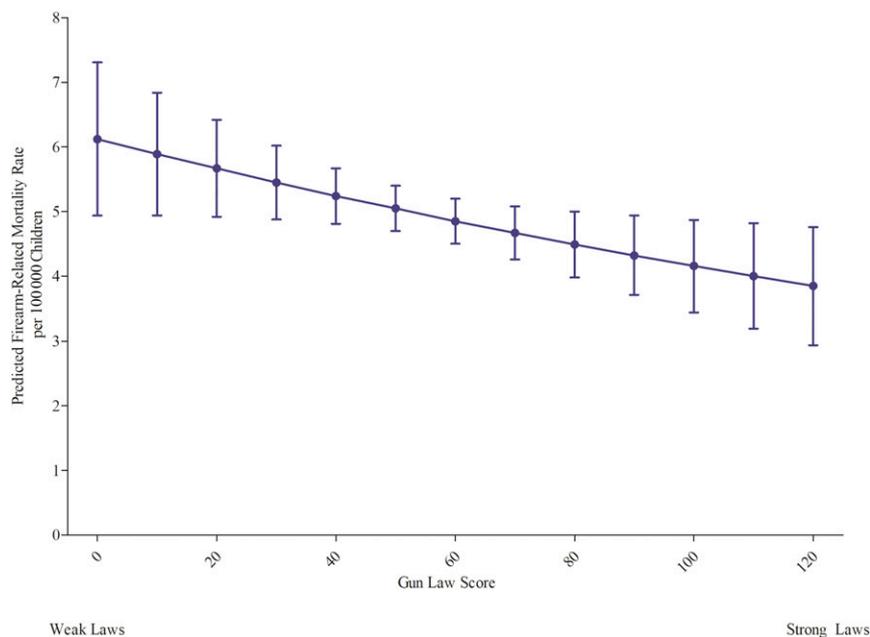


FIGURE 1 Gun law score and predicted pediatric firearm-related mortality rates, 2011–2015.

TABLE 3 Specific Firearm Legislation in 2015 and Pediatric Firearm-Related Mortality Rates

Law	No. States	Predicted Mortality Rate ^a (95% CI)	Predicted Mortality Rate ^b (95% CI)
Universal background checks for firearm purchase			
Not present	38	5.88 (5.25–6.52)	Referent
Present <5 y	5	5.25 (3.53–6.96)	0.89 (0.63–1.27)
Present ≥5 y	7	3.80 (2.67–4.94)	0.65 (0.46–0.90)
Universal background checks for ammunition purchase			
Not present	47	5.69 (5.17–6.22)	Referent
Present <5 y	1	2.18 (0.52–3.84)	0.38 (0.19–0.82)
Present ≥5 y	2	3.65 (1.94–5.36)	0.64 (0.39–1.03)
Identification requirement for firearms			
Not present	48	5.59 (5.03–6.15)	Referent
Present <5 y	0	—	—
Present ≥5 y	2	5.89 (2.86–8.91)	1.05 (0.63–1.77)

—, not applicable.

^a Per 100 000 children.

^b Population-level adjustments by race and ethnicity, education level, household income, and gun ownership.

In general, firearm legislation impacts overall mortality in adults; states with higher numbers of laws regulating firearms have lower rates of overall firearm mortality as well as fewer suicides and homicides than states with fewer total laws.²² Additionally, laws enforcing strict waiting periods before firearm purchases, universal background checks, restrictions to carrying guns in public, and mandated gun locks were associated with lower adult suicides.²⁴ Studies such as these suggest that specific laws may have particular efficacy in preventing firearm mortality. Kalesan et al⁹ studied 25 different regulations related to firearms and found that 3 laws were associated with a decrease in overall firearm mortality: universal background checks for firearm purchases, background checks for ammunition purchases, and a requirement of identification on the firearm (microstamping or ballistic fingerprinting). In our study, which was specific to children, we found that states with laws requiring universal background checks for firearm purchases had lower firearm-related mortality. The presence of these laws was associated with a >35% lower rate of firearm-related mortality, even after adjustment for socioeconomic factors and gun ownership. Few states had laws

regarding background checks for ammunition purchases or identification requirements for firearms; therefore, the sample was too small to draw conclusions on the impact. Furthermore, laws regarding firearm identification faced challenges at the state level in both California and Maryland. In 2013, California expanded its firearm identification laws and was the first state to pass a microstamping requirement for all new handguns. However, the law faced multiple legal challenges, and gun manufacturers refused to sell new handguns in the state to avoid this requirement. Additionally, in Maryland, a ballistics fingerprinting program that had been in place for almost 15 years was repealed in 2015.¹⁷ Therefore, it may be too early to study the impact of microstamping or ballistics identification on preventing firearm-related injury.

Although many state and federal laws are passed with the intent to reduce firearm-related morbidity and mortality, the nuances of differential implementation can make it difficult to elucidate the effectiveness of these laws individually or as a whole. In previous studies, mostly focused on the general population rather than specifically on children, authors have

suggested that there are lower firearm-related deaths in states with lower gun ownership^{25,26} in states with specific laws on safer firearm storage practices,^{20,27–29} and in states with background check requirements for firearm or ammunition purchase.^{9,19} Alternatively, authors of other studies have used composite scores, such as the gun law score, to measure differences in firearm-related injury and mortality. In these studies, authors found lower rates of firearm-related injury and death in states with more restrictive firearm legislation.^{13,18,22} However, these studies were limited to either a hospitalized population or a population consisting of both adults and children. We used a combined approach in our study in which we evaluated the association of firearm-related mortality among children with strictness of firearm legislation using the gun law score as well as the presence of the 3 laws previously noted by Kalesan et al⁹ to be associated with lower rates of firearm mortality across all ages. We also studied these trends over a 5-year study period rather than limiting our analysis to just 1 year. In addition, we were able to assess the impact of firearm legislation after adjustment for gun ownership.

Evidence-based policy to drive legislative change suggests that a combination of laws may be the most effective to reduce firearm-related injury and death. Moreover, the American Academy of Pediatrics affirms that the most effective method for preventing pediatric firearm-related injuries is a multilateral approach, advocating for legislation that reduces firearm availability and imposes stricter requirements regarding child access, safety, and design.² This approach requires more detailed data sources with information on the acquisition of firearms, types of firearms, and enforcement of firearm laws.

The findings of this study build on previous literature and help provide compelling data that an evidence-based, data-driven, public health approach to firearm legislation may be successful in reducing firearm-related injury in children. Legislation to decrease injury from other obvious public health hazards, such as motor vehicle collisions and secondhand smoke exposure, has shown that the adoption of restrictive laws (eg, seat belts, use of car seats, limits on where an individual can smoke, etc) results in lower injury rates.^{30,31} For instance, as a result of the evidence-based approach taken to reduce mortality from motor vehicle collisions, motor vehicle-related mortality rates have decreased from 9.8 per 100 000 children in 2007 to 6.1 in 2015.³² In contrast, firearm-related crude mortality has not changed, with 5.4 per 100 000 children in 2007 to 5.2 in 2015.³² Thus, an evidence-driven approach, based on more comprehensive data sources, is needed to inform decision-making to reduce childhood injury and death from firearms.

There are several potential limitations to this study. First, because this is a repeated cross-sectional study, we are unable to establish causality between the strictness of firearm legislation and state-based mortality. However, given that the study was conducted over

a 5-year period, we believe this adds to the robustness of our findings. Second, the Gun Law Scorecard is not a validated measure of strictness of firearm legislation. However, many studies have used the Gun Law Scorecard to assess “strictness” of firearm legislation at the state level.^{10,13,18,33} We are unaware of any validated scoring system for firearm legislation, but given the comprehensiveness of the Gun Law Scorecard and its use in published literature, it is a reasonable means to compare levels of firearm strictness. Third, we used the 2013 YouGov survey to estimate gun ownership in our models. Although this survey provides the most recent estimate of gun ownership in the United States, it is possible that this estimate is inaccurate. Nevertheless, it likely reflects relative patterns in gun ownership because its estimates approximate those derived from the Centers for Disease Control and Prevention 2002 Behavioral Risk Factor Surveillance System and has been used in previously published studies.^{9,34} Furthermore, although we assessed the presence or absence of certain firearm legislation, we were unable to assess the effectiveness of the enforcement of these laws. In addition, when the presence of specific gun laws was evaluated, the effect of other coexistent laws was not adjusted for in the multivariable

model. Lastly, these analyses were limited strictly to firearm-related deaths rather than firearm-related injuries, which underestimates the burden of firearm-related morbidity among children.

CONCLUSIONS

We found that states with stricter firearm legislation had lower rates of firearm-related death in children. This association remained after population-based adjustment for sociodemographic factors and gun ownership. Furthermore, states with laws requiring universal background checks for firearm purchase also had lower rates of pediatric firearm-related deaths. These results support the need for more robust research related to the impact of firearm legislation on firearm-related injury and death in children. Implementation of evidence-based policies and legislation is required to reduce firearm-related injury in children.

ABBREVIATIONS

aIRR: adjusted incident rate ratio
CI: confidence interval
IRR: incident rate ratio
WISQARS: Web-based Injury
Statistics Query and
Reporting System

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