Firearm Legislation Stringency and Firearm-Related Fatalities among Children in the US

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BACKGROUND: Firearm-related injuries are the second leading cause of pediatric deaths in the US. We sought to evaluate the effectiveness of both state child access prevention (CAP) laws and gun regulations on pediatric firearm mortality. We hypothesized that states with more stringent firearm legislation had lower pediatric firearm mortality.

STUDY DESIGN: We used 2014-2015 firearm mortality data from the Web-Based Injury Statistics Query and Reporting System, 2014 Brady scores (used to quantify stringency of state gun regulations) and CAP laws. State-level covariates were obtained from government sources, including the Bureau of Labor Statistics and the Department of Education. Spearman rank correlations and linear regression were used to determine the relationship between overall pediatric firearm mortality and gun regulations. We also examined the relationship between gun regulations and firearm-related homicides and suicides.

RESULTS: Annually, there were approximately 2,715 pediatric firearm fatalities among children; 62.1% were homicides and 31.4% suicides. There was a moderate negative correlation between states' firearm legislation stringency and overall pediatric firearm mortality ($\rho = -0.66$; $p < 0.001$), and between CAP laws and firearm suicide rates ($\rho = -0.56$; $p < 0.001$). After controlling for poverty, unemployment, substance abuse, and the number of registered firearms, the association between firearm legislation stringency and overall pediatric firearm mortality remained significant ($p = 0.04$). The association between CAP laws and firearm suicide rate remained significant after controlling for socioeconomic factors, registered firearms, and other firearm legislation ($p = 0.04$).

CONCLUSIONS: Strict gun legislation and CAP laws are associated with fewer pediatric firearm fatalities and firearm suicides, respectively, though no such association was identified with pediatric firearm homicides. Although more studies are needed to determine causality, state-level legislation could play an important role in reducing pediatric firearm-related deaths. (J Am Coll Surg 2019;229:150−157. © 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Firearm-related injuries and fatalities among children are important public health problems in the US. Mass shootings continue to occur with regrettable frequency and dominate news headlines, serving as grim reminders of the consequences of firearm violence on children. In 2018, there were more than 85 incidents of gunfire on school grounds, including the especially deadly shootings at Marjory Stoneman Douglas High School (Parkland, FL) and Santa Fe High School (Santa Fe, TX) that left 27 dead, 27 injured, and hundreds of thousands of teens speaking out to demand legislative change.[1-3] Less well publicized, but even more staggering, are the pediatric lives lost each year due to suicide, homicide, or accidental death. Firearms were the second leading cause of death among children in the US in 2014, resulting in more pediatric deaths than cancer and heart disease combined.[4] Firearms contribute substantially to pediatric suicide and homicide rates. In 2014, firearms accounted for

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71% of all homicides and 41% of all suicides among children.[5] In 2010, the combined medical and work-loss cost for all fatal firearm injuries among children was estimated to be more than $4.8 billion in the US.[5] In addition to the direct health and fiscal impacts of firearm injuries, there are significant long-term psychological effects on survivors and family members. Nearly 1 in 25 children have witnessed a shooting in the past year.[6]

Federal and state lawmakers are responsible for legislating public policy on firearms, though the effect of these policies on public health is often unclear and can be difficult to evaluate. Several studies have examined the association of overall firearm-related fatalities for all ages with state-level firearm legislation, but with varying results. Kwon and colleagues,[7] analyzing data from 1990, found that firearm legislation might have a very mild effect on the number of gun-related deaths, and socioeconomic variables have a significant impact. In their analysis of firearm fatalities between 2007 and 2010, Fleegler and colleagues[8] found the absolute number of firearm laws in a state is inversely correlated with firearm fatalities. Price and colleagues[9] found a strong association between restrictiveness of gun laws and firearm suicide, but little association with firearm homicide. However, these studies did not focus on the pediatric population.

Many states have enacted child-focused firearm legislation, known as child access prevention (CAP) laws intended to keep firearms away from youth. Several studies have examined the effect of CAP laws on unintentional injury or death in children and have suggested limited reductions in unintentional injury. These reductions have been limited largely to states that impose felony prosecution on CAP violations.[10-12] Webster and colleagues[13] found a modest reduction in adolescent suicides was associated with CAP laws; however, to our knowledge, no studies have examined the combined effects of CAP laws and overall state firearm legislation stringency on pediatric firearm mortality.

Previous research on the impact of firearm laws have focused largely on adults, or adults and children combined. To date, the few pediatric studies completed have largely evaluated the impact of firearm legislation on pediatric injuries or hospital admissions, with reference to in-hospital mortality, but not all pediatric firearm-related fatalities. In this article, we evaluate the association between CAP laws and state gun regulations on firearm mortality rates among children in 2014 and 2015. We also analyzed other state-level factors that have previously been associated with mortality, including socioeconomic variables and neighboring states' firearms legislation.[9] We hypothesized that states with more stringent legislation and CAP laws would correlate with a lower incidence of firearm-related fatalities among children.

METHODS

Firearm-related injury and mortality

Firearm-related mortality data from 2014 and 2015 for children (ages 0 to 19 years) were accessed from the Web-Based Injury Statistics Query and Reporting System (WISQARS).[5] The WISQARS provides injury-related deaths and mortality rates derived from the National Vital Statistics System maintained by the Centers for Disease Control and Prevention National Center for Health Statistics. The WISQARS stratifies fatalities based on intent of injury (ie unintentional, homicide, suicide, or undetermined), mechanism of injury (eg firearm, drowning, or poisoning), sex, age, race/ethnicity, and state of residence of the injured person. The WISQARS uses the following ICD-10 codes to determine firearm-related fatalities: W32 to W34, X72 to X74, X93 to X95, Y22 to Y24, Y35.0, and U01.4. To prevent inadvertent disclosure of identifiable cases, no data are reported if totals are <10 in tabulations for a specific geographic region.

State legislation data

The state-level variation in overall gun legislation stringency was quantified using the 2014 Brady Scorecard (Brady score) compiled annually by the Brady Campaign to Prevent Gun Violence since 2007.[14] In brief, the Brady score ranks 50 states based on a series of 33 gun policies, state gun death rates, and state crime gun export rates. Scores range from -100 for the least restrictive states to $+100$ for the most restrictive states.

We also considered state laws that are specifically designed to protect children from accessing firearms, or CAP laws. In 2014, the Brady score did not account for CAP laws, so this category of laws offered a second metric to measure child-specific gun legislation. Data on CAP laws by state were obtained from the Giffords Law Center, which tabulated CAP laws in effect in 2014.[15] The CAP scores (0 to 2 points) were assigned to each state, with 1 point given for presence of laws that address children gaining access to guns, and 1 point for any law that requires safe storage or firearm locks for guns in a home.

State-level factors

Socioeconomic and demographic factors that have been correlated previously with firearm-related violence[9] were included in the analysis. These variables include unemployment rates, poverty level, percent urbanization, alcohol

dependence, tobacco and marijuana use among teens, and high school graduation rates. Unemployment rates were obtained from the 2015 US Bureau of Labor Statistics[16]; state poverty rates and Supplemental Poverty Measures were taken from the US Census Bureau.[17] State public high school graduation rates for the 2014 to 2015 school year were obtained from the US Department of Education.[18] Health-related data (alcohol use, tobacco use, and marijuana use) were obtained from the 2014-2015 National Surveys on Drug Use and Health.[19] The surveys capture the percentage of 12- to 17-year-old individuals who have used marijuana in the past month or have had alcohol dependence in the past year, as defined by the Diagnostic and Statistical Manual of Mental Disorders, 4th edition.[20] In 2016, the Bureau of Alcohol, Tobacco, Firearms, and Explosives traced more than 60,000 firearms that were illegally trafficked across state lines, and many more are trafficked unnoticed.[21] To partially account for this, we examined the average Brady scores of neighboring states as separate state-level factors that could influence pediatric firearm mortality rates. Finally, the number of registered firearms per 100,000 children in each state was obtained from a 2014 Alcohol, Tobacco, Firearms, and Explosives report as a surrogate for total number of firearms in each state.[22]

Data analysis

The primary outcomes measures were annual pediatric firearm mortality rates, homicide rates, and suicide rates per 100,000 children, ages 0 to 19 years. We calculated simple descriptive statistics and performed correlation analysis of each state-level factor against our outcomes measures. We computed the Spearman's ρ statistic to estimate a rank-based measure of association between the state-level factors and the outcomes measures. Interpretation of correlation coefficients were defined by Mukaka,[23] with 0 to 0.3 considered negligible, 0.3 to 0.5 (−0.3 to −0.5) considered low positive (negative) correlations, 0.5 to 0.7 (−0.5 to −0.7) considered moderate positive (negative) correlations, and >0.7 (<−0.7) considered high or very high positive (negative) correlations. A p value < 0.05 was considered statistically significant. Data analysis was performed using R (R Foundation for Statistical Computing).

Multiple linear regression models were used to evaluate the relationship between the outcomes measures (overall pediatric firearm mortality rate, firearm-related homicide rate, and firearm-related suicide rate) and state-level factors. This allowed for evaluation of the association of firearm regulations and CAP laws with each of the outcomes measures, relative to other independent variables like socioeconomic factors.

RESULTS

There is considerable state-to-state variation in the stringency of firearm legislation (Fig. 1). In 2014, California had a Brady score of +76, and Arizona had a score of −39. The number of firearm-related fatalities among children and teens in the US has been relatively stable from 2008 to 2015, with an average of 2,715 victims per year (Fig. 2), and an overall pediatric firearm mortality rate of 3.28 per 100,000 children. However, there is significant variation in the pediatric firearm mortality rates between states, ranging from 0.45 deaths per 100,000 in Hawaii, to 7.55 deaths per 100,000 in Alaska. We found that an average of 62.1% of all the fatalities were homicides, and 31.4% were suicides; the remaining were categorized as unintentional firearm deaths, legal interventions, or deaths due to undetermined intent.

In unadjusted analysis, higher state gun legislation stringency (Brady score) was moderately associated with lower rates of firearm-related deaths among children and teens ($\rho = -0.66$; $p < 0.001$) (Fig. 3). States in the highest quartile of Brady scores have an annual pediatric firearm mortality rate of 2.563 per 100,000 population compared with states in the lowest quartile, where the mortality rate is almost twice as high at 5.005 per 100,000. A low negative association was found between CAP laws and firearm-related death rates ($\rho = -0.31$; $p = 0.03$).

There was a moderate association between higher pediatric firearm mortality rates and lower Brady scores in the neighboring states in unadjusted analysis ($\rho = -0.50$; $p < 0.001$). Non-legislative factors were also significantly associated with pediatric firearm mortality. There was a moderately positive association between state-wide unemployment and pediatric firearm homicide rates ($\rho = 0.55$; $p < 0.001$). Similarly, there was a moderately positive correlation between teen tobacco use and adolescent firearm suicide rates ($\rho = 0.50$; $p < 0.001$). No such association was found with marijuana use or alcohol dependence and any of our outcomes measures (Fig. 4).

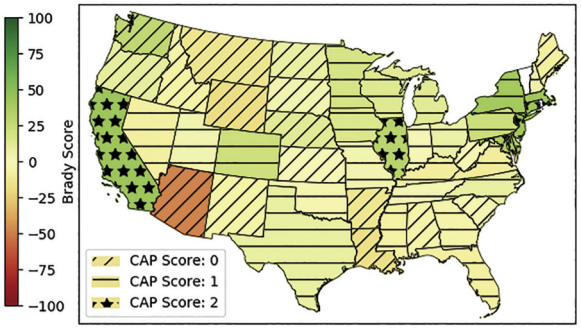

Figure 1. Brady scores and child access prevention (CAP) scores for 2014; higher scores indicate stricter overall and child-specific firearm legislation in that state, respectively.

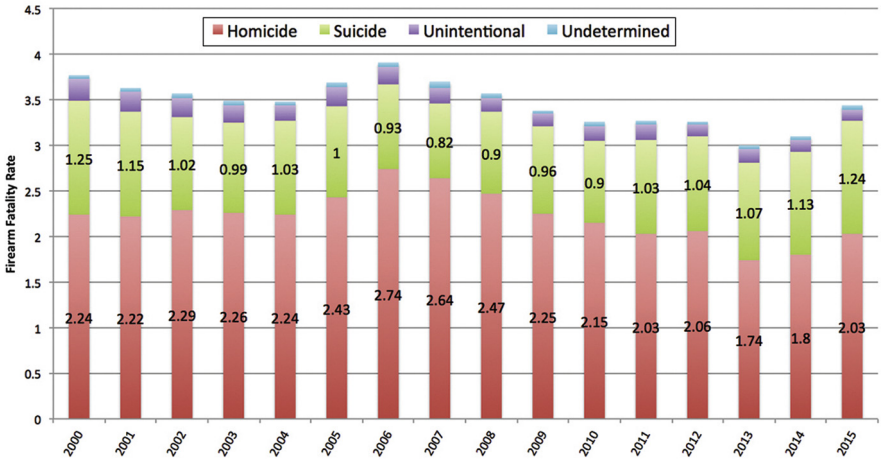

Figure 2. Pediatric firearm mortality rates in children (ages 0 to 19 years) in the US by year and by intent, 2000-2015.

After controlling for socioeconomic factors (poverty, unemployment, graduation rates, percent urbanization, alcohol dependence, tobacco use, and marijuana use) and number of registered firearms, the association between Brady scores and pediatric firearm mortality rates remained significant ($\beta = -0.018$; 95% CI -0.035 to -0.0006; $p = 0.04$). In adjusted analysis, other variables that maintained a significant relationship with pediatric firearm mortality rates included the state's unemployment rate ($\beta = 0.81$; 95% CI 0.35 to 1.27; $p < 0.001$) and the neighboring states' Brady scores ($\beta = -0.022$; 95% CI -0.038 to -0.005; $p = 0.01$). The association between CAP laws and pediatric firearm mortality was not significant after controlling for Brady score and number of registered firearms.

We next evaluated the association between laws and suicide and homicide rates separately. In unadjusted analyses, Brady scores had low negative associations with both firearm homicide rates ($\rho = -0.42$; $p = 0.01$) and firearm suicide rates ($\rho = -0.49$; $p = 0.001$) among children. The presence of CAP laws was moderately associated with fewer firearm suicides among children ($\rho = -0.56$; $p < 0.001$). States that had a CAP score of 2 had a pediatric firearm suicide rate of 0.633 per year per 100,000 children, although states that lack both access laws or laws regulating firearm storage or lock requirements (CAP score = 0) had a firearm suicide rate of 2.573 per year per 100,000 children (Fig. 5). The negative association between the presence of CAP laws and firearm homicide rates was negligible.

When controlling for unemployment rates, poverty rates, and the number of registered firearms, the correlation between Brady score and firearm homicide rates was no longer statistically significant. Similarly, the relationship between Brady score and firearm suicide rates was not statistically significant after controlling for the same state-level factors. However, even after controlling for socioeconomic factors, Brady score, and number of registered firearms, the association between presence of CAP laws and firearm suicide rates remained significant ($\beta = -0.22$; 95% CI -0.440 to -0.003; $p = 0.04$).

DISCUSSION

Our study found that stricter state firearm legislation as quantified by the Brady scorecard was significantly associated with fewer firearm-related fatalities in children and teens. The CAP laws were similarly and significantly associated (moderate negative) with decreased firearm-related suicide rates, but not with overall firearm-related mortality. These associations remained significant after accounting for socioeconomic factors. The Brady scorecard had low negative associations with firearm homicide and suicide rates individually that were not statistically significant after accounting for socioeconomic factors. Likewise, the CAP score had low negative and negligible associations with overall firearm mortality and homicide rates, respectively, which were also not significant on multivariate analysis.

This research contributes to the national dialogue on how to address firearm-related fatalities, particularly in children. There are more than 300 federal gun laws that regulate the sale, transport, and possession of firearms in the US[5,24]; however, there is great variability on the state and local levels in the implementation of firearm regulations and little research on the effect of these laws. When compared with countries with similar economic

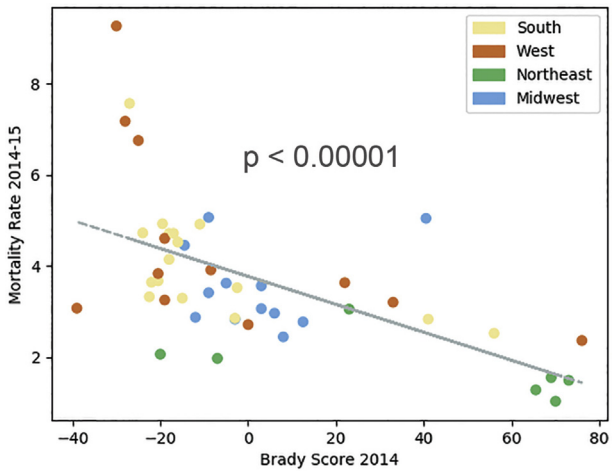

Figure 3. Relationship between Brady score (2014) and firearm-related mortality rate by state and region.

development and political structure, the US is the most dangerous of nations for children, with pediatric deaths from firearm injuries as a leading contributor. Among the 23 wealthiest developed nations, the US accounts for approximately 30% of the overall population, but >90% of deaths due to firearms among children aged younger than 15 years.[25] A child is 82 times more likely to die from firearm-related injuries in the US than in other similar nations.[26] Fowler and colleagues[27] estimated nearly 19 children per day die or are treated for gunshot wounds in the US. The US has higher rates of homicide, suicide, and unintentional injury by firearm than any other industrialized nation.[28]

To our knowledge, this is the first study to examine the relationship between firearm legislation stringency and pediatric firearm fatalities using both overall stringency and child-specific legislation. To date, a few studies have examined firearm legislation stringency and pediatric firearm injuries. Safavi and colleagues[29] dichotomized states into strict firearm law states or non-strict firearm law states, based on child-specific legislation using Brady Campaign data and data pulled from individual state resources. Their group found that non-strict states had a higher mean firearm injury rate per 1,000 pediatric trauma patients. Non-strict states in their analyses increased the mean firearm injury rate by 3.75 compared with strict firearm law states. Tashiro and colleagues[30] compared legislative stringency with inpatient pediatric hospital admissions. Using Brady scores to classify states as either lenient or strict, they found that more hospital admissions due to firearm-related injuries occurred in lenient states. They identified an overall pediatric in-hospital mortality of 7% from firearm injuries during their study period. Propensity score-matched analysis found mortality was higher in lenient states (7.5%) vs strict states (6.5%). Our study findings of a moderate negative correlation between pediatric fatality and increased legislative stringency are consistent with these previously noted overall trends in pediatric firearm-related injuries. We note that when firearm legislation is treated as a continuous variable, rather than dichotomous, there is a dose-dependent correlation: states with more stringent firearm legislation are associated with decreased pediatric firearm mortality. We found the states with the least stringent laws had an annual pediatric firearm mortality rate twice that of states with the most stringent laws. Additionally, we found suggestion that the cumulative stringency of laws of neighboring states might have a similar relationship, as exhibited by the low negative correlation with pediatric firearm mortality.

Of note, studies examining the effect of legislative stringency on firearm injuries have found the most common mechanism of injury is typically assault, followed by accidental or undetermined, and trailed distantly by self-

Variable	Correlation with Firearm Mortality Rate (0-19 yrs)	Spearman's rank correlation coefficient	Correlation with	
			Firearm Homicide rate	Firearm Suicide Rate
Brady score	Moderate negative	ρ = -0.662, P < 0.001	Low negative	Low negative
Neighbors' Brady score	Low negative	ρ = -0.497, P < 0.001	Low negative	Negligible
Unemployment rate	Low positive	ρ = 0.463, P = 0.003	Moderate positive	Negligible
CAP score	Low negative	ρ = -0.314, P = 0.03	Negligible	Moderate negative
Tobacco use %	Low positive	ρ = 0.382, P < 0.001	Low positive	Moderate positive
High school graduation rate	Low negative	ρ = -0.330, P = 0.02	Negligible	Low negative
Urban population %	Low negative	ρ = -0.338, P = 0.02	Low negative	Low negative
Firearms registration rate	Low positive	ρ = 0.426, P = 0.003	Negligible	Low positive
Supplemental poverty rate	Negligible	ρ = 0.202, P = 0.172	Low positive	Negligible
Marijuana use %	Negligible	ρ = -0.247, P = 0.100	Negligible	Negligible
Alcohol dependence %	Negligible	ρ = -0.162, P = 0.274	Negligible	Negligible

Figure 4. State-level factors and their correlation with the outcome measures. Spearman's rank correlation coefficient (ρ) and p values are given for the primary end point, overall pediatric firearm mortality. All variables treated as continuous. Child access prevention (CAP) scores hold values of 0, 1, or 2. Tobacco use and marijuana use reflect percentage of survey respondents who indicated use within the last 30 days; participants were 12 to 17 years old.

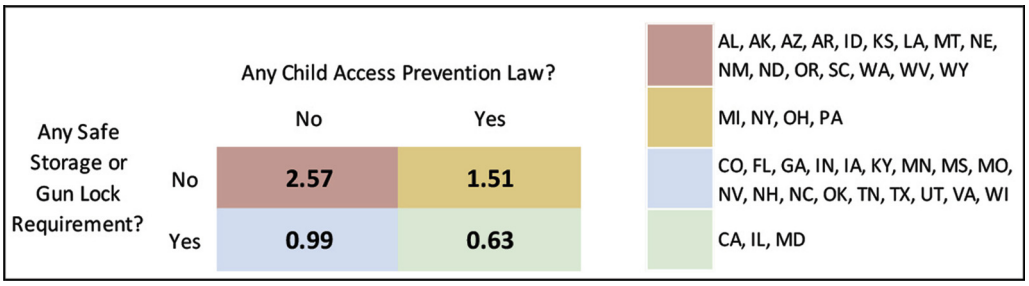

Figure 5. Firearm suicide rates by presence of any child access prevention law (ie laws imposing criminal liability when a minor child gains access to a firearm, laws preventing people from providing firearms to minors, and safe storage requirements that apply to all firearms) and safe storage or gun lock requirements (ie laws concerning locking devices or storage in certain circumstances, or with certain types of guns). Five states (CA, CT, MD, MA, NY) have state-mandated standards for locking devices.

inflicted/suicide, with suicide typically accounting for just 3% of the cohorts.[30,31] Consequently, many studies have focused on the effect of firearms legislation on unintentional injury.[11,12] In our study, we found that suicides accounted for 31.4% of national pediatric firearm fatalities. The leading cause of fatality remains assault. This underscores the lethality of firearms when the intent is to cause harm. The case-fatality rate (ie proportion of cases resulting in death) is highest for suicides. Fowler and colleagues[27] reported that from 2012 to 2014, average annual case fatality rate was 74% for firearm-related suicides, 14% for firearm-related assault, and 6% for unintentional firearm injuries. In unadjusted analyses, we found that higher Brady scores and CAP laws were negatively associated (moderate-strength correlation) with fewer firearm-related suicide deaths. States without CAP laws had a 4-fold higher firearm-related suicide rates compared with states with the most extensive CAP laws (CAP score = 2). This association remained significant, even after accounting for potential confounders, such as gun ownership rates.

The use of firearms has consistently been one of the most common methods for suicide in adolescents in the US, accounting for 42.6% of adolescent suicides from 2000 to 2016.[5] Numerous case-control studies have demonstrated that the presence of firearms in the home substantially increases the risk of adolescent suicide.[32-34] A separate case-control study in 2005 found that safe gun storage practices are associated with a decreased risk of teen suicide and unintentional firearm injuries.[35] Our analysis found only a low negative association between overall state firearm legislation stringency and suicide; however, CAP laws were more significantly associated (moderate correlation) with decreased suicide rates, suggesting that they can play an important role in reducing pediatric firearm suicide. Firearm storage and lock requirements can provide enough of a barrier to adolescents who are contemplating suicide, which is often an impulsive decision in this age group. Studies have demonstrated that teens who attempt suicide deliberate for as few as 10 minutes or less.[36,37] Preventing access to lethal means like firearms, even without adapting broader firearm legislation, can help reduce pediatric suicide rates across the country.

Between 2002 and 2007, there was a 17% increase in firearm homicide rates among children; from 2007 to 2014, there was a 60% increase in child firearm suicide rates.[27] Although we did find a significant association (moderate negative correlation) between firearm legislation stringency and overall pediatric mortality after accounting for socioeconomic factors, the correlation did not remain significant when considering homicide deaths alone. The CAP scores similarly had a negligible association with pediatric firearm homicide rates that was not statistically significant. Firearm homicide rates, however, are thought to be multifactorial and more closely associated with socioeconomic variables. Price and colleagues[9] found that firearm legislation was associated with only 10% of the variation in homicide rates; the majority of the variation was ascribed to firearm ownership rates and socioeconomic factors. Other studies have noted significant variations in pediatric firearm homicide rates associated with racial disparities, drug and alcohol abuse, and poverty.[38,39] Our study similarly found many socioeconomic variables, including unemployment rates, percent urbanization, poverty rates, and teen tobacco use, were associated with firearm homicide rates in unadjusted analysis. Firearm-related homicide in children remains a complex, multifaceted problem. Given the recent trends, more research is needed to identify meaningful ways to reduce firearm-related homicides among children.

There are several limitations to this study. As we evaluated only state-level information, these results are not

generalizable at the individual person level. Our study examined a limited time period, and a longitudinal study can provide additional details about important time trends and draw stronger conclusions on the effect of firearm legislation on pediatric firearm mortality. This study was not able to control for differences in enforcement of state firearm legislation. There might be additional state-level variables or socioeconomic factors that were not captured by our identified confounders. Some of the state-level variables, like tobacco use and marijuana use, were gathered from a subset of the pediatric population (ages 12 to 17 years). Extrapolating data from subsets of the population and applying it to the entire group can cause error in our analysis, including our positive correlation between tobacco use and firearm-related suicide rates. However, suicide by any mechanism in children younger than 10 years is exceedingly rare,[40] therefore, we are confident that the correlation is valid, despite the limitation in the data set. Overall state gun death rates are a component of the Brady scores, which can correlate to pediatric firearm mortality rates independently. However, the death rates contribute only 10% to the Brady scores and include both adults and children, minimizing the possible correlation to pediatric firearm mortality rates independently. Lastly, when analyzing independent predictors, we attempted to control for the number of firearms in each state with the number of registered firearms, which is a limited subset of the total number of firearms, as only certain types of firearms are required to be registered. Furthermore, each state has separate and variable laws related to what type of firearm must be registered in that state. Future work will aim to address some of these limitations by examining pediatric firearm-related deaths and state-level legislation over time.

CONCLUSIONS

Stricter state firearm legislation and CAP laws are associated with lower overall pediatric firearm mortality rates and pediatric firearm suicide rates, respectively. Additional state legislation could play an important role in reducing firearm fatalities in the pediatric population, particularly by reducing the number of suicides.

Author Contributions

Study conception and design: Madhavan, Staudenmayer, Chao

Acquisition of data: Madhavan, Taylor, Chandler, Chao

Analysis and interpretation of data: Madhavan, Taylor, Chandler, Staudenmayer, Chao

Drafting of manuscript: Madhavan, Taylor, Chandler, Staudenmayer, Chao

Critical revision: Madhavan, Taylor, Staudenmayer, Chao

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