

**Title:** Firearm legislation and firearm mortality in the United States

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## **Panel: Research in context**

### **Evidence before this study**

We searched PubMed with the terms ("gun" OR "firearm") AND (policy OR law OR legislation OR legislature OR laws OR policies) for articles published in any language before May 1, 2015. The search yielded a total of 1154 articles, with 1008 remaining after restriction to “humans”. There were several articles that assessed the effect of one or few firearm laws or policies. We identified six articles that studied the impact of multiple laws on firearm deaths in the United States,<sup>1-6</sup> and only two considered all firearm laws as a score.<sup>1,6</sup>

### **Added value of this study**

Our findings demonstrate the effectiveness of a few laws in reducing firearm mortality, while the majority of laws were either ineffective or inconclusive. We found that federal level implementation of the three most effective laws; universal background checks for firearm purchase, background checks for ammunition, and requiring firearm identification by either micro-stamping or ballistic fingerprinting would markedly reduce the overall national firearm mortality rates.

### **Implications of all the available evidence**

Very few of the existing state-specific firearm laws are effective at reducing firearm mortality rates and underscore the importance of legislative focus on relevant and effective legislation.

## Abstract

**Background:** In an effort to reduce firearm mortality rates in the US, states have enacted a variety of firearm laws to either strengthen or deregulate the existing primary federal gun control law, the Brady Law. We determined the independent effect of different firearm laws on overall, homicide, and suicide firearm mortality rates across all US states. We also projected the potential reduction of firearm mortality rates if the three most effective firearm laws were enacted at the federal level.

**Methods:** We constructed a state-level panel dataset using firearm mortality rates from the Centers for Disease Control and Prevention's Web-based Injury Statistics Query and Reporting System in 2010, 25 firearm state laws implemented in 2009, and state specific characteristics such as firearm ownership, firearm export rate, non-firearm homicide rate and unemployment rate. Poisson regression with robust variances was used to derive the incidence rate ratios (IRR) and 95% confidence intervals (95%CI).

**Findings:** We identified nine effective, nine ineffective, and seven firearm laws with inconclusive effect to reduce firearm mortality. After adjusting for relevant covariates, the three most effective laws in reducing overall firearm mortality were universal background checks for firearm purchase (IRR=0.39, 95%CI=0.23-0.67), ammunition background checks (IRR=0.18, 95%CI=0.09-0.36) and identification requirement for firearms (IRR=0.16, 95%CI=0.09-0.29). These laws also reduced homicide firearm mortality rates, while firearm identification reduced suicide rates. Projected federal level implementation of universal background checks for firearm purchase would reduce

national firearm mortality rates from 10·35 to 4·46, background checks for ammunition purchase to 1·99 and firearm identification to 1·81 per 100,000.

**Interpretation:** Implementation of universal background checks for firearm or ammunition purchase and firearm identification nationally can substantially reduce firearm mortality in the US.

**Funding:** There was no funding for this study.

Keywords: firearm mortality, legislature, policy, regulations

Firearm violence in the United States is an issue of substantial public health concern.<sup>7</sup> Mortality due to firearms is endemic, characterized by stable national fatality rates since 2000.<sup>8</sup> On average, more than 90 people are killed every day using firearms in the US.<sup>9</sup> This burden of fatal firearm injuries varies widely between states and by race/ethnicity with higher firearm mortality rates among blacks than whites.<sup>8,9</sup> Firearm mortality primarily occurs among young adults and accounts for 80% of all homicides and 45% of all suicides within this age group.<sup>9,10</sup>

Firearms are ubiquitous in the US, and the high rates of firearm ownership have been directly associated with increased risk of firearm-related mortality.<sup>11,12</sup> Firearm violence prevention has had limited success in the form of a federal law, “Brady Handgun Violence Prevention Act”, (Pub.L.103–159, 107 Stat. 1536, enacted November 30, 1993, effective on February 28, 1994), commonly called the Brady Law. The Brady Law requires background checks to be conducted on individuals before a firearm may be purchased from a federally licensed dealer, manufacturer or importer—unless an exception applies.<sup>13</sup> However, the loopholes to this statute allow unfettered sales from unlicensed dealers. To offset the limitations of the Brady Law, several states have instituted separate laws intended to fill these gaps.<sup>1,4</sup> States have implemented firearm laws in an effort to reduce firearm access to children and to regulate firearm storage practices.<sup>2,3</sup> Conversely, many states have also enacted laws aimed to further deregulate the carrying of firearms through “Stand Your Ground” laws.<sup>2</sup> These state regulations have been implemented either as amendments to an existing firearm law or as a separate legislation.

There is some preliminary evidence regarding the effectiveness of the different state laws in reducing firearm mortality.<sup>1,3,14</sup> However, current evidence has focused on assessing either the cumulative effect of number of firearm laws or an arbitrary legislative strength score<sup>1</sup> and the effect of a select few laws such as “stand-your-ground” or “child access prevention” (CAP).<sup>3,14</sup> To our knowledge, there are no studies that have assessed multiple firearm laws together with all relevant state-level characteristics. Given the numerous firearm laws in different states, we built on the available evidence to determine the independent effect of different firearm laws on firearm mortality taking into account relevant firearm laws and state-specific characteristics. We determined the independent effect of these laws on firearm-related homicide and suicides separately. We also projected the potential reduction of firearm mortality rates if the three most effective firearm laws were enacted at the federal level.

## **Methods**

### *Study design*

We conducted a state-level panel study to study the impact of different firearm legislation on firearm mortality taking into account state-specific firearm legislation, unemployment, non-firearm homicide, firearm export and firearm ownership rates based on previous studies (**Supplementary Figure 1**).<sup>1,3,4,15</sup> The Columbia University Ethics Review Board deemed the study exempt from federal regulations for the protection of human research participants.

## *Data sources*

### *Firearm mortality*

Counts of firearm deaths in each state for years 2008-2010 and according to intent (homicide and suicide) were obtained from querying the restricted version of Center for Disease Control's (CDC), Web-Based Injury Statistics Query and Reporting System (WISQARS).<sup>9</sup> We extracted counts of non-firearm homicide and overall firearm mortality counts and rates in each state during 2009. Mortality data in the WISQARS is compiled by the National Center for Health Statistics using data from the death registry.

### *Firearm legislation*

State-specific firearm related legislation for the year 2009 was obtained from the Brady Center to Prevent Gun Violence<sup>16</sup> and validated using LexisNexis Academic. Since 2007, the Brady Center has published annual reports regarding state-specific firearm legislature and an arbitrary legislative scorecard with specific score.<sup>16</sup> Since firearm legislation pivoted increasingly pro-firearm beginning in 2009, we grounded our study in 2009 firearm legislation to assess the positive impact of firearm laws.

### *State-level characteristics*

The annual averages of the employment status of the civilian non-institutional population for the year 2010 was obtained from the Bureau of Labor Statistics.<sup>17</sup> We used employment status from 2010, since a major proportion of firearm fatality are suicides, and suicides are associated with critical incidents such as loss of a job.<sup>18</sup> Annual data on employment, and unemployment in the states and sub-groups within the United States are available from the Current Population Survey (CPS) and the Local Area Unemployment Statistics (LAUS) program.<sup>19,20</sup> The CPS is conducted by U.S. Census Bureau for the

Bureau of Labor Statistics and samples about 50,000 households,<sup>19</sup> while LAUS is a Federal-State cooperative program in participation with State employment security agencies.<sup>20</sup> Firearm export data for each state was obtained from Bureau of Alcohol, tobacco, firearms and explosives (ATF), United States Department of Justice.<sup>21</sup> The ATF traces firearms on behalf of thousands of Federal, State, local and foreign law enforcement agencies and prepares state-by-state reports utilizing trace data, which is intended to provide the public with insight into firearms recoveries. Firearm ownership was assessed using data from a survey by YouGov among individuals >18 years in United States in 2013.<sup>15</sup> We used firearm ownership rates from 2013, since the last available rates in each state are available for year 2004 and firearm ownership rates are reported to decline.

### *Outcome*

Our primary outcome measures were overall firearm-related mortality per 100,000 persons in 2010. Secondary outcomes were firearm-related homicides and suicides.

### *State characteristics*

All firearm legislations are presented in **Supplementary Appendix I** and **Table 1**. The annual averages of the employment status of the civilian non-institutional population for the year 2010,<sup>17</sup> firearm export rate of crime guns for each state in 2009,<sup>21</sup> firearm ownership rates in different states<sup>15</sup> and non-firearm homicide rates in 2009 per



100,000 persons<sup>9</sup> were categorized into four groups by quartiles. Details of covariates are presented in **Supplementary Appendix 2**.

### *Statistical analysis*

First, we assessed the distribution of the total counts of firearm-related mortality rates in 2010. Since the variance of our outcome was equal to the mean, we used poisson regression with population as offset to normalize population sizes and robust standard errors.<sup>22</sup> We performed crude and multivariable poisson regression to estimate how the presence of a given law corresponded to rates of firearm mortality in the US states and derived the incidence rate ratios (IRR), 95% confidence intervals (95%CI) and corresponding p-values. Model fit was assessed using deviance goodness-of-fit, McFadden's Adjusted  $R^2$  and Akaike Information Criteria.<sup>23</sup> The model fit statistics are presented in **Supplementary Table 1**. Second, from the final model, we predicted the probabilities for observing firearm mortality rates for each state. Third, using the firearm risk profile for each state, we predicted the relative risk as of 2009 and then the relative risk if the states passed each of the effective firearm law. Fourth, we then predicted the discrete change in firearm mortality rates associated with federal level implementation of three most effective laws. Fifth, we performed sensitivity analysis using the change in firearm mortality rate from 2008 to 2010 as the outcome. We also assessed the effectiveness of laws after combining the laws into categories, while keeping stand-your-ground and restriction in “conceal carry” as separate laws. Sixth, crude and multivariable models were used to determine the effectiveness of each firearm law separately for firearm homicides and suicides. STATA 13.1 (STATA Corp LP, College Station, TX,

USA) was used to manage the data, to conduct the analyses. All statistical tests were two-sided.

### *Role of the funding source*

There was no funding for this study. The corresponding author had full access to all the data and had final responsibility for the decision to submit for publication.

## **Results**

A total of 31,672 firearm-related deaths occurred in 2010 (10.1 per 100,000) in the US, with a mean state-specific count of 631.5 and standard deviation of 629.1 events, Hawaii had the lowest rate (3.31 per 100,000, count=45) while Alaska had the highest (20.3 per 100,000, count=144). There were 25 laws in existence that were either control or permissive. Laws prohibiting firearms in the workplace or campus was present in most states and not used for this analysis.

**Figure 1** presents the crude and adjusted analysis to assess the independent effect of each firearm law on firearm-related deaths. Predicted probabilities of firearm deaths in 2010 in each state are presented in **Supplementary Figure 2**. After adjusting for covariates, nine laws were found to be associated with a lower likelihood of firearm-related deaths (effective), nine laws to be associated with a higher likelihood (ineffective) and seven laws did not show any significant effect (inconclusive). The nine effective control laws were state license to sell firearms (IRR=0.91, 95%CI=0.85-0.97), keep and retain sales records (IRR=0.79, 95%CI=0.74-0.85), at least one store security precaution (IRR=0.84, 95%CI=0.76-0.92), firearm identification (IRR=0.16, 95%CI=0.09-0.29),

report lost or stolen firearms (IRR=0.54, 95%CI=0.40-0.74), universal background checks for all firearms (IRR=0.39, 95%CI=0.23-0.67), safety training or testing requirement to purchase firearms (IRR=0.57, 95%CI=0.45-0.73), law enforcement involvement in obtaining a permit (IRR=0.70, 95%CI=0.61-0.80) and background check for the purchase of ammunition (IRR=0.18, 95%CI=0.09-0.36).

The nine laws associated with an increase in the risk of firearm-related deaths were dealer requirement to report records to state for retention, allowing police inspection of stores, limitation in the number purchased, a three-day limit for background extension, background checks and/or permits during gun shows in those states without universal background check requirement, integrated or external or standard locks on firearms, ban or restrictions placed on assault weapons, law enforcement discretion permitted when issuing conceal carry permits and stand-your-ground.

**Table 2** presents the predicted relative risk of firearm mortality rate in four states using 2009 state laws in each state. In 2009, Alaska had only stand-your-ground, a permissive law, low unemployment, highest rates of firearm ownership, non-firearm homicide and export rates with a 2009 rate of 14.9 per 100,000 and IRR=2.74, 95%CI=2.29-3.30. The firearm mortality rate was 20.27 per 100,000 in 2010. Firearm mortality rate can be maximally reduced by firearm identification, firearm background check and ammunition background checks laws. For Florida with stand-your-ground and CAP laws, IRR=2.09; 95%CI=1.84-2.37, firearm identification and ammunition background check laws will significantly reduce the incidence rate by 66% and 63% respectively. For California with 20 laws, seven effective, eight ineffective and five inconclusive, IRR=1.36; 95%CI=1.20-1.54, implementing owner theft reporting and

ammunition background check will reduce the incidence by 26% and 76% respectively. For New York with 15 laws, five effective, six ineffective and four inconclusive,  $IRR=0.90$ ,  $95\%CI=0.79-1.01$ , store security precaution, safety training, universal background checks and ammunition background checks were determined to reduce the incidence of firearm deaths by 25%, 48%, 65% and 84% respectively. **Supplementary Table 2** presents the predicted relative risk of firearm mortality rate in the remaining 46 states.

**Table 3** presents the change in national firearm mortality rate with federal-level implementation of three effective firearm laws. Keeping 2009 firearm mortality rates at the national rate, if background check law was implemented, we found the firearm mortality rate to reduce from 10.35 to 4.46 per 100,000. Similarly, in the presence of ammunition background checks, the rates would decrease to 1.99 per 100,000 and with firearm identification requirements the rates will be 1.81 per 100,000. Based on our model, national-level implementation of background checks for firearm purchases, for ammunition purchases and firearm identification may reduce firearm mortality rates by 57%, 81% and 83% respectively.

**Table 4** presents the results of the adjusted analysis to assess the independent effect of each firearm law on homicide and suicide firearm-related deaths. Six laws significantly reduced the rates of firearm-related homicide deaths, with the largest reduction by background checks for ammunition and firearm identification. There were five ineffective laws and 14 inconclusive laws. Firearm identification and permit process involving law enforcement reduced firearm-related suicide deaths while there were three ineffective laws and remaining 20 laws were inconclusive.

Sensitivity analyses to assess the effectiveness of firearm law categories on overall, homicide and suicide firearm-related deaths are presented in **Supplementary Table 3**, and effectiveness of firearm laws on the change in firearm-related mortality rate from 2008 to 2010 in **Supplementary Table 4**. These results were similar to the main findings.

## **Discussion**

Using a comprehensive dataset including all state-specific firearm laws, we found nine laws to be effective in reducing overall firearm mortality, nine to be ineffective, and seven to be inconclusive in decreasing firearm mortality rate. The three most effective laws were universal background checks for firearm purchase, background checks for ammunition, and requiring firearm identification by either micro-stamping or ballistic fingerprinting. We found that federal-level implementation of the three effective laws would markedly reduce the overall national firearm mortality rates. Finally, the three most effective laws to reduce homicide-specific firearm mortality rates were universal background checks for firearm purchase, background checks for ammunition and firearm identification; firearm identification reduced the suicide-specific firearm mortality rates.

We identified nine laws that reduced firearm mortality rates, in line with evidence from national and international studies that established the protective effect of firearm control policies.<sup>1,3,4,24</sup> Legislation regarding background checks for firearm and ammunition purchase was the most effective legislation identified in our study, similar to another panel study demonstrating the protective effect by those laws that strengthened the federal Brady Law.<sup>1</sup> The major flaw in the Brady Law allows private owners, gun

shows and unlicensed dealers to transfer firearms freely, even to persons prohibited from owning firearms.<sup>25</sup> Together with laws to strengthen background checks, we found three effective firearm dealer regulations, which was in contrast to results in a cross-sectional study that found all firearm laws that curb trafficking to be inconclusive.<sup>1</sup> The inconclusive effect in this earlier study could be due to a pooled category containing all dealer and owner regulatory laws, while our study considered the laws individually under separate categories. Another panel study evaluating the effect of state regulations found similar results to our study where individual laws were either effective or ineffective, specifically the effect of state license requirement for dealers to sell firearms.<sup>4</sup>

The presence of both effective and ineffective laws has also been reported in another study that assessed the impact of firearm regulatory laws on firearm homicides, where state licensing and authorized inspections were associated with lower homicide rates, while record keeping did not reduce homicides.<sup>4</sup> Our analysis indicates ineffective CAP laws, which are in line with conflicting results regarding the impact of CAP laws available to-date.<sup>1,3</sup> In a nationally representative study that used Brady legislative score, an protective effect of CAP laws was found with a differential according to firearm storage characteristics.<sup>14</sup> In contrast, we found that requirements for firearm locks, one of the CAP laws to be ineffective, which was similar to the null effect reported in a study evaluating the effect of firearm dealer regulations on firearm homicides.<sup>1</sup> The increased risk attributed to firearm locks in our study could be explained by the results of this longitudinal study where presence of CAP laws was associated with an increased likelihood of unsafe firearm storage in states with fewer firearm policies.<sup>22</sup> On the other hand, we found the permissive stand-your-ground law, to be associated with an increased

risk in firearm mortality rate, which was similar to an analysis, where stand-your-ground was associated with an increase in accidental firearm injuries.<sup>2</sup>

After establishing the independent impact of each firearm law based on 2009 state firearm policies and related characteristics and 2010 firearm mortality rates in each state, we predicted the impact of nine effective laws in each of the 50 states and the magnitude of reduction in firearm mortality rates. Strengthening the Brady Law<sup>13</sup> by universal background checks was found to be the most effective legislation along with firearm identification, a firearm owner regulation. Our projected decrease related to comprehensive background checks was in line with current scientific evidence and the scientific support for passing this crucial legislation.<sup>3,5,26</sup> On a national level, our projected rates of reduction in firearm mortality rates directly addresses the primary recommendation by an interdisciplinary, inter-professional group of leaders of national health professional organizations and the American Bar Association.<sup>27</sup>

Our finding of the three most effective laws for homicide firearm mortality rates to be expanding background checks to all firearm and ammunition purchase in addition to firearm identification, was analogous to the results by a few state panel studies that assessed the impact on all and intent-specific firearm mortality rate.<sup>1</sup> Our results also substantiate the findings by a state-level study that determined the effects of the differences among states in the background checks required for firearm purchase and reported that performing local-level background checks was associated with a 22% lower homicide rate.<sup>5</sup>

Several limitations are to be considered when interpreting our findings. The main limitation is that our study design takes into consideration state characteristics in 2009

and the outcome of firearm mortality rate in 2010, without considering the various changes and the duration of the firearm laws in place. Assessing the impact of legislative policies is akin to evaluating the impact of natural experiments or real world data. We expect the drop in mortality to be a long-term effect and may take years to take effect. There are several confounding social and state-level factors along with multiple firearm laws that act both before and after the respective laws, therefore, there may be some residual confounding. Due to the lack of state-specific firearm ownership rates, we used ownership rates from 2013 as an approximation since we found no difference in national rates at 2004 and 2013.<sup>28</sup> However, we recognize state-level differences and the direction of the error cannot be assessed. We were unable to obtain state-level estimates of firearm storage practices to be used as a covariate. The majority of firearm deaths are either homicide or suicide, with a small proportion of unintentional mortality, which is directly related to unsafe storage practices. Some of the firearm laws that were intended to reduce firearm violence did not show any conclusive effect; and this could be a reflection of either a true non-impact or may be as chance or not having sufficient duration after implementation to demonstrate true effect. We have not included suicide prevention programs in our model due to wide variation in the setting of such programs. Variation in suicide prevention programs (implementation and effectiveness) across different states may also contribute to some residual confounding.

In conclusion, we demonstrate an overall strong benefit by comprehensive background check laws for firearm and ammunition purchases and firearm identification laws to effectively reduce firearm mortality rates, while the stand-your-ground law was associated with a significant increase in firearm mortality rates. Implementation of



background checks was associated with a reduction in firearm homicide rates and firearm identification laws with suicide rates. It is important to understand that only some of the existing state-specific firearm laws are effective at reducing firearm mortality rates, underscoring the importance of legislative focus on relevant and effective legislation.

### Contributors

All authors were involved in study design, data consolidation and processing, model development, analysis, and writing and editing of the manuscript.

### Declaration of interests

We declare no competing interests.

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