# State firearm laws, gun ownership, and K-12 school shootings: Implications for school safety

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## Abstract

Limited research has been conducted on the state-level factors that may be associated with intentional school shootings. We obtained school shooting data from the *Washington Post* that identified any act of intentional interpersonal gunfire in a K-12 school over the course of two decades. We also compiled new data on active school shootings during the same twenty-year time period, which identified any attempted mass shooting incident in a K-12 school. We conducted a time-series analysis to measure the association of permissiveness of state firearm laws and state gun ownership with K-12 school shootings and active shootings. More permissive firearm laws and higher rates of gun ownership were associated with higher rates of both school shootings and active school shootings after controlling for critical covariates. Specific recommendations for K-12 schools to consider as they seek to prevent acts of intentional gunfire on school grounds are presented.

## Keywords

school violence; mass shootings; shooting shootings; school safety; active shootings; gun violence

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## Introduction

Gun violence in the United States persists as a significant public health crisis; in 2019, over 100,000 Americans were injured with a firearm (*Web-Based Injury Statistics Query and Prevention*, 2020). Approximately 38,000 individuals die via firearms each year, of whom an estimated 3,000 are children ages 1–19 years (*Web-Based Injury Statistics Query and Prevention*, 2020), and firearm injury was the leading cause of death among 10–24 year olds in the U.S. in 2019 (*Firearms Are the Leading Cause of Death for American Children and Teens*, 2021). While gun violence specifically in K-12 schools represents a relatively small proportion of the total number of deaths from firearms (*Web-Based Injury Statistics Query and Prevention*, 2020), it remains a prominent public safety concern (Kalesan et al., 2017).

Early research on school shootings highlighted that access to firearms was key to explaining gun violence in K-12 schools (Newman et al., 2004). However, in the past, data that addressed access to firearms were not readily available. Indeed, national efforts to collect data on school violence more broadly did not begin until 1989 (Carlton, 2017). Studies were able to document where school shootings were occurring, but the quantitative data required to rigorously assess the relationship between incidence and location was limited (Newman et al., 2004). The question has since remained: are some states more likely to experience school shootings and, if so, what factors offer insight into state-level differences? In this present study, we utilize novel data on K-12 school shootings to address this important question and discuss the implications of these findings for the prevention of school gun violence.

It is important to note that school shootings have been occurring for decades, however, there has been a uptick in school shootings since the 1990s (Carlton, 2017; Katsiyannis et al., 2018). Following the Columbine shooting in 1999, the yearly incidence of school shootings remained relatively constant until a noticeable uptick occurred again beginning in 2015 (Cox et al., 2021; *Gunfire on School Grounds in the United States*, 2019; Parks et al., 2019). In addition, the ripple-effect of gun violence on school communities is not limited to physical injuries or death, with potentially traumatic implications for children, thus underscoring the importance of making every effort to prevent these types of violent acts (Rajan et al., 2019). Indeed, researchers have argued that the prevention of school gun violence must draw on safety principles that conceptualize the prevention of gun violence as a public health crisis in ways that also attend to the developmental, health, and learning needs of students in particular (Cohen, 2021; Rajan, 2021). And this present study builds on this further by considering the ways in which the safety of a school's surrounding community impacts the safety of a school's environment (Lewallen et al., 2015).

Estimates suggest that more than 275,000 K-12 students have been exposed to some form of gun violence in their schools since the Columbine High School mass shooting in Colorado in 1999 (Cox et al., 2021). Intentional forms of gun violence in particular (for example, attempted mass shootings) have undoubtedly also had a significant effect on the health of those who, while not physically injured, may have witnessed a shooting and/or had a friend or family member victimized by gunfire (Rajan et al., 2019). Consequently, K-12 schools

across the country have continued to engage in efforts to prevent this kind of violence in their communities, but with mixed results. For example, schools have implemented zero-tolerance policies to punish students for more minor infractions (for example, bringing a knife to school), hoping this will ultimately deter more serious behaviors in the long-term (Borum et al., 2010). Yet, the effectiveness of these policies at deterring such violence has not been established (P.M. Reeping et al., 2021). For example, work by the American Psychological Association has noted that such policies likely negatively impact the well-being of its students without any corresponding and notable improvement in the safety of the school environment (Skiba, 2008). And additional research has confirmed that zero tolerance efforts do not effectively address the root cause of the problem and cause more disruption to students and schools than good (Teske, 2011). However, educators and psychologists alike have expressed many concerns about the potential harm zero tolerance policies may cause by criminalizing a school and its students (Borum et al., 2010).

Threat assessment (an investigation by school personnel into a student whose behavior raises concerns) has shown some promise (Astor et al., 2013; Borum et al., 2010; Cornell & Maeng, 2018). And new research suggests that, when implemented thoughtfully, with clearly defined objectives, and framed with the goal of empowering students and teachers, lockdown drills may be able to help schools feel prepared if a school shooting were to occur (Borum et al., 2010; Schildkraut et al., 2020). Nonetheless, it is important to note that in spite of the increased presence of these various school safety tactics and policies, the number of K-12 school shootings has nevertheless continued to increase across the U.S. over the past five years (*Gunfire on School Grounds in the United States*, 2019) suggesting that macro-level changes are likely needed to effectively prevent this kind of violence on a larger scale.

One factor that contributes to the persistence of gun violence more broadly in the U.S. is the ubiquity of firearms. For example, researchers have reported a clear relationship between gun possession and the likelihood of being shot (Branas et al., 2009). And data from the Centers for Disease Control and Prevention have indicated that the majority of firearms used in school shootings (whether homicides or suicides that take place on a school's campus) come from the perpetrator's home or from a home of a friend or relative (*School-Associated Violent Death Study*, 2019). Therefore, one might hypothesize that higher rates of firearm ownership would be associated with the higher rates of school shootings.

In addition, a considerable body of research has specifically examined the permissiveness of a state's body of firearm laws, indicating that states with more permissive firearm laws and higher rates of gun ownership are associated with higher levels of gun homicide, gun suicide, and mass shootings (Anestis et al., 2015; Conner & Zhong, 2003; Fleegler et al., 2013; L. Hepburn et al., 2006; M. Miller et al., 2006; Paul M Reeping et al., 2019; Siegel et al., 2013) including among children (Goyal et al., 2019; Mathew Miller et al., 2001). It is therefore also reasonable to hypothesize that the permissiveness of a state's body of gun laws may also contribute to higher rates of shootings K-12 schools. To date, we know of no research that has evaluated the relationships between (1) firearm ownership and K-12 school shootings, and (2) permissiveness of a state's body of gun laws and K-12 school shootings.

At the same time, and contributing to the challenges associated with preventing gun violence in K-12 schools, the operationalization of the term "school shooting" is not fixed. Researchers have no agreed upon definition, with expansive parameters often allowing for definitions to include unintentional discharges and suicide attempts as well as shootings that occur off of school property but within the federally demarcated "gun-free school zone." Although the prevention of accidents, suicides, and nearby shootings is extremely important, we are specifically interested in efforts that focus on the prevention of intentional interpersonal school gun violence. To our knowledge, no studies exploring the relationship between state firearm laws and gun violence that have also considered if the perpetrator intended to commit a mass shooting when defining school shooting have been published. This work is particularly needed as communities struggle to identify the most effective ways to reduce injury and death from intentional interpersonal gun violence on school grounds.

To address this critical knowledge gap, our research team developed a comprehensive dataset that captured, over a two-decade period, all active school shootings, defined as any *attempted* mass shooting incident in a K-12 school, as confirmed by authorities where four or more individuals were at risk of being shot. Using this dataset in addition to a pre-existing dataset created by the *Washington Post* that includes any school shooting, or incident of intentional interpersonal gunfire, we then conducted a time-series analysis to examine whether permissiveness of a state's firearm laws and state gun ownership were associated with rates of active school shootings and rates of school shootings, separately. By running this analysis on both datasets, it allowed our research team to consider the ways in which state-level factors may affect attempted mass gun violence differently from (or similarly to) any type of intentional school gun violence. (Hereinafter, all references to school gun violence will be limited to intentional interpersonal shootings.)

## Objectives

The specific objectives of this study are therefore as follows:

1. To develop a novel and comprehensive dataset identifying every K-12 active school shooting since 1999, including key details about each event (for example, the shooting location and the number of casualties).

2. To compare these data on active school shootings to an existing data source that was designed to capture all K-12 school shootings since 1999, regardless of number or people injured or killed.

3. To examine the relationship between state firearm laws, state gun ownership, active school shootings and school shootings using both of these two datasets, which cover the same two-decade time period

## Methods

### Datasets

**Active School Shooting Dataset**—Our research team put together a comprehensive dataset that includes all active shootings at K-12 schools over a two-decade period, spanning

January 1, 1999 (the calendar year in which the Columbine High School shooting in Littleton, CO took place) through December 31, 2018. We also collected key details about each event, including the shooting location, age of perpetrator(s), school type (public or private), and the number of casualties. As noted earlier, we defined active school shootings as incidents where a firearm was discharged on school property, while school was in session, and authorities determined that the attack was intended to be a mass shooting (which is generally defined as a shooting resulting in four or more victims, not including the shooter(s)) (Booty et al., 2019). These data were collected by drawing on six existing datasets about different types of school gun violence over various time periods: the aforementioned *Washington Post* dataset, the Naval Postgraduate School K-12 School Shooting Database (*K-12 School Shooting Database*, n.d.), the FBI Active Shooter reports (*Active Shooter Incidents in the United States in 2018*, 2018), the Angels of Columbine website (Moore, n.d.), the School Shooting Database (Laurine, n.d.) and the data appendices of *School Killers Speak* (Crews, 2014).

To determine whether or not authorities identified a given case as an attempted mass shooting—our chief criterion for an active school shooting—two members of our research team comprehensively examined and appropriately coded media coverage of school shootings, reviewing all relevant articles in the following news resources: EBSCO Newspaper Source Plus, EBSCO Newswires, Gannett Newsstand, Lexis-Nexis, NewsBank, and ProQuest Newsstand. Any discrepancies were assessed and coded by a third member of our team and resolved the discrepancy between the first two reviewers. Reviewing news media reports also allowed our team to collect the aforementioned key details about each event (shooting location, age of perpetrator(s), school type, and the number of casualties). In sum, our collection and coding efforts identified 49 qualifying incidents between January 1, 1999, and December 31, 2018.

**Existing K-12 School Shooting Dataset—**As noted, the *Washington Post* created a dataset that captured any school shooting, or incident of intentional interpersonal gunfire, in a K-12 school. Its data set begins with the Columbine shooting incident (which occurred on April 20, 1999), and covers incidents through the end of 2018, specifically including any incident where there was intentional gunfire at a primary or secondary school (Cox et al., 2021). This *Washington Post* dataset is one of the only public sources of data available on intentional K-12 school shootings that spans the two-decade period under study. For example, other databases, such as the K-12 School Shooting Database from the Naval Postgraduate School and the Center for Homeland Defense and Security also include unintentional shootings in their numbers (Riedman & O'Neill, 2020), while the *Washington Post* dataset does not. According to the *Washington Post* website, "shootings at after-hours events, accidental discharges that caused no injuries to anyone other than the person handling the gun, and suicides that occurred privately or posed no threat to other children were excluded. Gunfire at colleges and universities, which affects young adults rather than kids, also was not counted" (Cox et al., 2021). For purposes of uniformity, we used the *Washington Post's* exact criteria to extend the newspaper's dataset back to January 1, 1999. This resulted in the addition of four incidents, bringing the total number of school shootings meeting its criteria from January 1, 1999 until December 31, 2018 to 232.

## Comparison of Datasets

We were first interested in the differences between our novel K-12 active school shooting dataset (where a firearm was discharged, and four or more individuals were at risk of being shot while school was in session) and the existing K-12 dataset created by *The Washington Post* (all school shootings). We therefore compared the datasets in terms of median age of perpetrator(s), if there was more than one perpetrator, if the event occurred at a public or private school, and average number of injuries or deaths per incident. We also plotted the total number of school shootings and active school shootings per year to compare the two datasets.

## Regression Analysis

We next wanted to understand if the landscape permissiveness of a state's gun laws and state gun ownership were associated with K-12 active school shootings and/or K-12 school shootings. The specific independent and outcome variables and their corresponding data sources are described in detail below.

### Data

**Independent variables:** We used the 1998–2018 editions of the *Traveler's Guide to the Firearms Laws of the Fifty States* to obtain the first independent variable of interest, an annual restrictiveness-permissiveness scale of firearm laws for each state (Kappas, 2019). This report is published yearly as a legal reference for gun owners traveling between states. The score ranges between 0 (completely restrictive) and 100 (completely permissive), based on the number of specific types of firearm laws present in all 50 states. The maximum, minimum, and mean permissiveness of each state between 1999 and 2018 is displayed in Figure 1. This permissiveness scale is not only highly correlated, but also statistically reliable and consistent with seven other commonly used and cited permissiveness scales, including Gifford's Annual Gun Scorecard (*Annual Gun Law Scorecard*, 2019), Siegel's measure of gun laws (Siegel et al., 2017), and Everytown for Gun Research (*Gun Law Navigator*, 2020), according to a recent analysis (Paul M Reeping et al., 2021).

This measure has also been used in previous research (Irvin et al., 2014; Paul M Reeping et al., 2019) and considers many types of laws, including some that are directly related to school safety, such as laws that regulate whether firearms are allowed on school property or whether firearms can be stored in vehicles in school parking lots. Other policies considered in the making of the scale include: standard firearms ownership and permit requirements and if the license to carry is up to the discretion of law enforcement (a may issue state) or determined only by a set of criteria without discretion from law enforcement (a shall issue state); reciprocity and recognition of out of state carry permits; state self-defense laws, including if the state has implemented castle doctrine laws, which dictate that citizens are permitted to defend themselves with deadly force without retreating in their own home, or stand your ground laws, which extend that right to most public spaces; restrictions on semi-automatic firearms, large-capacity magazines, machine guns, and silencers/suppressors (for example, in some states it is illegal to own a firearm magazine that holds more than ten rounds or to own a silencer); laws governing concealed-, open- and vehicle-carry, including

if a state has enacted constitutional carry, that allows concealed carry in some public places without a permit; and laws related to the duty to notify law enforcement of permit status.

The second independent variable of interest was a proxy for the level of gun ownership in each state. Unfortunately, data on state level gun ownership cannot be obtained from state administrative records, as states generally do not require registration. Furthermore, surveys that examine gun ownership are mostly at the national level, and when employed at the state level, have spotty coverage or are inconsistent (Kleck, 2004). Consistent with the literature (Azrael et al., 2004; Paul M Reeping et al., 2019; Siegel & Rothman, 2016), we employed the percentage of suicides committed with a firearm as our measure of gun ownership by state, a validated measure that was found to perform better than alternative proxies (Kleck, 2004). This measure is also highly correlated with the newly developed state-level estimates of household gun ownership database by RAND Corporation (Schell et al., 2020). We obtained the data for the total number of suicides and number of suicides committed with a firearm for each year and state from the Centers for Disease Control and Prevention's WONDER database (*Underlying Cause of Death 1999–2017 on CDC WONDER Online Database.*, n.d.). We then divided the number of suicides committed with a firearm by the number of total suicides to create this proxy measurement for firearm ownership per-state-per-year.

The state firearm laws permissiveness scale and gun ownership were highly correlated (Pearson's r 0.84, p<0.001) and interdependent; however, it is not possible to know the true relationship between these variables. For example, firearm laws could cause gun ownership to increase or decrease. This change in gun ownership could then lead to a change in future firearm laws. Via this feedback loop, the two variables end up acting as a proxy for one another. For this reason, we did not include them in the same regression models, and rather calculated two regressions with each in the model individually.

**Confounders:** In order to account for possible confounding factors, we included the following annual measures of state-level characteristics in our analyses: percent high school graduates, percent female headed households, percent in poverty, percent unemployment, and percent white, retrieved via the American Community Survey from the US Census Bureau (*American FactFinder*, n.d.), as well as incarceration rates, retrieved from the Bureau of Justice Statistics (Carson, 2019). These variables were chosen based on there being a plausible common cause of both exposure and outcome (Hernán, 2008), and the choices are also in line with previous studies (Paul M Reeping et al., 2019; Siegel et al., 2013). For example, measures of socio-economic status like the ones included may be hypothesized as a cause of not only the types of gun laws that are passed and levels of gun ownership on the state level, but also the extent to which school shootings occur (Verlinden et al., 2000), although analytical research is limited on the underlying causes of school shootings. Other variables were considered as confounders, including voting rates, violent crime rates, and median income, but were not included due to collinearity or extreme lack of association with the outcome and/or exposure (p=0.99), the latter indicating that they were unlikely to be a common cause of both the exposure and outcome.

**Outcome variables:** We used the previously described two school shooting constructs for our dependent variables: K-12 school shooting incidents and K-12 active school shootings from the two datasets described in the previous sections of this paper. Scatterplots of the average number of K-12 school shootings and K-12 active school shootings by permissiveness of firearm laws and gun ownership, as well as the corresponding Pearson's correlation coefficients were calculated.

**Regression**—Data were analyzed with generalized estimating equations in R, using the package *geepack* (Hojsgaard et al., 2016). Because the outcome variable is a count, a quasi-Poisson distribution with a natural log link was used. Overdispersion is automatically accounted for in this R package. Although many zeros existed in this model, a zero-inflated Poisson model would be inappropriate because we did not have two types of data generating processes (e.g. binary and count). Robust standard errors and adjustment for the covariates listed above, as well as the offset of state population per year, were also included. An autoregressive (AR1) covariance structure was specified in the regression. Repeated cross-sectional time-series measures were calculated as state-per-year. Year was also included in all analyses as a fixed effect.

## Results

### Comparison of Datasets

Overall, the characteristics of each dataset are similar. Twenty percent (47 out of 232) of K-12 school shootings were perpetrated by an individual over the age of 18, with a median age of 16. With respect to active school shootings, 18% (9 out of 49) were perpetrated by someone older than 18, with a median age of 16. For all K-12 school shootings, 95% (220 out of 232) occurred in a public school. Among the active school shootings, 98% (48 out of 49) occurred in a public school. Only 2% (5 out of 232) of the school shootings and 4% (2 out of 49) of the active school shootings involved more than one perpetrator. The primary difference between the two datasets was the mean number of casualties per incident. On average, 1.3 individuals were injured and 0.6 were killed in K-12 school shootings. However, with regard to active shootings, on average, 3.2 individuals were injured and 2.1 individuals were killed. This difference was expected given the qualification criteria for each dataset.

Plots of the total number of school shootings per year from the *Washington Post* data and the active school shooting data are shown in Figure 2. We observed an increase in both types of incidents since 2015. Between 2015 and 2018, the rate of K-12 school shootings increased more than 3.5 times (from seven to 25 incidents), and the rate of K-12 active school shootings increased six-fold from one incident to six incidents.

### Regression Analysis

Scatterplots of the average number of school shootings and active school shootings by permissiveness of firearm laws and gun ownership, as well as the corresponding Pearson's correlation coefficients are shown in Figure 3.

**K-12 school shootings—**For every ten-unit higher score on the permissiveness of state firearm laws scale, the rate of school shootings was 10.5% higher (95% CI 2.5% to 19.3%, p<0.01). Additionally, for every ten-unit higher score in the gun ownership proxy, the rate of school shootings was 27.0% higher (95%CI 6.8% to 51.1%, p<0.01) (Table 1). We did not include the estimates of the confounders in the main text as this could lead to mistaken interpretations, and it has been discouraged by contemporary epidemiologists (Westreich & Greenland, 2013); however, these estimates can be seen in the appendix.

**K-12 active school shootings—**For every ten-unit higher score in permissiveness of state firearm laws, the rate of active school shootings was 13.9% higher, although this measure was not statistically significant at the 0.05 level (95%CI –3.9% to 34.9%, p=0.13). Additionally, for every ten-unit higher score in gun ownership proxy, the rate of active school shootings was 50.8% higher (95%CI 13.1% to 101%, p<0.01) (Table 1). We did not include the estimates of the confounders in the main text as this could lead to mistaken interpretations, and it has been discouraged by contemporary epidemiologists (Westreich & Greenland, 2013); however, these estimates can be found in the appendix.

## Discussion

### Summary of Key Findings

In this present study we developed a novel database of K-12 active school shootings over the course of a 20-year period and also obtained data from the existing *Washington Post* dataset of all K-12 school shootings during the same period. We identified 49 active school shootings and 232 school shootings in the twenty years between January 1, 1999 and December 31, 2018. The characteristics between the two datasets were very similar, although the average number of individuals injured and killed in the active K-12 school shootings dataset was higher, as expected. Our findings further illustrated that while intentional gun violence in K-12 schools has occurred with some consistency each year over the past two decades, the incidence has increased substantially since 2015. We also found that permissiveness of the state firearm law landscape and higher gun ownership are associated with higher rates of K-12 active school shooting and K-12 shooting incidents, after for controlling for critical confounders.

These findings are consistent with previous research (Anestis et al., 2015; Conner & Zhong, 2003; Fleegler et al., 2013; Goyal et al., 2019; L. M. Hepburn & Hemenway, 2004; Lester & Murrell, 1982a; M. Miller et al., 2006; Mathew Miller et al., 2001; Paul M Reeping et al., 2019; Siegel et al., 2013) on whether firearm laws and gun ownership might influence gun violence, although this is the first study to specifically consider the relationship between state-level factors and intentional gun violence on K-12 school grounds. Prior to this study, it was unclear if factors that might be associated with other forms of gunfire off of school grounds would be the same as those associated with intentional gun violence in K-12 schools. Understanding that permissiveness of the state firearm law landscape and gun ownership are associated with both types of intentional school gun violence contributes to ongoing discussions about school safety (Newman et al., 2004).

## Implications

K-12 schools in states with more permissive gun laws and higher rates of gun ownership must bear in mind the increased likelihood of access to firearms within their communities as they consider the best ways in which to keep their schools safe. Specifically, this study provides clear evidence that every state, first and foremost, should implement more restrictive firearm policies to meaningfully reduce the likelihood of K-12 school shootings. Such policies include implementing permit requirements, eliminating concealed carry, and banning high-capacity magazines (Paul M Reeping et al., 2019). This study also emphasizes that states with higher rates of gun ownership are at particular risk for school shootings at K-12 schools and, thus, efforts to account for the higher prevalence of gun ownership are also needed.

While our findings are focused on the implementation of specific policies at the state-level, the existing literature confirms that meaningful responses to school gun violence are multifaceted and require efforts that go hand-in-hand with the aforementioned policies (Branas et al., 2020). Building on the existing body of research about school gun violence prevention, there are ways in which K-12 schools could consider different strategies. For example, in states with more permissive gun laws and higher rates of gun ownership, schools may engage teachers to implement firearm safety education efforts among their students (Obeng, 2010) and support school nurses to communicate effectively with parents about gun safety and storage practices (Selekman et al., 2019). To date, many K-12 schools have chosen to respond to the anticipation of intentional gun violence by implementing various reactive strategies such as installing security cameras and metal detectors, implementing locker and student searches, and arming teachers (Borum et al., 2010; Hankin, A; Hertz, M; Simon, 2011; Rajan & Branas, 2018; Tanner-Smith & Fisher, 2016). These strategies have limited empirical support for prevention and may even weaken, rather than improve, a school's learning environment (Hankin, A; Hertz, M; Simon, 2011; Tanner-Smith & Fisher, 2016). By encouraging school districts to focus on efforts such as student firearm safety education, safe gun storage promotion among parents, and advocating for specific policies that decrease the presence of firearms in schools, school districts may be able to reduce the likelihood of shootings within their schools while avoiding further harm to school climate.

We chose to focus our present analyses on state-level factors—notably the permissiveness of state gun law landscapes—given the established impact of gun laws on gun violence (Anestis et al., 2015; Conner & Zhong, 2003; Fleegler et al., 2013; L. M. Hepburn & Hemenway, 2004; Lester & Murrell, 1982b; M. Miller et al., 2006; Mathew Miller et al., 2001; Newman et al., 2004; Paul M Reeping et al., 2019; Siegel et al., 2013; Zeoli et al., 2019). Substantial research has identified a number of policies that contribute to reduced access to firearms and subsequently lower rates of gun violence across the broader population (Kaufman et al., 2018; Webster & Wintemute, 2015). This area of work also has implications for school shootings and provides important context for the present study. This is particularly important as our work has also confirmed that most active school shootings are committed by individuals under the age of 18. For example, researchers have demonstrated that increasing the accountability of gun sellers regarding who they sell to and similarly increasing the accountability of gun owners regarding who accesses their firearms

(which have subsequent implications for the unauthorized transfer of firearms to youth) is one important component for reducing access to firearms among children (Salhi et al., 2021; Vossekuil et al., 2002). Similarly, enforcing rigorous "permit-to-purchase" policies, can also help limit gun access by high-risk subgroups (Webster et al., 2013). Similarly, child access prevention laws are associated with significant reductions in youth access to guns, unintentional shootings, and firearm suicide deaths (Zeoli et al., 2019). And recent research has confirmed that large-capacity magazine bans reduce the lethality of high-fatality mass shootings (Klarevas et al., 2019). By analyzing state firearm law permissiveness, our work considers how all of these types of firearm laws, together, may influence K-12 school shootings and the injuries and deaths that result from such violence.

## Limitations

We do note some limitations of this work to bear in mind when interpreting these findings. Firstly, there are currently no existing measures of gun law permissiveness or gun ownership on any level lower than a state (i.e. county or city), limiting the power and generalizability of the results. While multiple sources of firearm law exist on the state level, the *Traveler's Guide to the Firearm Laws of the Fifty States* was chosen as the best permissiveness measure for several reasons. Most importantly, we have twenty years of consistent data, while other sources only began collecting these data more recently. For example, Gifford's Annual Gun Scorecard (*Annual Gun Law Scorecard*, 2019) only has scores since 2010, and Siegel's list of Firearm Law Provision only has data until 2016 (Siegel et al., 2017). The *Traveler's Guide to the Firearm Laws of the Fifty States* was also found to be statistically reliable when compared to seven other gun law permissiveness scales (Paul M Reeping et al., 2021). The *Traveler's Guide* is also unique as it was created by gun owners for use by gun owners. The guide is written by a firearms dealer, lawyer, and member of the National Rifle Association (NRA) (Kappas, 2019). NRA Shooting Illustrated has called the guide an "invaluable reference" ("Shooter's Bookshelf," 2018), and the NRA American Rifleman has called the publication "a quick reference guide that covers everything" (*Traveler's Guide To The Firearm Laws of The Fifty States*, 2016).

Another limitation of this work is that because state ownership of guns is not directly measured, we instead used a validated proxy: the of percentage of firearm suicides over total suicides (Azrael et al., 2004; Cook & Ludwig, 2006; Price et al., 2004). It has also been previously used in studies related specifically to children (Mathew Miller et al., 2001). In particular, the association between gun ownership and school shootings lends itself to a reasonable hypothesis. If gun ownership is relatively high in a state, it is plausible that it would be more likely that a child or adolescent would be in an environment where firearms are present, heightening their probability to access and then use a firearm to commit a school shooting.

Furthermore, although our study design implements a time-series component across twenty years, multiple covariate adjustment, and the use of two different but related outcome measures, the potential for omitted variable biases and reverse causation remains. These results should be used for hypothesis building. Future analyses are encouraged to expand on our work, including analyses looking at the relationship between specific laws and the

onset of active shootings and school shootings in K-12 schools, as we do not know if these policies work together or if the association is driven by a few key laws.

## Conclusions

More permissive firearm laws and higher rates of gun ownership are associated with higher rates of both K-12 active school shootings and K-12 school shootings. Officials in states with more permissive gun laws and higher rates of gun ownership must bear in mind the increased likelihood of access to firearms within their communities as they consider the best ways in which to keep their schools safe.

## Acknowledgements

## Data Availability

Data is available upon reasonable request from the authors.

## Appendix

## Appendix

### Appendix Table 1:

Percent changes in relative rate of school shootings and active school shootings for every ten-unit change in state gun law permissiveness

| | School Shootings | | |
| --- | --- | --- | --- |
| | Estimate (%) | 95%CI | p-value |
| **Permissiveness** | 10.5 | (2.5, 19.3) | <0.01 |
| **% White** | −48.1 | (−91.3, 208) | 0.47 |
| **% Single Mother Homes** | 19.6 | (−7.4, 54.5) | 0.17 |
| **% Unemployment** | 21.1 | (8.1, 35.6) | <0.01 |
| **% High School Graduation** | −0.1 | (−7.1, 5.8) | 0.79 |
| **% Poverty** | −4.6 | (−12.7, 4.3) | 0.3 |
| **Incarceration Rate** | 0.001 | (−0.16, 0.02) | 0.59 |
| | **Active School Shootings** | | |
| | Estimate (%) | 95%CI | p-value |
| **Permissiveness** | 13.9 | (−3.9, 34.9) | 0.13 |
| **% White** | 12.8 | (−96, 3630) | 0.38 |
| **% Single Mother Homes** | 40 | (−30.6, 182) | 0.35 |
| **% Unemployment** | 24.8 | (−8.4, 70.1) | 0.16 |
| **% High School Graduation** | −9.3 | (−20.4, 3.4) | 0.15 |
| **% Poverty** | −5.1 | (−17.1, 8.6) | 0.45 |
| **Incarceration Rate** | −0.3 | (−0.6, 0.007) | 0.12 |

**Appendix Table 2:**

Percent changes in relative rate of school shootings and active school shootings for every ten-unit change in state gun ownership

| | School Shootings | | |
|---|---|---|---|
| | Estimate (%) | 95%CI | p-value |
| **Gun ownership** | 27 | (6.8, 51.1) | <0.01 |
| **% White** | −56 | (−91.3, 122) | 0.32 |
| **% Single Mother Homes** | 9 | (−14.9, 39.5) | 0.49 |
| **% Unemployment** | 20.2 | (7.0, 35.1) | <0.01 |
| **% High School Graduation** | 0.1 | (−5.3, 5.9) | 0.95 |
| **% Poverty** | −5.1 | (−13.2, 39.5) | 0.26 |
| **Incarceration Rate** | 0.004 | (−0.2, 0.2) | 0.66 |
| | **Active School Shootings** | | |
| | Estimate (%) | 95%CI | p-value |
| **Gun ownership** | 50.8 | (13.1, 101) | <0.01 |
| **% White** | 897 | (−98.2, 3399) | 0.5 |
| **% Single Mother Homes** | 33 | (−38.9, 185) | 0.46 |
| **% Unemployment** | 23.5 | (−7.4, 64.6) | 0.15 |
| **% High School Graduation** | −9.5 | (−21.8, 3.4) | 0.14 |
| **% Poverty** | −7.5 | (−18.4, 4.9) | 0.22 |
| **Incarceration Rate** | −0.4 | (−0.7, 0.06) | 0.1 |

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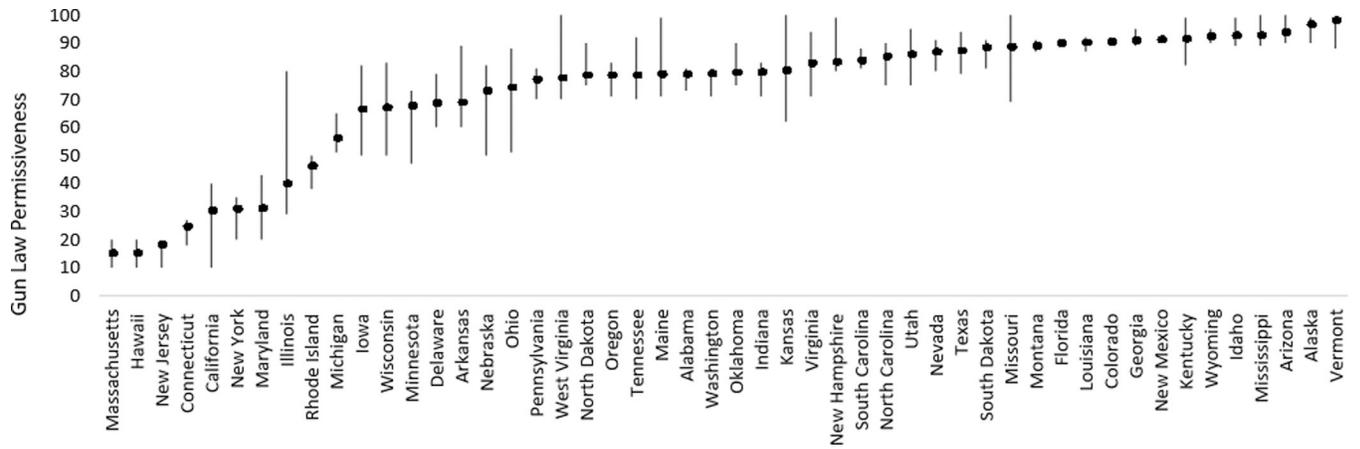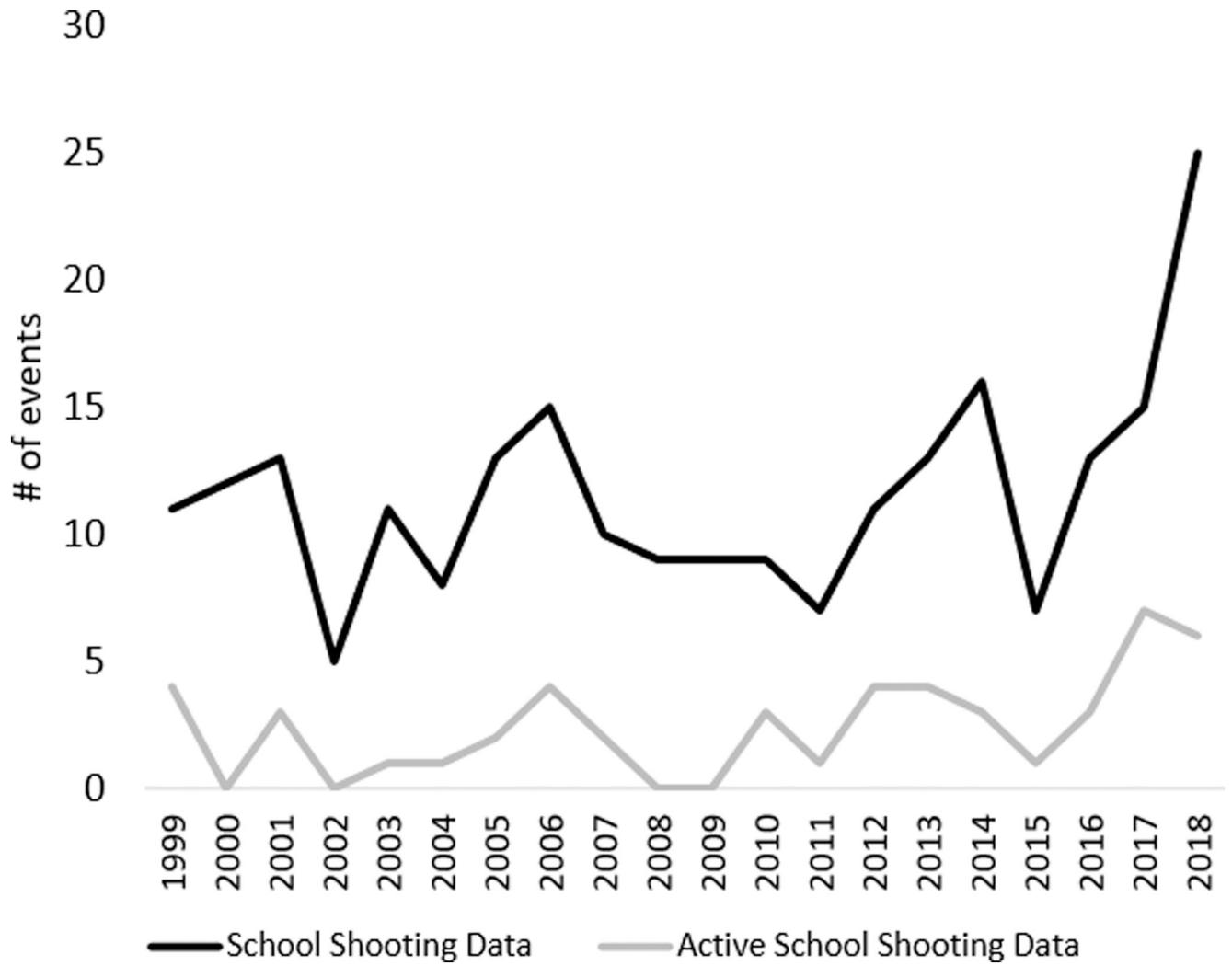
**Figure 1:**
Maximum, minimum, and mean gun law permissiveness for each state (1999–2018)

**Figure 2:**
Plots of total number of K-12 school shootings and K-12 active school shootings (1999–2018).
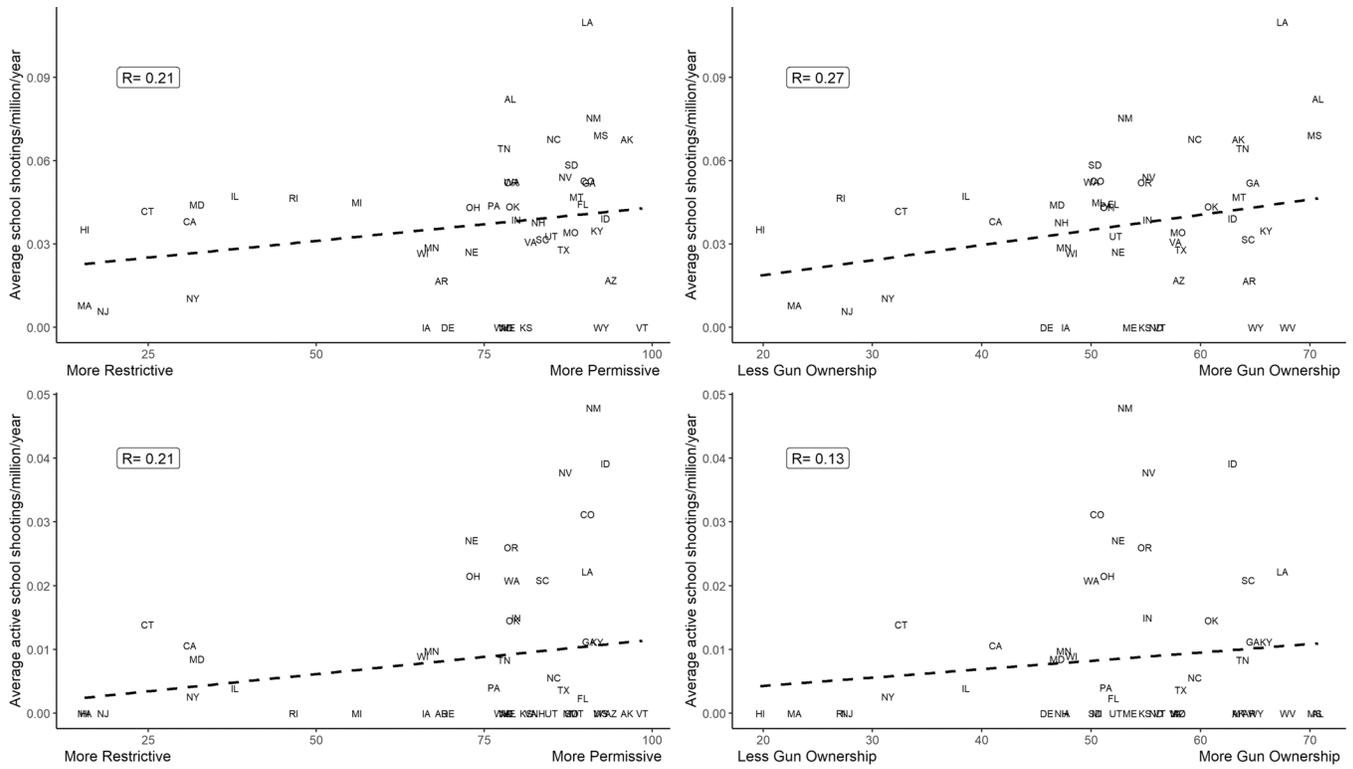
**Figure 3:**
Scatterplots with Pearson correlation coefficients of the average number of K-12 shootings and K-12 active school shootings by average permissiveness of firearm laws and gun ownership

**Table 1:**

Percent changes in relative rate of school shootings for every ten-unit change in state gun law permissiveness or gun ownership

| | School Shootings | | |
|---|---|---|---|
| | Estimate (%) | 95%CI | p-value |
| **Permissiveness** | 10.5 | (2.5, 19.3) | <0.01 |
| **Gun ownership** | 27 | (6.8, 51.1) | <0.01 |
| | **Active School Shootings** | | |
| | Estimate (%) | 95%CI | p-value |
| **Permissiveness** | 13.9 | (−3.9, 34.9) | 0.13 |
| **Gun ownership** | 50.8 | (13.1, 101) | <0.01 |