Are gun ownership rates and regulations associated with firearm incidents in American schools? A forty-year analysis (1980–2019)

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ABSTRACT

Purpose: This study examines the relationship between state gun ownership rates and school firearm incidents (*n* = 1275) and injured/killed victims (*n* = 2026) of these incidents over a forty-year period (1980–2019). It also investigates whether child access prevention, minimum age requirements for gun purchases, and mandatory gun safety training laws are associated with fewer school firearm incidents and injured/killed victims.
Methods: Data were linked together from the School Shootings Database, State Firearm Law Database, the National Center for Education Statistics, and the US Census Bureau. State fixed effects and interrupted time series analyses were performed.
Results: State gun ownership rates declined between 1980 and 2019 while school firearm incidents generally ranged between 20 and 40 incidents before skyrocketing to 102 incidents in 2018 and 110 incidents in 2019. Findings were mixed on the relationship between state gun ownership rates and school firearm incidents and injured/killed victims. Additionally, child access prevention, minimum age requirements for gun purchases, and mandatory gun safety training laws exhibited weak and inconsistent relationships with school firearm incidents.
Discussion: Although access to firearms plays an undeniable role in school shootings, it remains unclear what policies are needed to reduce these incidents. Future research may be needed to explore holistic approaches to addressing this problem.

1. Introduction

School shootings have become a pressing concern for the American public education system. In the United States, the number of shootings on school grounds is consistently higher than that of any other country in the world (Hahn et al., 2005). While many gun incidents in US schools do not lead to injury or death, a non-trivial number of devastating mass shootings occurring in the past decade have resulted in substantial numbers of victims and ignited intense gun control debates. One of these highly distressing incidents was in 2012 when a 20-year old with a history of mental health problems murdered six adults and twenty children between the ages of six and seven in a mass shooting at an elementary school in Connecticut (Langman, 2015). More recently in 2018, national attention became refocused on gun control after a 19-year old assailant killed fourteen students and four school staff at a high school in Florida where he had been previously expelled (Aslett, Webb Williams, Casas, Zuidema, & Wilkerson, 2020). Loss of life and psychological trauma are directly observable ramifications for schools and communities that experience a school shooting. The traumatic

effects of these incidents also appear to extend beyond the location of the shooting itself, inflicting damage on the psyche, confidence, and wellbeing of the broader public (Collins, 2014; Newman, Fox, Harding, Mehta, & Roth, 2005).

Public outcry after major school shootings has spurred varying proposals for action from federal, state, and local officials (Schildkraut & Hernandez, 2014). While policy recommendations have ranged from arming teachers to strengthening mental health supports for troubled youth, gun control has been at the forefront of disputes over how to prevent school shootings (Rajan & Branas, 2018). Many states have enacted gun safety legislation following rampage-style school shootings (Schell, Cefalu, Griffin, Smart, & Morral, 2020). The main rationale for enhanced gun control is straightforward. The United States has both the highest rate of gun ownership and the greatest number of school shooting incidents in the developed world. Proponents of strong legal restrictions on firearms argue that these patterns demonstrate that guns are too accessible to those with mental health issues and a history of violence, making school shootings an inevitable consequence. Yet, opponents claim that gun prevalence is a response to existing crime and

violence, and that restrictive gun laws violate the right to bear arms enshrined in the US Constitution by preventing law abiding citizens from owning guns (Stolzenberg & D'alessio, 2000).

In the empirical literature, many researchers have estimated correlational associations between gun ownership rates and general crime and violence, but this work is inconclusive (Kleck, 2015; Shetgiri, Boots, Lin, & Cheng, 2016; Siegel, Ross, & King III, 2013). Investigations of gun control regulations have exhibited more consistent associations with lower crime and violence (Andres & Hempstead, 2011; Fleegler et al., 2013; Hurka & Knill, 2020; Schell et al., 2020; Smith & Spiegler, 2020). For school-based incidents with firearms, empirical analyses are lacking. Nevertheless, there are compelling reasons to expect that high rates of gun ownership increase the likelihood of school firearm incidents as school shootings often involve weapons stolen by minors from family members, friends, and neighbors (Jeynes, 2020; Shetgiri et al., 2016). Some evidence on regulation is suggestive, indicating that laws holding gun owners criminally liable for negligent storage of firearms (e.g. child access prevention laws) are linked to lower prevalence of gun carrying in school (Anderson & Sabia, 2018; Fla. Stat. Ann. § 790.174, 2011; Hawaii Rev. Stat. § 134-10.5, 2011). Other scholarship on preventative measures is predominantly theoretical, drawing from threat assessment models (Cornell, 2020) or in-depth analyses of a subset of school shootings (Langman, 2009a). Broader empirical analysis is needed to launch a line of inquiry that can shed light on policy responses that might hold promise for reducing school shootings.

This study investigates the relationship between state gun ownership rates and school firearm incidents ($n = 1275$) and injured/killed victims ($n = 2026$) of these incidents from 1980 to 2019 in the United States. Over this forty-year period, it also examines whether child access prevention, minimum age requirements for gun purchases, and mandatory gun safety training laws are associated with decreases in school firearm incidents and injured/killed victims. For the analyses, data from the School Shootings Database were linked to data from the State Firearm Law Database, the National Center for Education Statistics, and US Census. State-level fixed effects models are performed to explore whether state-level gun ownership rates are related to the number of school firearm incidents and injured/killed victims. Interrupted time series analyses are then used to examine whether child access prevention, minimum age requirements for gun purchases, and mandatory gun safety training laws are associated with declines in school firearm incidents and injured/killed victims. This study provides a quantitative analysis of school firearm incidents over a forty-year period that has the potential to contribute to an underdeveloped literature. It may also raise important questions for gun policy and regulation.

2. Literature review

2.1. The relationship between gun ownership and crime and violence

The literature on school firearm incidents and gun ownership is limited. However, a large body of work has investigated links between general gun violence and gun ownership. In the United States, rates of gun violence are marked by different trends over the past sixty years (Kleck, 2004; Gramlich, 2019). For example, between 1960 and the mid-1970s, gun homicide and crime in the United States rose sharply when the homicide rate went from 4.7 to 9.9 per 100,000 people (Blumstein, 1995; Kleck, 2017). In 1974, the highest gun death rate on record, gun deaths (including both homicide and suicide) reached 16.3 per 100,000 people (Gramlich, 2019). In the 1980s, the gun death rate decreased during the first part of the decade before rising to a peak of 15.6 incidents per 100,000 people in 1993 (Federal Bureau of Investigation, E, 2002). The gun death rate then moved downward before plateauing at approximately 10 gun deaths in 2000 where it has remained steady until relatively recently. In the past several years, the gun death rate has been trending upward to about 12 gun deaths per 100,000 people, but this rate is lower than highs that were experienced

in the mid-1970s and early 1990s. These rises in the gun death rate appear to be more attributable to an increase in gun suicide rather than gun homicide (Violence Prevention Research Program, 2021). The number of multiple victim homicides have remained stable over time though multiple-victim shootings appear to have increased in 2020 (Smith & Cooper, 2013; Gun Violence Archive, 2021).

Researchers have sought to identify factors underlying gun crime and violence (Duggan, 2001; Sanchez et al., 2020; Siegel et al., 2013). The central argument behind gun control debates is that high accessibility of guns increases the likelihood of gun crime and violence, so many studies have investigated the relationship between gun ownership and crime and violence (Kleck, 2015; Siegel et al., 2013). This line of inquiry presents mixed results. Three separate literature reviews offer different conclusions, reporting that gun ownership is related to greater crime and violence (Hepburn & Hemenway, 2004); associated with no change or less crime and violence (Kates & Mauser, 2006); or that the literature is inconclusive (National Research Council, 2005). Kleck (2015) argues that these inconsistencies are partly attributable to substantial variation in the methodological rigor of studies. In Kleck's (2015) review of the literature, methodologically rigorous studies tended not show an association between gun prevalence and crime and violence. Nonetheless, research designs used even in these comparatively rigorous studies are not causal. Other scholars distinguish between possession of legal and illegal firearms, finding evidence that the availability of illegal guns is what explains violent crime levels (Stolzenberg & D'alessio, 2000).

2.2. The relationship between gun regulation and crime and violence

Gun control in the United States is an impassioned debate with large, well-funded coalitions on opposing sides. To bring evidence to bear on this debate, scholars have attempted to examine the effects of gun regulations on crime and violence. US states have enacted a diverse array of legislative and regulatory frameworks for gun control. Types of gun regulations may be roughly classified into registration, licensing, safety training, storage, and sales and distribution requirements (Carter, 2006; Hurka & Knill, 2020; Kleck, Kovandzic, & Bellows, 2016; Kwon & Baack, 2005). On the whole, studies find that gun regulations are associated with lower levels of crime and violence (Andres & Hempstead, 2011; Fleegler et al., 2013; Hurka & Knill, 2020; Smith & Spiegler, 2020). In analysis of all 50 US states, Fleegler et al. (2013) observe that laws instituting or strengthening background checks were related to fewer gun-related deaths from 2007 to 2010. Correlational studies in the United States (Kwon & Baack, 2005; Smith & Spiegler, 2020) and Western Europe (Hurka & Knill, 2020) that use an index of gun restrictiveness report that restrictive gun controls are linked to fewer gun deaths. A smaller body of research slightly diverges from these patterns. For example, in a quasi-experimental study, Kleck et al. (2016) investigated 19 gun control laws in more than one-thousand US cities but did not find strong evidence that gun control affected crime rates. Only licensing requirements and bans on gun purchases by those with a history of alcoholism were related to declines in homicide and robbery (Kleck et al., 2016).

2.3. School firearm incidents

High-profile mass school shootings occurring in the past decade have increased public concern over gun violence in US schools (Kolbe, 2020; Langman, 2009a). Empirical analyses of trends in gun violence in American schools are somewhat limited in scope, exploring different time periods and lengths of time. In recent work, Holland et al. (2019) find that multiple-victim incidents in schools from 2009 to 2018 increased with 95% of these incidents being firearm-related. By analyzing descriptive data, Shultz, Cohen, Muschert, and Flores de Apodaca (2013) report that most school shootings were targeted attacks as opposed to random killings. Although prior research has investigated the effects of gun ownership and regulation, very little work has

examined how gun ownership and legal restrictions on firearms influence school shootings. To understand conditions underlying school shootings, most studies are theoretical or descriptive studies that are based on a small number of specific incidents (Borum, Cornell, Modzeleski, & Jimerson, 2010; Huesmann, 2016; Langman, 2009; Moore et al., 2003). Among these studies, one of the most comprehensive analyses examined 37 incidents of targeted school violence from 1974 to 2000 (Vossekuil, Fein, Reddy, Borum, & Modzeleski, 2002). This study found that the majority of perpetrators had no history of prior violent or criminal behavior; that only one-third of attackers were known to have acted violently toward others prior to the incident; and that many attackers had considered suicide and felt bullied by peers (Lee, 2013; Vossekuil et al., 2002). This report indicated that 98% of attackers had experienced difficulty with significant losses and personal failures before carrying out an attack (Vossekuil et al., 2002). School shooters were also found to plan their attacks and share their plans with confidants or others (Vossekuil et al., 2002).

In a psychological analysis of forty-eight school shooters, Langman (2009a) observed that attackers were not loners or on medications in many instances, and that the background factors underlying school shootings were moderated by whether the shooter was classified as psychopathic, psychotic, or traumatized. Researchers have also investigated the role of environmental factors, such as school, community, and cultural contexts (Huesmann, 2016). In an in-depth analysis of twenty-five mass school shootings, social exclusion, ineffective surveillance systems, and gun availability were also identified as having significant roles in enabling shootings on school grounds (Newman et al., 2005). Other studies have focused on experiences at school with bullying, victimization on school grounds, and social exclusion being thought to create a desire for revenge in eventual attackers (Huesmann, 2016). Geographic factors may also be relevant. Newman, Fox, Harding, Mehta, & Roth, 2005 theorize that small communities can create restrictive environments that increase peer and social pressure for those who do not fit in with the community. In addition, overarching cultural mores may contribute to school shootings by providing "cultural scripts" through video games, songs, movies, and gun culture that glorify violence and attach manhood and respect to violent acts (Lawrence & Birkland, 2004; Newman, Fox, Harding, Mehta, & Roth, 2005). These analyses have deepened understanding of factors behind individual school shootings, but little empirical work has attempted to examine whether existing policies are associated with attacks involving firearms at school.

One of the most important influences affecting the number of incidents with firearms in schools may be the policy context, which can influence youth access to guns and the likelihood that a school shooting incident occurs on school grounds (Jeynes, 2020). In the United States, there is considerable variation in gun ownership across states (Schell, Peterson, et al., 2020). In states with lenient gun control laws, the likelihood of a school shooting may rise since youth may have greater access to guns (Hahn et al., 2005). There are also laws that are directly relevant for youth, such as minimum age requirements for gun purchases, safety training requirements for gun purchases, and child access prevention laws that hold gun owners responsible for safely storing their firearms. Youth who live in homes where firearms are present but not safely stored are reportedly more likely to be involved in some form of gun violence (Johnson et al., 2010). In addition, child access prevention laws are related to lower rates of accidental death with firearms among youth (Webster & Starnes, 2000), lower teenage suicide rates (Webster et al., 2004), and lower prevalence of self-reported gun carrying at school (Anderson & Sabia, 2018). Research on the effect of gun prevalence and regulations on firearm incidents in schools is lacking in the literature.

3. Current study

The purpose of this study is to examine the relationship between state-level gun ownership rates and the number of firearm incidents and injured/killed victims of firearm incidents in schools. Fixed-effects models are used to investigate results within states over a forty-year period. For these analyses, the following question is addressed: *Are state gun ownership rates associated with the number of school firearm incidents and injured/killed victims of these incidents*? This study also explores three gun control laws that are thought to influence youth access to firearms (i.e. child access prevention laws, mandated handgun safety training, and a minimum age requirement of 21 years of age for gun purchases). After performing analyses of these gun control regulations, mandatory handgun safety training showed the strongest associations with school firearm incidents, so this regulation was further analyzed using interrupted time series models. The following question was addressed for this analysis, *Are mandatory handgun safety training laws in a state associated with a decline in the number of school firearm incidents and injured/killed victims*?

4. Data and methods

4.1. Data sources

For the analyses, data from the School Shootings Database were linked to data from the State Firearm Law Database, the National Center for Education Statistics, and US Census. Developed by the Center for Homeland Defense and Security, the School Shootings Database contains all firearm incidents occurring in American schools from 1970 to the present. The School Shootings Database is the most comprehensive dataset on school firearm incidents in the United States, recording the details of every incident in which a gun is displayed or fired in a school or when a bullet hits school grounds (Center for Homeland, 2020). Incidents from this database were linked to Rand Corporation's State Firearm Law Database, which contains categories of firearms laws across states, including prohibitive and restrictive firearms laws (Schell, Peterson, et al., 2020). Rand Corporation's state-level estimates of household gun ownership rates from 1980 to 2016 were also linked to each school firearm incident. These estimates of gun ownership rates combine four individual surveys and other proxy measures for gun ownership to derive precise estimates of gun ownership in each state. For 2017, 2018, and 2019, a state's 2016 gun ownership rate was used because 2016 was the final year that Rand Corporation collected data on state gun ownership rates (Schell, Peterson, et al., 2020). From 2017 to 2019, gun sales declined, but it is unclear whether gun ownership rates fell (Trotta, 2019). Data on geographic locale and state population from the US Census along with student enrollments were used to provide contextual details on each school firearm incident.

Table 1 presents different types of school firearm incidents recorded in American K-12 schools between 1980 and 2019. The most common type of school firearm incident stems from an escalation a dispute, accounting for approximately 27% of all school firearm incidents. Indiscriminate shooting incidents, which include high-profile rampage and mass school shootings, comprise 4% of school firearm incidents over the forty-year period of analysis, but they are responsible for the second highest number of injured or killed victims at nearly 18% of all injured or killed victims from school firearm incidents from 1980 to 2019. Among all incidents, data from the School Shootings Database indicate that 68% of incidents occurred at high schools and 83% (when the type of firearm was able to be determined) involved handguns. When the assailant was known, non-officer involved single shooter incidents were 95% male and 64% of shooters were between 14 and 18 years of age. The number of injured or killed victims per firearm incident remained stable from 1980 to 2019, averaging 1.67 injured or killed victims for each school firearm incident.

Table 2 presents the number and percentage of school firearm incidents by region, locale, and decade. As the most populous region, the South region reports the highest number of school firearm incidents, but the Northeast has the highest number of gun incidents in school as a

Table 1

Types of school firearm incidents and injured/killed victims by incident type (1980–2019)

Incident Type	School Firearm Incidents		Injured/Killed Victims	
	Frequency	(%)	Frequency	(%)
Escalation of Dispute	338	26.5	430	21.2
Gang-related / Drug-related	164	12.9	295	14.6
Unclassified / Unknown	161	12.6	170	8.4
Accidental	145	11.4	136	6.7
Suicide/Attempted Suicide	125	9.8	125	6.2
Domestic w/ Targeted Victim	60	4.7	84	4.1
Indiscriminate Shooting	56	4.4	354	17.5
Bullying	32	2.5	64	3.2
Anger over Grade/Suspension/ Discipline	31	2.4	74	3.7
Hostage Standoff	31	2.4	110	5.4
Robbery	31	2.4	35	1.7
Murder / Murder-Suicide	30	2.4	56	2.8
Mental Health	26	2.0	59	2.9
Officer Involved Shooting	22	1.7	19	0.9
Intentional Property Damage	16	1.3	3	0.1
Racial	5	0.4	9	0.4
Self Defense	2	0.2	3	0.1
Total	1275		2026	

Table 2

School firearm incidents and injured/killed victims by region, locale, decade

	School firearm incidents		Injured/killed victims of school firearms	
	(#)	(%)	(#)	(%)
Region				
Midwest	273	21.4	382	18.9
Northeast	151	11.8	234	11.5
South	573	44.9	845	41.7
West	278	21.8	565	27.9
Locale				
Large city	479	37.6	662	32.7
Midsize	160	12.6	235	11.6
Small city	161	12.6	179	8.8
Suburb	214	16.8	408	20.1
Town/Rural	261	20.5	542	26.8
Decade				
1980s	215	16.9	444	21.9
1990s	255	20.0	478	23.6
2000s	346	27.1	439	21.7
2010s	459	36.0	665	32.8

proportion of total student enrollments. Approximately half of school firearm incidents occur in large (250,000 or larger) or midsize cities (100,000–249,999). The decade between 2010 and 2019 resulted in more than double the number of incidents in the 1980s. Moreover, 44% of the incidents occurring between 2010 and 2019 happened in 2018 and 2019.

4.2. Measures

School firearm incidents denote the total number of school firearm incidents occuring in a state from 1980 to 2019. The number of injured or killed victims for each incident was also recorded. State gun ownership rates from 1980 to 2019 were based on the proportion of adult residents in each state who live in a household where there is a firearm (Schell, Peterson, et al., 2020). To generate precise estimates of state-level gun ownership rates each year, survey data from the Behavioral Risk Factor Surveillance System, Gallup, and Pew Research Center were combined with data on the proportion of suicides with a firearm, hunting licenses from US Fish and Wildlife Service, subscriptions to Guns and Ammo magazine, and the number of criminal background checks per 10 residents. By collecting data from these different sources, Schell, Peterson, et al. (2020) used a structural equation model to obtain

state-level gun ownership rates each year. This measure offers a robust estimate of gun ownership rates across states that improves on prior analyses.

Drawing on the State Firearm Law database, dummy variables were created indicating whether the state required safety training to own a handgun, had a minimum age requirement of 21 years of age to purchase a gun, and had a child access prevention law holding firearm owners criminally responsible in instances of negligence that allow minors to gain access to their guns (e.g. failure to store firearm in securely locked container) (Fla. Stat. Ann. § 790.174, 2011; Hawaii Rev. Stat. § 134-10.5, 2011). Between 1980 and 2019, twenty-nine states implemented a child access prevention law holding firearm owners responsible for allowing minors to gain access to their guns, twenty-one states enacted a minimum age law of 21 years of age for handgun purchases, and six states created laws mandating safety training for all handgun purchases. State-level K-12 student enrollments were recorded for each year of analysis. This variable was rescaled to represent 100,000 students. The geographic location of each school firearm incident was marked as large city (250,000 or greater), midsize city (100,000-249,999), small city (99,999–25,000), suburb (contiguous to large or midsize city), and small town/rural (less than 25,000). From US Census data, the state poverty rate was denoted for each year of analysis (1980–2019).

4.3. Analytical techniques

The data analysis proceeded as follows. In the first phase of analysis, descriptive trends from 1980 to 2019 were generated for state-level school firearm incidents, changes in state gun ownership rates, injured/killed victims in schools, and state gun ownership rates. State-level correlations were then explored for school firearm incidents, changes in firearm ownership rates, and injured/killed victims. In subsequent models, state-level fixed effects negative binomial regression models were performed. To consider the practical significance of the association between state gun ownership rates and school firearm incidents, marginal effects estimates were investigated. In subsequent models, laws on required safety training for handgun purchases, child access prevention, and minimum age requirements of 21 years of age were analyzed. Mandated handgun safety training was the focus of the analyses because it exhibited the strongest associations with the number of school firearm incidents and injured/killed victims of these incidents. Single and two multiple group interrupted times series models were performed to examine whether trends in school firearm incidents decreased after the passage of required safety training for handgun purchases. In supplementary analyses, there was little or no evidence of an association between school firearm incidents and child access prevention and minimum age requirements of 21 years of age for gun purchases.

5. Results

Fig. 1 presents average state gun ownership rates from 1980 to 2019 and the total number of school firearm incidents and injured/killed victims of school firearm incidents over the same period. In 1980, the average state gun ownership rate was nearly 51% but trended downward to a little under 40% as of 2019. From 1980 to 2017, the total number of school firearm incidents generally stayed near the range of 20 to 40 incidents each year. However, school firearm incidents skyrocketed to unprecedented levels in the final two years of analysis, reaching 102 incidents in 2018 and 110 incidents in 2019. The number of injured or killed victims was 174 in 2018 and 121 in 2019.

Table 3 presents each state's forty-year change in firearm ownership, average gun ownership rate, total school firearm incidents, school enrollment per school firearm incident, and the number of injured or killed victims of school firearm incidents from 1980 to 2019. During this period, most states experienced declines in rates of gun ownership. In
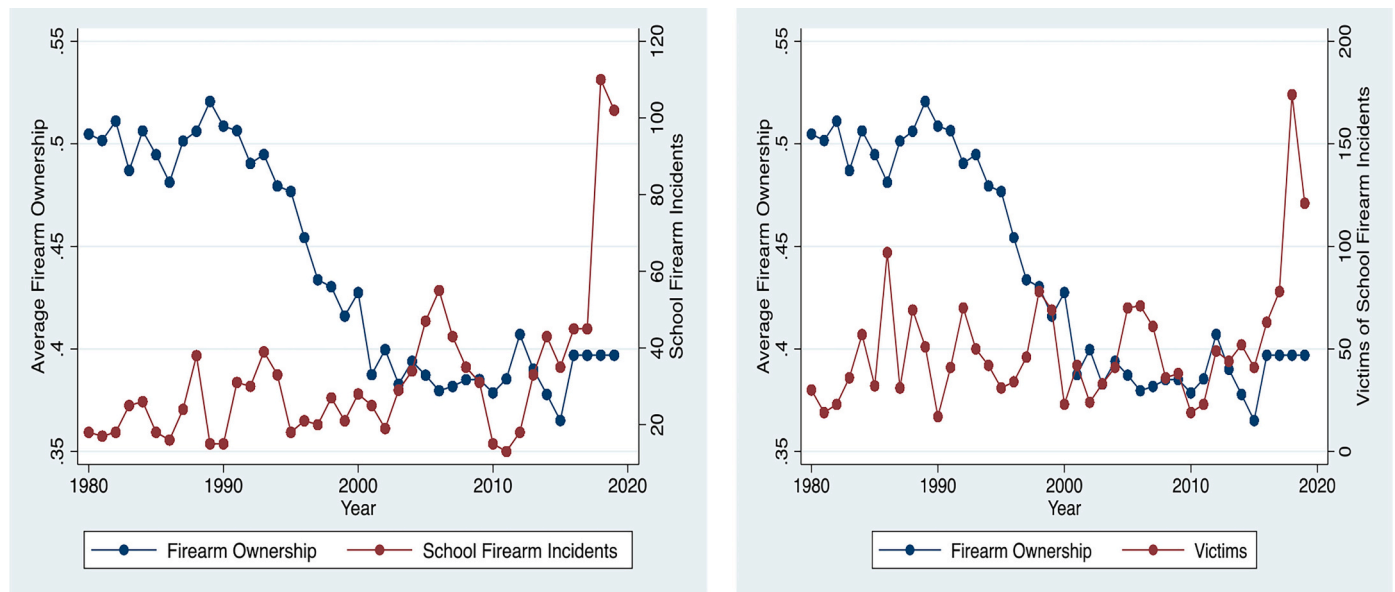
Fig. 1. State gun ownership (%) and school firearm incidents and injured/killed victims (1980–2019).

some states, declines were substantial. For example, the gun ownership rate dropped by 20% or more in approximately one in five states. Only four states, all of which are clustered in the northeast, experienced an increase, but these increases are small ranging between 1 and 6%. Among the 50 states, Montana and Wyoming have the highest average gun ownership rates at 66%. At 14%, Hawaii, New Jersey, and Massachusetts report the lowest average gun ownership rates. The three most populous states (i.e. California, Texas, and Florida) have the highest number of school firearm incidents and injured or killed victims of these incidents. Delaware, Louisiana, Alabama, and Montana have the highest number of incidents as a proportion of student enrollment (17,000–19,000 students per school firearm incident).

Table 4 presents correlations among gun ownership rates, school firearm incidents, and injured/killed victims. The annual gun ownership rate is not associated with changes in the gun ownership rate, but the annual gun ownership rate is closely associated with the forty-year average gun ownership rate ($p < 0.001$). Annual and forty-year averages for school firearm incidents and injured/killed victims of school firearm incidents are negatively associated with gun ownership rates ($p < 0.001$), meaning increases in gun ownership rates are correlated with decreases in school firearm incidents. This association is partly attributable to state size as annual gun ownership rates are also negatively related to school enrollment per school firearm incident ($p < 0.001$). The bivariate correlations demonstrate insightful descriptive patterns but are limited in their ability to explain whether high gun ownership rates lead to greater numbers of incidents with guns in schools. Furthermore, many specific state characteristics (e.g. poverty rate) may coincide with changes in gun ownership within a state.

Table 5 presents state-level fixed effects negative binomial regression models predicting the number of school firearm incidents and the number injured/killed victims of school firearm incidents. In Model 1, gun ownership rates exhibit small positive associations with school firearm incidents, controlling for year ($p < 0.01$). For example, the mean state gun ownership rate is 44%. When the state gun ownership rate increases by approximately 2 standard deviations from 15% to 44%, the predicted number of school firearm incidents increases by 1.6 incidents. In Model 2, the relationship increases after adding controls for state school enrollment, region, state size, and state poverty rate ($p < 0.001$). By holding all other variables at their means, when the state gun ownership rate increases from 15% to 44%, the predicted number of school firearm incidents increases by 2.3 incidents. In 2018 and 2019,

school firearm incidents rose to levels far higher than previous years so supplementary analyses were performed with these two unprecedented years excluded. By excluding these two years, results are no longer statistically significant (See Appendix Table 1a for full results). In Model 3, binary variables were added indicating the existence of laws requiring safety training for handgun purchases, a minimum of 21 years of age for gun purchases, and child access prevention legislation that may make handgun owners responsible for allowing minors to gain access to their firearms. Although none of these laws is statistically significant for school firearm incidents, associations for each are in a negative direction, meaning that they are related to decreases in school firearm incidents. Safety training for handgun purchases exhibits the strongest association of the three regulations.

In Models 4 to 6, the same progression of models is performed for the number of injured/killed victims of school firearm incidents. In Model 4, gun ownership rates are related to fewer injured/killed victims ($p < 0.001$). This finding is inconsistent with that of Model 1. When the state gun ownership rate increases from 15% to 44%, the predicted number of injured/killed victims decreases by 0.29. In Model 5, after including controls, the direction of the relationship changes so that increased gun ownership is related to more injured/killed victims but this estimate is not statistically significant. By excluding 2018–2019, supplementary analyses do not show a statistically significant relationship between state gun ownership rates and injured/killed victims of school firearm incidents (See Appendix Table 1a for full results). In Model 6, binary variables were introduced for mandatory safety training for handgun purchases, a minimum of 21 years of age for gun purchases, and child access prevention. Each of these gun control regulations is associated with fewer numbers of injured or killed victims. Safety training requirements for handgun purchases and child access laws are statistically significant, but the strongest association of the two is observed for safety training requirements for handgun purchases. The predicted number of injured/killed victims decreases by 0.1 in states with safety training requirements for handgun purchases. There is no statistical association between state gun ownership rates and injured/killed victims after these three gun laws are introduced.

Results from the state fixed effects models are inconclusive but among gun control laws, mandatory safety training for handgun purchases demonstrated the strongest associations with school firearm incidents and injured/killed victims. Required gun safety training for handgun purchases might represent a comprehensive approach that

Table 3

State gun ownership rates and school firearm incidents (1980–2019)

State	Change in firearm ownership rate (%)	40-yr. avg. firearm ownership rate (%)	40-yr. school firearm incidents	40-yr. Injured/killed victims of school firearm incidents	40-yr. School enrollment / school firearm incident
Georgia	−23	48	48	63	29,505
Nevada	−23	46	12	22	26,682
Texas	−23	45	123	168	33,522
Alaska	−22	64	5	6	24,652
North Carolina	−21	45	42	43	30,956
Virginia	−21	44	23	27	49,219
California	−20	27	150	327	37,366
Arizona	−20	45	10	13	85,293
Maryland	−20	29	39	43	20,623
New Mexico	−19	45	9	10	35,080
Hawaii	−18	14	3	4	59,264
Arkansas	−18	57	16	31	28,733
Kansas	−17	48	12	18	38,239
Washington	−17	41	33	42	28,783
Wyoming	−17	66	2	81	47,258
Iowa	−17	43	11	10	45,013
Oregon	−16	50	14	51	37,908
Colorado	−16	45	20	68	35,752
Nebraska	−15	45	7	9	41,297
Florida	−15	35	81	127	28,009
Minnesota	−14	43	10	26	81,210
Utah	−13	46	12	12	42,178
Montana	−13	66	8	10	18,947
South Carolina	−13	49	25	42	27,119
Indiana	−12	45	22	21	45,721
New Jersey	−11	14	13	21	97,476
Tennessee	−10	51	41	41	22,292
Illinois	−9	27	56	88	35,404
Idaho	−8	60	2	0	124,729
Alabama	−8	55	43	47	17,144
Massachusetts	−8	14	11	20	84,199
Connecticut	−7	23	17	50	30,883
Oklahoma	−6	55	9	13	69,774
New York	−6	19	44	56	62,288
Michigan	−6	40	62	96	26,370
Mississippi	−5	56	16	26	30,697
Louisiana	−5	53	44	47	16,985
South Dakota	−4	55	4	3	32,539
Missouri	−4	49	26	29	33,792
Ohio	−4	40	46	61	39,062
Pennsylvania	−4	41	51	71	34,587
West Virginia	−3	59	2	2	153,292
Vermont	−2	50	2	3	47,674
Kentucky	−2	54	13	38	50,976
Wisconsin	−1	45	16	20	52,765
North Dakota	0	55	1	1	110,084
Maine	1	47	3	2	67,422
Rhode Island	3	15	4	6	36,308
Delaware	4	35	6	6	18,971
New Hampshire	6	41	6	5	30,996
United States (state avg.)	−11	44	26	41	46,101

Table 4

Correlational table of state gun ownership rates, school firearm incidents, and injured/killed victims (1980–2019)

1. Gun ownership rate							
2. Forty-year gun ownership change	−0.05						
3. Forty-year gun ownership rate	0.90***	−0.06**					
4. School firearm incidents	−0.17***	−0.17***	−0.14***				
5. School enrollment / school firearm incident	−0.22***	−0.14***	−0.21***	0.39***			
6. Injured/killed victims of school firearm incidents	−0.08***	−0.12***	−0.08***	0.57***	0.24***		
7. Forty-year total school firearm incidents	−0.21***	−0.29***	−0.23***	0.59***	0.61***	0.36***	
8. Forty-year total school victims	−0.18***	−0.30***	−0.20***	0.54***	0.57***	0.39***	0.92***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

helps to reduce youth access to guns. To investigate the potential efficacy of this particular regulation further, Table 6 presents the results of single and multiple group interrupted times series models for six states that passed legislation requiring safety training for handgun purchases. For the single comparisons of each state before and after the new regulation, the first-year change indicates slightly fewer school firearm

Table 5

State-level fixed effects negative binomial regression models predicting school firearm incidents and the number killed or injured victims of school firearm incidents

Variables	School firearm incidents			Injured/killed victims of school firearm incidents		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
State gun ownership rate	2.16**	3.16***	2.72**	−2.13***	0.78	−0.08
	(0.78)	(0.84)	(0.87)	(0.52)	(0.70)	(0.73)
Year	0.04***	0.04***	0.05***	0.01**	0.02***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
State school enrollment		0.01	0.01		0.04***	0.05***
		(0.01)	(0.01)		(0.01)	(0.01)
Midwest		0.82	0.74		0.46*	0.38
		(0.51)	(0.52)		(0.22)	(0.23)
Northeast		1.13	1.14		−0.02	−0.04
		(0.81)	(0.84)		(0.27)	(0.27)
West		0.61	0.58		−0.83***	−0.81***
		(0.54)	(0.55)		(0.19)	(0.20)
Large state		0.90	0.65		0.32	0.11
		(0.53)	(0.54)		(0.31)	(0.32)
State poverty rate		−0.04*	−0.04*		−0.01	−0.01
		(0.02)	(0.02)		(0.02)	(0.02)
Safety training required for handgun purchase			−0.22			−0.45*
			(0.21)			(0.23)
Twenty-one minimum age requirement			−0.16			−0.21
			(0.13)			(0.14)
Child access prevention			−0.13			−0.29*
			(0.13)			(0.13)
Constant	−0.71	−1.35*	−1.15	−0.40	−2.25***	−1.82***
	(0.39)	(0.60)	(0.61)	(0.28)	(0.48)	(0.49)
Observations	2000	2000	2000	1960	1960	1960
States	50	50	50	49	49	49

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Negative binomial regression coefficients are presented. Standard errors are in parentheses. South is the reference category for regions. Large states are California, New York, Texas, and Florida. In Models 4–6, Idaho was dropped from the fixed effects analysis because Idaho did not have any injured/killed victims during the period of analysis (1980–2019).

incidents and injured/killed victims after passing the law requiring safety training for handgun purchases, but these results are not statistically significant. The trend over time for the single group comparisons presents a mixed set of results across states. Only Maryland exhibits statistically significant patterns over time, but in the wrong direction for both the number of school firearm incidents and injured/killed victims of school firearm incidents. In the first set of multiple group comparisons (i.e. excludes states with laws requiring gun safety training for handgun purchases), both the first-year change and trends over time exhibit a mixed set of results across the six states. In the second set of multiple group comparisons, six states requiring safety training for handgun purchases were compared to states without required safety training for handgun purchases, a minimum age requirement of 21 years of age for handgun purchases, and child access prevention laws. However, both the first-year change and trends over time exhibit a mixed set of results for this second series of multiple group comparisons. The overall analyses in Table 6 show weak and inconsistent results.

6. Discussion

Gun ownership and regulation are at the center of debates over how to address the high number of firearm incidents occurring in American schools. Yet, little prior empirical work exists on state gun ownership, gun regulations, and school incidents with firearms. This study sought to understand whether state gun ownership rates and gun control laws are associated with school firearm incidents. The analyses produced mixed results that did not offer consistent evidence of a relationship between state gun ownership rates and the number of firearm incidents and injured or killed victims of firearms in schools. Similarly, three relevant gun control laws exhibited weak and inconsistent associations with school firearm incidents and injured or killed victims of firearm incidents in schools. By linking together multiple datasets to perform a comprehensive analysis of gun ownership rates, gun control regulations,

and school firearm incidents over a forty-year period, the analyses in this study offer valuable empirical contributions to a mostly theoretical literature.

In the United States, gun ownership and school shooting incidents are high, so there is a strong rationale for examining the nature of the relationship between these two factors. While access to a gun is a necessary precondition for an incident with a firearm to take place on school grounds, results of this study do not provide clear evidence that gun ownership itself is the driving force behind school firearm incidents, at least at varying levels of gun ownership observed in US states from 1980 to 2019. Gun ownership, for example, trended downward in nearly every US state over the four decades of analysis, and some states experienced large declines of 20% or more. In spite of these trends, school firearm incidents hovered near the range of 20 to 40 incidents a year during this time period before soaring to over 100 incidents in 2018 and 2019. It is plausible that at lower thresholds for gun ownership, youth access to guns would be sufficiently restricted to contribute to reducing school firearm incidents. Whether such reductions are politically feasible is uncertain given constitutional protections for gun ownership in the United States. Scholars have further questioned if focusing on large decreases in gun ownership would fail to resolve the underlying problems behind school shootings and if assailants might end up substituting guns for other types of deadly weapons (e.g. explosives) (Jeynes, 2020).

Gun control regulation may be a key lever for intervention. Even though weak associations were observed in this study for child access prevention, safety training for handgun purchases, and minimum age requirements of 21 years of age, other regulations that specifically seek to reduce school shootings as opposed to general gun violence may prove more effective. Some research on school shootings indicates that preventing youth from accessing firearms is an important step toward reducing youth access. In spite of weak findings observed for child access prevention in this study, it may be that child access prevention laws

Table 6
Results for single and multiple group interrupted time series models

Implementing States	School firearm incidents			Victims of school firearm incidents		
	Single	Multiple Group[1]	Multiple Group[2]	Single	Multiple Group	Multiple Group
California						
First-year change	−1.55	−1.48	−1.38	−6.47	−6.12	−6.04
	(1.47)	(1.40)	(1.41)	(3.68)	(3.51)	(3.53)
Trend change	−0.20	−0.25	−0.26	0.36	0.29	0.32
	(0.18)	(0.17)	(0.17)	(0.47)	(0.44)	(0.45)
Connecticut						
First-year change	−0.51	−0.17	−0.28	−0.72	−0.29	−0.55
	(0.53)	(0.52)	(0.52)	(0.78)	(0.79)	(0.83)
Trend change	0.06	0.05	0.04	0.22	0.22	0.22
	(0.06)	(0.06)	(0.06)	(0.14)	(0.13)	(0.13)
Hawaii						
First-year change	−0.12	0.26	0.23	−0.14	0.25	0.06
	(0.11)	(0.16)	(0.19)	(0.12)	(0.28)	(0.37)
Trend change	0.01	−0.02	−0.02	0.01	−0.01	0.01
	(0.01)	(0.01)	(0.02)	(0.01)	(0.03)	(0.03)
Maryland						
First-year change	−0.67	−0.56	−0.54	−1.19	−0.94	1.28
	(0.57)	(0.57)	(0.58)	(0.67)	(0.69)	(0.74)
Trend change	0.71*** (0.16)	0.48 ** (0.17)	0.48** (0.18)	1.02*** (0.19)	0.69** (0.22)	0.87*** (0.22)
Massachusetts						
First-year change	−0.21	0.01	−0.01	−0.52	−0.27	−0.48 (0.62)
	(0.36)	(0.36)	(0.37)	(0.51)	(0.55)	
Trend change	0.01	−0.02	−0.02	0.09	0.07	0.08
	(0.03)	(0.03)	(0.03)	(0.06)	(0.06)	(0.07)
Rhode Island						
First-year change	−0.13	0.08	0.06	−0.29	−0.038 (0.34)	−0.25
	(0.14)	(0.17)	(0.19)	(0.23)		(0.45)
Trend change	0.01	−0.03*	−0.03*	0.01	−0.01	0.01
	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
States	1	45	17	1	45	17
Observations	40	1800	680	40	1800	680

*** p < 0.001, ** p < 0.01, * p < 0.05. Incident estimates are presented. Standard errors are in parentheses. 1. This model compares the state to all other states but excludes states that require safety training for handgun purchases. 2. This model compares the state to states that did not have laws requiring safety training for handgun purchases, a minimum age of purchase at 21 years of age, and child access prevention.

need to be strengthened in certain ways, possibly enhancing consequences for gun owners who do not secure their firearms sufficiently. Future research might explore whether highly strict regulations on preventing youth access help to reduce school firearm incidents. Even with effective regulation, scholars reason that family, school, and community level factors require consideration when exploring ways to prevent school shootings (Hamlin & Li, 2020; Collins, 2014; Newman, Fox, Harding, Mehta, & Roth, 2005). Family dysfunction, childhood trauma, severe bullying, glorification of violence, gang activity, suicidal tendencies, and mental health challenges are considered relevant factors in the lives of those who commit violent acts with weapons on school grounds (Agnich, 2015; Fox & Levin, 2015; Huesmann, 2016; Langman, 2009). Many interacting factors appear to influence the likelihood of school firearm incidents, particularly in the case of rampage and gang-related school shootings.

Part of the methodological challenge of identifying effective gun regulations is that school firearm incidents follow inconsistent patterns that are not well suited to many types of statistical techniques. Over the 40 years of analysis in this study, the number of firearm incidents that occurred on school grounds stayed near the range of 20 to 40 incidents a year before spiking to unprecedented levels in 2018 and 2019. Investigation of the factors behind the sharp rises in school firearm incidents 2018 and 2019 is needed. Furthermore, it is unclear if these two years are anomalous or if they signify a new, higher trend in school firearm incidents. In 2020, many schools moved to remote and hybrid learning models in response to the COVID-19 pandemic so 2020 does not provide a valid comparison with 2018 and 2019. Subsequent academic years will be informative once schools return to regular in-person learning.

6.1. Limitations

There are methodological limitations to this study that necessitate cautious interpretation of the results. The lowest 40-year average state gun ownership rate was 14%. It is uncertain how lower rates of state gun ownership might reduce incidents with firearms in schools. Gun ownership rates may also be less consequential than the number of guns per owner as greater stocks of guns in households may increase the likelihood of youth access. Additionally, the state gun ownership rate for 2016 was used for 2017–2019. While little information indicates gun ownership rates changed significantly from 2017 to 2019, gun sales did decline. If gun ownership rates followed this pattern and were considerably lower than 2016 estimates, the relationship between state gun ownership rates and school firearm incidents could weaken further.

Incidents with firearms in schools seem to be driven by different interacting home, school, and community factors that vary based on the circumstances of a particular case (Collins, 2014; Jeynes, 2020). In the statistical models used in this study, unobserved family, school, and community characteristics may confound the relationship between state gun ownership rates and school firearm incidents. Along with these limitations, the analyses of gun control regulations were limited to three regulations that are thought to be germane to youth violence. Other types of regulations may be more efficacious for preventing school firearm incidents. Future work should explore this possibility. The interrupted time series analyses used to test three gun control regulations are also limited because firearm incidents within schools tended not to follow a clear linear trend prior to the passage of gun control laws that were examined. Interrupted time series at the state level could mask variation among localities within states themselves. There may be

different results within states but such designs will be difficult to perform given the statistical infrequency of firearm incidents in schools.

7. Conclusion

The search for policy levers that can reduce incidents with firearms in schools is of critical importance. This study's empirical results showed weak and inconsistent evidence of links between school firearm incidents and state gun ownership rates and three gun control laws. Although this study does not provide immediate direction on which policies should or should not be undertaken in the short term, the analyses contribute empirical data to a largely theoretical debate over how to address school shootings. The analyses in this work set the stage for new inquiry that probes different levels of gun ownership, alternative gun regulations, and family, school, community supports that reduce the problem of violence with firearms in American schools.

Appendix

Table 1a

State-level fixed effects negative binomial regression models predicting school firearm incidents and the number killed or injured victims of school firearm incidents (1980–2017).

Variables	School firearm incidents			Injured/killed victims		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
State gun ownership rate	0.61	1.15	0.76	−2.32***	0.07	−0.76
	(0.85)	(0.95)	(0.97)	(0.56)	(0.77)	(0.80)
Year	0.02***	0.02***	0.02***	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
State school enrollment		0.01	0.01		0.03***	0.04***
		(0.01)	(0.01)		(0.01)	(0.01)
Midwest		0.86	0.80		0.26	0.23
		(0.75)	(0.74)		(0.24)	(0.25)
Northeast		0.54	0.68		−0.42	−0.40
		(0.78)	(0.86)		(0.29)	(0.30)
West		0.44	0.57		−1.12***	−1.05***
		(0.60)	(0.62)		(0.20)	(0.21)
Large state		0.25	−0.06		0.57	0.38
		(0.56)	(0.58)		(0.36)	(0.37)
State poverty rate		−0.01	0.01		0.02	0.02
		(0.02)	(0.02)		(0.02)	(0.02)
Safety training required for handgun purchase			−0.36			−0.48
			(0.22)			(0.25)
Twenty-one minimum age requirement			−0.21			−0.28*
			(0.14)			(0.14)
Child access prevention			0.04			−0.16
			(0.14)			(0.14)
Constant	0.54	−0.26	−0.15	−0.09	−1.74***	−1.38**
	(0.47)	(0.70)	(0.70)	(0.31)	(0.52)	(0.53)
Observations	1900	1900	1900	1862	1862	1862
States	50	50	50	49	49	49

Negative binomial regression coefficients are presented. Standard errors are in parentheses

*** p < 0.001, ** p < 0.01, * p < 0.05

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