

The Impact of Firearm Legislation on Firearm Deaths, 1991–2017

John F. Gunn III¹, Paul Boxer², Tracy Andrews³, Michael Ostermann⁴,
Stephanie L. Bonne⁵, Michael Gusmano⁶, Elizabeth Sloan-Power⁷, Bernadette Hohl⁸

¹School of Public Health, Department of Biostatistics & Epidemiology & NJ Gun Violence Research Center, Rutgers University, Piscataway, NJ 08854

²Department of Psychology, Rutgers University, Newark, NJ 07102

³Biostatistics & Epidemiology Services, Rutgers University, USA

⁴School of Criminal Justice, Rutgers University, Newark, NJ 07102

⁵Division of Trauma and Critical Care, Department of Surgery, Rutgers New Jersey Medical School, Newark, NJ 07103

⁶School of Public Health, Department of Health Behavior, Society, and Policy, Piscataway, NJ 08854

⁷Department of Social Work, Rutgers University, Newark, NJ 07102

⁸School of Public Health, Department of Biostatistics & Epidemiology, Piscataway, NJ 08854

Address correspondence to John F. Gunn III, E-mail: john.gunn@rutgers.edu.

ABSTRACT

Firearm violence is a major public health concern in the USA with firearm suicide and homicide accounting for the majority of gun deaths. The present work seeks to explore the role of firearm legislation in reducing suicide and homicide rates. Using the State Firearm Law Database (www.statefirearmlaws.org), suicide and homicide rates were compared across the 50 US states from 1991 to 2017. A firearm regulations index was computed to represent the total number of state firearm laws. Generalized estimating equations were used to explore population-level increases or decreases in firearm regulations and their association with state suicide and homicide rates after controlling for several state-level covariates. Even after accounting for several key covariates (US region; time; gun ownership; percent of the state population that was White, Black, below the poverty line and 25 years or older with a bachelor's degree; incarceration rate, unemployment rate and divorce rate), we found that firearm laws significantly predicted state firearm suicide and homicide rates. States with greater numbers of laws had reduced suicide and homicide rates compared with those with fewer laws. The present findings point to the role of firearm legislation in curbing rates of gun violence across the USA.

Keywords firearm suicide, firearm homicide, firearm laws

Introduction

In 2017, 66 683 people died by suicide (47 173) and homicide (19 510) in the USA, placing suicide as the 10th leading cause of death and homicide as the 16th.¹ Firearms are the most common means, accounting for 48 and 74% of these deaths, respectively.^{2–3} In the absence of uniform federal regulations, states have implemented firearm regulations that vary significantly across states both in the number of regulations and the types of laws in place.⁴ The State Firearm Laws Project categorizes 14 different types of firearm regulations across the 50 US states (see Supplementary Appendix A).² In addition to the variation in firearms regulations across states, the exact number of firearms in the USA is not well established, making it difficult to ascertain the impact of gun availability on suicide and homicide rates.^{3–4} The present work seeks to explore what impact firearm regulations have

on firearm suicide and homicide rates within each of the US's 50 states from 1991 to 2017.

Impact of firearm legislation on firearm mortality

Previous work has explored the role of firearm legislation in suicide and homicide mortality. Lester and Murrell⁵ found

John F. Gunn III, Postdoctoral Associate

Paul Boxer, Professor

Tracy Andrews, Biostatistician

Michael Ostermann, Associate Professor

Stephanie L. Bonne, Assistant Professor of Surgery

Michael Gusmano, Professor

Elizabeth Sloan-Power, Associate Professor

Bernadette Hohl, Assistant Professor

that stricter handgun laws were linked to lower suicide rates but not homicide rates. Likewise, the passage of Bill C-51 in Canada was associated with significant decreases in suicides.⁶ Recently, Anestis and Anestis⁷ found that four handgun related laws (waiting periods, universal background checks, firearm locks and open carrying regulations) were each associated with significantly lower firearm suicide rates. Anestis and *et al.*⁸ likewise found that states that lacked universal background checks and waiting periods saw greater increases in suicide rates from 1999 to 2015. Following the repeal of a handgun purchaser licensing law, a 16% increase in homicide rates was observed in Missouri.⁹ Conversely, a 40% reduction over a 10-year period was observed after the implementation of a permit-to-purchase law in Connecticut.¹⁰

Lower state-level suicide rates have also been observed in relation to permit requirements, ban on purchase by minors, mental health prohibitions, alcohol problem prohibitions, drug problem prohibitions, misdemeanor conviction prohibitions, domestic violence prohibitions, undocumented immigrant prohibitions, felony prohibitions, juvenile offense prohibitions and fugitive prohibitions in the USA¹¹ Anestis *et al.*,¹² focusing on permit to purchase a handgun, registration of handguns and license to own a handgun, found that states with any of these laws in place had lower overall suicide rates as well as lower firearm suicide rates. Firearm regulations, firearm availability and safe storage practices have also been found to be significant predictors of state suicide rates, indicating that the more available firearms are, the more relaxed regulations, and the use of unsafe storage practices were all associated with increased suicide rates.¹³

Previous work using Brady Campaign data found that a higher number of firearm laws in states were associated with lowered suicide and homicide rates for the period of 2007–2010.¹⁴ Siegel *et al.*¹⁵ investigated the impact of universal background checks, violent misdemeanor prohibitions on handgun possession, age 21 limitations for handgun possession, shall issue laws, permitless carry, trafficking laws, junk gun bans, stand your ground laws, assault weapons ban, and large-capacity magazine bans on suicide and homicide rates from 1991 to 2016. They found that universal background checks and regulations prohibiting possession by those convicted of violent misdemeanors were associated with significant decreases in homicide rates while shall issue laws were associated with significant increases in homicide rates. None of the other laws examined were associated with increased or decreased homicide rates, and none of the laws examined were associated with overall suicide rates.

The present work builds on the existing literature in several ways. Whereas previous work explored the impact of specific firearms regulations^{6,11,12} or only a selected set of firearm regulations,^{7,14,15} we focus on total firearm regulations.

Building on previous work,¹⁵ our analysis considers the expanded universe of firearm laws across all 50 US states for 1991–2017. In the absence of indicators of enforcement, it can be difficult to compare specific regulations or even sets of regulations across states. By aggregating all regulations in a state, we create a general index of that state's overall approach to firearms regulation—a measure of whether a given state is broadly restrictive or lenient towards firearms. We incorporate an array of covariates known to be associated with suicide and homicide.^{7,10,15–17} We hypothesized that stricter state laws regarding firearm possession would produce lower suicide and homicide rates. The mechanism by which it is hypothesized that these would operate is in reducing access to firearms, a particularly lethal method of injury.

Methods

State-level data

Gun regulations

We obtained data from the State Firearms Law Database (statefirearmlaws.org). An in-depth discussion of the development of this database can be found in Siegel *et al.*¹⁸ The total number of firearm laws on record in states across the 1991–2017 time period ranged from 2 (e.g. Idaho in 2016 and 2017) to 106 (e.g. California in 2017) laws. States were rated as either (1) having a law in place or (0) not having a law in place. An overall firearm law index was then created by summing across all laws providing a score indicating the total number of gun laws in each state and serving as an indicator of the permissiveness or restrictiveness of the state. Descriptive statistics on the firearm law index and our other measures can be seen in [Table 1](#).

Suicide & homicide rates

Suicide and homicide rates were obtained through the Centers for Disease Control and Prevention's (CDC) web-based Wide-Ranging Online Data for Epidemiologic Research program (CDC¹⁹). These scores represent the age-adjusted rate per 100 000 persons who died by either suicide or homicide and allow for comparisons between states of different population levels. Data were collected for firearm and overall suicide and homicide. Poisson regression was the appropriate method given the use of count data. Before the Poisson regression was run, suicide and homicide rates were multiplied by a factor of 10 to create whole numbers. Rates reported in results are adjusted back to the original format (i.e. per 100 000).

Control measures

To assess the impact of other state-level correlates of suicide and homicide rates, US census region, percentages White

Table 1 Descriptive statistics of study variables for 1991–2017

	<i>Suicide (N = 50 states)</i>		
	<i>Minimum</i>	<i>Maximum</i>	<i>M (SD)</i>
Firearm suicide rates per 100 000	1.4	20.3	7.7 (3.1)
Overall suicide rates per 100 000	6.0	29.7	13.5 (3.8)
Firearm regulation index	2.0	106	23.5 (22.0)
Gun ownership	3.4	71.6	41.5(13.8)
% White	25.7	98.2	75.2 (15.1)
% Male	47.9	52.6	49.2 (0.8)
% Black	0.3	38.3	10.8 (9.5)
% 25 and Older with a bachelors	11.4	42.6	25.9 (5.3)
% Below poverty line	4.5	25.8	12.7 (3.5)
Unemployment rate per 100 000	2.3	13.6	5.6 (1.8)
Divorce rate per 1,000	0.0	22.6	6.5 (2.3)
Incarceration rate per 100 000	65.0	893.0	369.2 (146.3)
	<i>Homicide (N = 40 states)</i>		
	<i>Minimum</i>	<i>Maximum</i>	<i>M (SD)</i>
Firearm homicide rates per 100 000	0.8	16.3	4.4 (2.3)
Overall homicide rates per 100 000	1.4	20.2	6.4 (3.0)
Firearm regulation index	2	106	25.1 (21.9)
Gun ownership	5.6	71.6	40.5 (12.4)
% White	38.2	95.9	73.0 (12.8)
% Male	47.9	52.6	49.1 (0.8)
% Black	0.7	38.3	13.0 (9.4)
% 25 and Older with a bachelors	11.4	42.6	25.8 (5.5)
% Below poverty line	5.7	25.8	13.1 (3.6)
Unemployment rate per 100 000	2.3	13.6	5.8 (1.9)
Divorce rate per 1000	0.0	15.5	6.1 (1.7)
Incarceration rate per 100 000	78.0	893.0	392.0 (144.5)

(non-Hispanic) and Black, percentage male, percentage of those 25 years or older with at least a Bachelor's degree, gun ownership, percentage below the poverty line, unemployment rates, incarceration rates, divorce rates and time were included in the analysis. These controls were selected to be consistent with previous work.^{7,15} Classifications for US region and data on percent white and black, percent over 25 years with a Bachelor's degree or more, and percent below the poverty line were obtained from the US Census Bureau.^{20,21} Unemployment rates by state were obtained through the Bureau of Labor Statistics.²² Divorce rates were obtained from CDC's detailed marriage and divorce tables (CDC²³). Incarceration rates were obtained from the Bureau of Justice Statistics' Prisoners reports²⁴ outlining the number and rate of state and federal prisoners by year. Gun ownership estimates were obtained from RAND Corporation.²⁵

Procedures

As with similar work^{26,27}, generalized estimating equations (GEE) was utilized to explore the associations between firearm laws and suicide and homicide rates. GEE is a semi-parametric method often used with longitudinal panel data to account for data from 1-year correlating with data from the next. GEE estimates indicate the degree to which the average response of the entire population changes with one-unit changes in the covariates. Thus, the estimates indicate how changes in predictors and changes in the outcome over time are associated while accounting for any correlation within-subjects. The present analysis utilized a GEE regression model with a Poisson distribution, an AR (1) correlation matrix and Log link function with state as the subject and time as the within-subject variable. Our four models examined (i) firearm suicide rates, (ii) overall

suicide rates (iii) firearm homicide rates and (iv) overall homicide rates. Firearm and overall homicide rates were not available for states with < 10 decedents, therefore the analysis for these categories includes only the 40 states for which we had complete data from 1991 to 2017. Further details on data analysis can be seen in an online [Supplementary Material](#).

Results

Sample characteristics and bivariate results

There was a greater range of rates for firearm suicide than for firearm homicide across the 50 US states (Table 1). Firearm regulations had a strong and negative association with firearm suicide rates ($r = -0.72$, $P < 0.001$; Table 2). This pattern held for firearm homicide rates as well but with a weaker association ($r = -0.20$, $P < 0.001$).

Firearm regulation and firearm suicides

US region, firearm regulation index, time, gun ownership, percentage of the state below the poverty line and divorce rates all significantly contributed to the prediction of firearm suicide rates (Table 3). US region, firearm regulation index, time, gun ownership, percentage of the population that are Black and divorce rate all significantly contributed to the prediction of overall suicide rates. The firearm regulations index had an inverse association with firearm and overall suicide rates, indicating that as the number of firearm laws increased, suicide rates decreased. Figure 1 plots the estimated marginal means at different levels of gun regulations, illustrating this trend. As can be seen, even with covariates factored in, mean scores of firearm and overall suicide rates decrease as the number of firearm laws increase, with estimated marginal means of 7.9 (lowest regulation) to 3.6 (highest regulation) for firearm suicide rates. Additionally, as can be seen in the Exp(B) values, states with higher firearm regulations index scores had greater decreases in suicide rates compared with those with lower values on the firearm regulations index. For example, states with the highest number of gun laws had an Exp(B) value of 0.45 compared with states with the lowest number of gun laws having an Exp(B) of 1.09 for firearm suicide rates. In other words, the impact of firearm laws on suicide rates grew stronger as the number of laws increased.

Firearm legislation and firearm homicides

For firearm homicide rates the firearm regulations index, time, gun ownership, percentage of the state population that is White, percentage of the population that is Black and the divorce rate all significantly contributed to the prediction of

firearm homicide rates (Table 3). For overall homicide rates, the firearm regulations index, time, gun ownership, the percentage of the state population that is White, the percentage of the state population that is Black, the percentage of the state population that is 25 years and older with a bachelor's degree or higher, the unemployment rate and the divorce rate all contributed significantly to the model. The firearm regulations index had an inverse association with homicide rates indicating that as firearm laws increase the homicide rates decrease. Figure 1 plots the estimated marginal means at different levels of gun regulations. There is a clear negative trend showing that the incidence of homicide decreases with increasing gun legislation. With estimated marginal means of 5.0 (lowest regulation) to 3.4 (highest regulation) for firearm homicide rates. Even when other covariates are accounted for, the mean rates of homicide decrease as the number of firearm laws increase. This is further illustrated in the Exp(B) values which indicate that states with higher firearm regulations index scores had greater decreases in homicide rates than did those with lower scores. For example, states with the highest number of gun laws had an Exp(B) value of 0.68 while states with the lowest number of gun laws had an Exp(B) value of 1.15 for firearm homicide rates. This once more underlines the impact of firearm regulations such that homicide rates increased as the total number of firearm laws decreased.

Discussion

Main findings of this study

The present work set out to explore the association between firearm regulations and suicide and homicide rates, building on recent critical findings.¹⁵ We hypothesized that states with stricter (i.e. a greater number of) firearm regulations would have lower suicide and homicide rates by decreasing access to a highly lethal means of injury. Our expectations were met, with some critical expansion and divergence from what Siegel *et al.*¹⁵ reported. Even with several state-level covariates included in the model, the total firearm regulation index significantly contributed to the prediction of suicide rates and homicide rates (firearm and overall). As states' strictness increased, their suicide and homicide rates decreased.

What is already known of this topic

These findings are in line with previous work looking at the impact of firearm legislation on suicide and homicide rates. For example, the passage of Bill C-51 in Canada was followed by significant decreases in suicides.⁶ Additionally, states with waiting periods, universal background checks, firearm locks and open carrying regulations have lower suicide rates than

Table 2 Bivariate associations among study variables for all 50 US states, 1991–2017

	1	2	3	4	5	6	7	8	9	10	11	12
1. Firearm suicide rate	—											
2. Firearm homicide rate	0.24	—										
	<0.001											
3. Firearm regulations index	-0.72	-0.20	—									
	<0.001	<0.001										
4. Gun ownership	0.83	0.60	-0.81	—								
	<0.001	<0.001	<0.001									
5. % White	0.21	-0.38	-0.39	0.45	—							
	<0.001	<0.001	<0.001	<0.001								
6. % Male	0.48	-0.29	-0.24	0.31	-0.04	—						
	<0.001	<0.001	<0.001	<0.001	0.15							
7. % Black	-0.16	0.69	0.07	-0.12	-0.44	-0.55	—					
	<0.001	<0.001	0.02	<0.001	<0.001	<0.001						
8. % 25 years + with a bachelors	-0.44	-0.41	0.52	-0.61	-0.18	0.08	-0.10	—				
	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001					
9. % Below the poverty line	0.30	0.52	-0.21	0.27	-0.31	-0.22	0.36	-0.21	—			
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				
10. Unemployment rate	0.06	0.17	0.08	-0.06	-0.23	-0.10	0.21	-0.04	0.48	—		
	0.04	<0.001	0.01	0.02	<0.001	<0.001	<0.001	0.16	<0.001	<0.001		
11. Divorce rate	-0.01	-0.19	0.04	-0.11	-0.20	0.19	-0.11	0.09	-0.07	-0.18	—	
	0.66	<0.001	0.12	<0.001	<0.001	<0.001	<0.001	0.003	0.01	<0.001	<0.001	
12. Incarceration rate	0.13	0.43	-0.10	0.04	-0.41	-0.02	0.50	-0.08	0.31	0.15	0.11	—
	<0.001	<0.001	<0.001	0.19	<0.001	0.38	<0.001	0.002	<0.001	<0.001	<0.001	<0.001

Note: Values in bold represent correlation coefficients, non-bolded values represent P-values.

Table 3 GEE results for firearm and overall suicide and homicide rates, 1991–2017

	<i>Suicide rates</i>				<i>Homicide rates</i>				
	<i>Firearms</i>		<i>Overall</i>		<i>Firearms</i>		<i>Overall</i>		
	B	Exp (B)	B	Exp (B)	B	Exp (B)	B	Exp (B)	
US region									
Northeast	-ref-	-ref-	-ref-	-ref-	Northeast	-ref-	-ref-	-ref-	-ref-
Midwest	-0.01	0.99	-0.01	1.00	Midwest	0.19	1.21	0.13	1.14
South	0.15**	1.17	0.08*	1.09	South	0.19	1.20	0.15	1.16
West	0.33***	1.39	0.26***	1.30	West	0.11	1.11	0.10	1.11
Firearm regulation index					Firearm regulation index				
[total = 106]	-0.80***	0.45	-0.58***	0.56	[total = 106]	-0.39*	0.68	-0.42***	0.66
[total = 104]	-0.62***	0.54	-0.50***	0.61	[total = 104]	-0.29	0.75	-0.34**	0.71
[total = 102]	-0.62***	0.54	-0.51***	0.60	[total = 102]	-0.32	0.73	-0.38**	0.68
[total = 101]	-0.91***	0.40	-0.38***	0.69	[total = 101]	-0.49*	0.61	-0.43**	0.65
[total = 100]	-0.63***	0.53	-0.50***	0.61	[total = 100]	-0.43*	0.65	-0.46***	0.63
[total = 99]	-0.58***	0.56	-0.50***	0.61	[total = 99]	-0.34*	0.71	-0.41***	0.66
[total = 95]	-0.66***	0.52	-0.55***	0.58	[total = 95]	-0.31	0.74	-0.35**	0.70
[total = 94]	-0.57***	0.56	-0.47***	0.62	[total = 94]	-0.29	0.75	-0.36**	0.70
[total = 93]	-0.59***	0.56	-0.47***	0.62	[total = 93]	-0.26	0.77	-0.33**	0.72
[total = 90]	-0.59***	0.56	-0.24***	0.78	[total = 90]	-0.88***	0.42	-0.82***	0.44
[total = 86]	-0.56***	0.57	-0.49***	0.61	[total = 86]	-0.41*	0.66	-0.47***	0.63
[total = 85]	-0.58***	0.56	-0.35**	0.71	[total = 85]	-0.56**	0.57	-0.57***	0.57
[total = 84]	-0.74***	0.48	-0.41***	0.67	[total = 84]	-0.68**	0.51	-0.69***	0.50
[total = 79]	-0.99***	0.37	-0.16	0.85	[total = 75]	-0.44*	0.65	-0.41**	0.66
[total = 78]	-0.78***	0.46	-0.09	0.91	[total = 74]	-0.69***	0.50	-0.62***	0.54
[total = 77]	-0.73***	0.48	-0.15	0.87	[total = 73]	-0.32	0.72	-0.44***	0.65
[total = 75]	-0.70***	0.50	-0.28***	0.76	[total = 72]	-0.29	0.75	-0.38**	0.68
[total = 74]	-0.75***	0.47	-0.36***	0.70	[total = 71]	-0.57**	0.57	-0.51***	0.60
[total = 73]	-0.56***	0.57	-0.29***	0.75	[total = 70]	-0.44*	0.65	-0.41**	0.66
[total = 72]	-0.58***	0.56	-0.29***	0.75	[total = 69]	-0.32	0.73	-0.35*	0.70
[total = 71]	-0.56***	0.57	-0.31***	0.73	[total = 67]	-0.29	0.75	-0.29	0.75
[total = 70]	-0.56***	0.57	-0.31***	0.74	[total = 66]	-0.35	0.71	-0.36*	0.70
[total = 69]	-0.48***	0.62	-0.25***	0.78	[total = 65]	-0.12	0.89	-0.15	0.86
[total = 67]	-0.70***	0.50	-0.30***	0.74	[total = 64]	0.11	1.12	0.10	1.11
[total = 66]	-0.59***	0.55	-0.38***	0.68	[total = 63]	-0.33	0.72	-0.30*	0.74
[total = 65]	-0.38***	0.68	-0.23***	0.80	[total = 62]	-0.43*	0.65	-0.46***	0.63
[total = 64]	-0.48***	0.62	-0.30***	0.74	[total = 61]	-0.25	0.78	-0.25	0.78
[total = 63]	-0.60***	0.55	-0.29***	0.75	[total = 60]	-0.36	0.70	-0.30	0.74
[total = 62]	-0.46***	0.63	-0.24***	0.79	[total = 59]	-0.37	0.69	-0.37**	0.69
[total = 61]	-0.59***	0.55	-0.34***	0.72	[total = 58]	-0.17	0.85	-0.17	0.84
[total = 60]	-0.45***	0.64	-0.28***	0.76	[total = 57]	-0.28	0.76	-0.24	0.79
[total = 59]	-0.62***	0.54	-0.39***	0.68	[total = 56]	-0.29	0.75	-0.23	0.80
[total = 58]	-0.34**	0.72	-0.22**	0.80	[total = 55]	-0.28	0.75	-0.20	0.82
[total = 57]	-0.46***	0.63	-0.26***	0.77	[total = 54]	-0.23	0.79	-0.20	0.82
[total = 56]	-0.50***	0.61	-0.26***	0.77	[total = 52]	-0.31	0.73	-0.22	0.80

Continued

Table 3 Continued

	<i>Suicide rates</i>				<i>Homicide rates</i>				
	<i>Firearms</i>		<i>Overall</i>		<i>Firearms</i>		<i>Overall</i>		
[total = 55]	-0.48***	0.62	-0.22***	0.81	[total = 51]	-0.27	0.76	-0.24	0.78
[total = 54]	-0.35***	0.70	-0.25***	0.78	[total = 50]	-0.18	0.83	-0.15	0.86
[total = 53]	-0.54***	0.58	-0.18***	0.84	[total = 49]	-0.26	0.77	-0.17	0.84
[total = 52]	-0.36***	0.70	-0.27***	0.77	[total = 48]	-0.21	0.81	-0.20	0.82
[total = 51]	-0.45***	0.64	-0.29***	0.75	[total = 46]	-0.37*	0.69	-0.27*	0.76
[total = 50]	-0.35***	0.70	-0.19***	0.83	[total = 44]	-0.05	0.96	-0.06	0.94
[total = 49]	-0.45**	0.64	-0.19*	0.83	[total = 43]	-0.34	0.71	-0.22	0.81
[total = 48]	-0.19**	0.82	-0.19***	0.83	[total = 42]	-0.41*	0.66	-0.38**	0.68
[total = 46]	-0.69***	0.50	-0.39***	0.68	[total = 41]	-0.19	0.83	-0.11	0.89
[total = 45]	-0.53***	0.59	-0.22***	0.81	[total = 40]	-0.23	0.79	-0.29*	0.75
[total = 44]	-0.33**	0.72	-0.10	0.90	[total = 39]	-0.46**	0.63	-0.33*	0.72
[total = 43]	-0.45**	0.64	-0.25***	0.78	[total = 38]	-0.18	0.84	-0.20	0.82
[total = 42]	-0.39**	0.68	-0.25**	0.78	[total = 37]	-0.12	0.89	-0.18	0.84
[total = 41]	-0.25**	0.78	-0.15**	0.86	[total = 35]	-0.41*	0.66	-0.28*	0.75
[total = 40]	-0.45***	0.64	-0.24***	0.79	[total = 34]	-0.11	0.90	-0.14	0.87
[total = 39]	-0.32**	0.73	-0.21***	0.81	[total = 33]	-0.20	0.82	-0.18	0.84
[total = 38]	-0.19*	0.82	-0.09*	0.91	[total = 32]	-0.23	0.80	-0.16	0.85
[total = 37]	-0.09	0.91	-0.07	0.93	[total = 31]	-0.29	0.75	-0.22	0.80
[total = 35]	-0.14*	0.87	-0.13**	0.88	[total = 30]	-0.29*	0.75	-0.24*	0.79
[total = 34]	-0.24*	0.79	-0.16**	0.85	[total = 29]	-0.27	0.76	-0.21	0.81
[total = 33]	-0.22**	0.80	-0.15**	0.86	[total = 28]	-0.06	0.94	-0.08	0.92
[total = 32]	-0.21*	0.81	-0.19**	0.83	[total = 27]	-0.33	0.72	-0.30*	0.75
[total = 31]	-0.26***	0.77	-0.21***	0.81	[total = 26]	-0.11	0.90	-0.14	0.87
[total = 30]	-0.04	0.96	-0.04	0.96	[total = 25]	-0.31	0.73	-0.25*	0.78
[total = 29]	-0.09	0.92	-0.08	0.92	[total = 24]	-0.27	0.76	-0.26*	0.77
[total = 28]	-0.13	0.88	-0.04	0.96	[total = 23]	-0.24	0.78	-0.25*	0.78
[total = 27]	-0.23**	0.80	-0.07	0.93	[total = 22]	-0.31	0.73	-0.22	0.80
[total = 26]	-0.24*	0.79	-0.08	0.92	[total = 21]	-0.22	0.81	-0.18	0.84
[total = 25]	-0.17*	0.85	-0.13*	0.88	[total = 20]	-0.30*	0.75	-0.26*	0.77
[total = 24]	-0.15*	0.86	-0.10*	0.90	[total = 19]	-0.18	0.83	-0.18	0.83
[total = 23]	-0.13	0.88	-0.10*	0.90	[total = 18]	-0.17	0.84	-0.18	0.84
[total = 22]	-0.10	0.90	-0.10	0.91	[total = 17]	-0.29	0.75	-0.21*	0.81
[total = 21]	-0.07	0.93	-0.05	0.96	[total = 16]	-0.17	0.84	-0.13	0.88
[total = 20]	-0.13	0.88	-0.11*	0.90	[total = 15]	-0.21	0.81	-0.18	0.83
[total = 19]	-0.08	0.93	-0.07	0.93	[total = 14]	-0.18	0.83	-0.15	0.86
[total = 18]	-0.07	0.93	-0.07	0.93	[total = 13]	-0.23	0.80	-0.17	0.85
[total = 17]	-0.08	0.93	-0.06	0.94	[total = 12]	-0.20*	0.82	-0.15	0.86
[total = 16]	-0.01	0.99	-0.02	0.98	[total = 11]	-0.15	0.87	-0.09	0.92
[total = 15]	-0.03	0.97	-0.03	0.97	[total = 10]	-0.18	0.84	-0.13	0.88
[total = 14]	-0.04	0.96	-0.03	0.97	[total = 9]	-0.20	0.82	-0.14	0.87
[total = 13]	-0.06	0.94	-0.05	0.95	[total = 8]	-0.12	0.89	-0.10	0.90
[total = 12]	-0.03	0.97	-0.02	0.98	[total = 7]	-0.15	0.86	-0.12	0.89
[total = 11]	-0.03	0.97	-0.02	0.98	[total = 6]	-0.19	0.82	-0.15	0.86
[total = 10]	-0.02	0.98	-0.01	0.99	[total = 5]	-0.15	0.86	-0.10	0.90

Continued

Table 3 Continued

	Suicide rates				Homicide rates				
	Firearms		Overall		Firearms		Overall		
[total = 9]	0.02	1.02	0.02	1.02	[total = 4]	0.12	1.13	0.10	1.11
[total = 8]	-0.01	0.99	-0.02	0.98	[total = 3]	0.14	1.15	0.32**	1.38
[total = 7]	0.01	1.01	0.00	1.00	[total = 2]	-ref-	-ref-	-ref-	-ref-
[total = 6]	-0.01	0.99	-0.002	1.00	Time	-0.01**	0.99	-0.02***	0.99
[total = 5]	-0.07	0.94	0.001	1.00	Gun Ownership	0.01**	1.01	0.004**	1.00
[total = 4]	0.03	1.03	0.07	1.07	% White	-0.01***	0.99	-0.01***	0.99
[total = 3]	0.08	1.09	0.06	1.06	% Male	-0.07	0.93	-0.06	0.94
[total = 2]	-ref-	-ref-	-ref-	-ref-	% Black	0.02***	1.02	0.02***	1.02
Time	0.01***	1.01	0.02***	1.02	% 25+ with B.A.	-0.01	0.99	-0.01*	0.99
Gun ownership	0.01***	1.02	0.01***	1.01	% Below Poverty Line	-0.003	1.00	0.000	1.00
% White	0.001	1.00	-0.00006	1.00	Unemployment Rate	-0.01	0.99	-0.01*	0.99
% Male	-0.01	1.00	0.004	1.00	Divorce Rate	-0.02***	0.98	-0.02***	0.98
% Black	-0.003	1.00	-0.01***	0.99	Incarceration Rate	-0.00005	1.00	-0.00007	1.00
% 25+ with B.A.	-0.01	0.06	-0.003	1.00					
% Below poverty line	0.004*	1.00	0.002	1.00					
Unemployment rate	0.001	1.00	0.000	1.00					
Divorce rate	-0.02***	0.99	-0.01***	0.99					
Incarceration rate	0.00002	1.00	-0.000002	1.00					

Notes: Intraclass correlations (ICC) for firearm and overall suicide rates indicated that 86% and 80% of the variations in deaths were due to differences across states, respectively. ICCs for firearm and overall homicide were 77 and 73%, respectively. Quasi-likelihood under independence model criterion (QIC) values for firearm-suicide, overall-suicide, firearm-homicide, and overall-homicide were 1724.8, 2189.0, 4592.1 and 4730.7, respectively.

* $P \leq 0.05$.

** $P \leq 0.01$.

*** $P \leq 0.001$.

states who lack these regulations.⁷ Though some previous work failed to find support for a reduction in suicide rates.¹⁵ Likewise, states with more firearm laws also tend to have lower homicide rates¹⁴ though the evidence suggests this may be only for certain laws.¹⁵

What this study adds

Previous work focused either on specific laws^{6,11,12} or only a selected number of firearms^{7,14,15}, the present work examines the total number of firearm laws present in each of the states. We believe this to be important to consider, given the absence of any indicators of enforcement. Though states may have firearm laws in place, whether they are enforced matters. Through aggregating all regulations, we may get a general sense of the 'gun law culture' that is indicative of the overall permissiveness or restrictiveness of the state. Like previous work by Siegel and colleagues¹⁵, we found that firearm legislation is associated with homicide rates over time. However, unlike Siegel and colleagues, we also found an association with suicide rates. This is

likely due to our including firearm legislation in our total score that was missed in the more specified analysis by Siegel *et al.*

Limitations of this study and implications for future research

The present findings must be viewed in light of several limitations. Although our focus on total firearm regulations allowed us to view the overall impact of firearm regulation permissiveness or strictness on state-level suicide and homicide rates, it lacks specificity, making policy or public health implications unclear. Maintaining a focus in future research on the impact of changes in specific laws over time might further illuminate the association between firearm regulations and firearm mortality. Only by doing this can specific recommendations be made for policymakers and public health practitioners. Then again, our aggregate provides a novel means of considering states' overall permissiveness or strictness towards firearms—a potential index of their 'gun law culture'. As such, it positions us well to raise a second

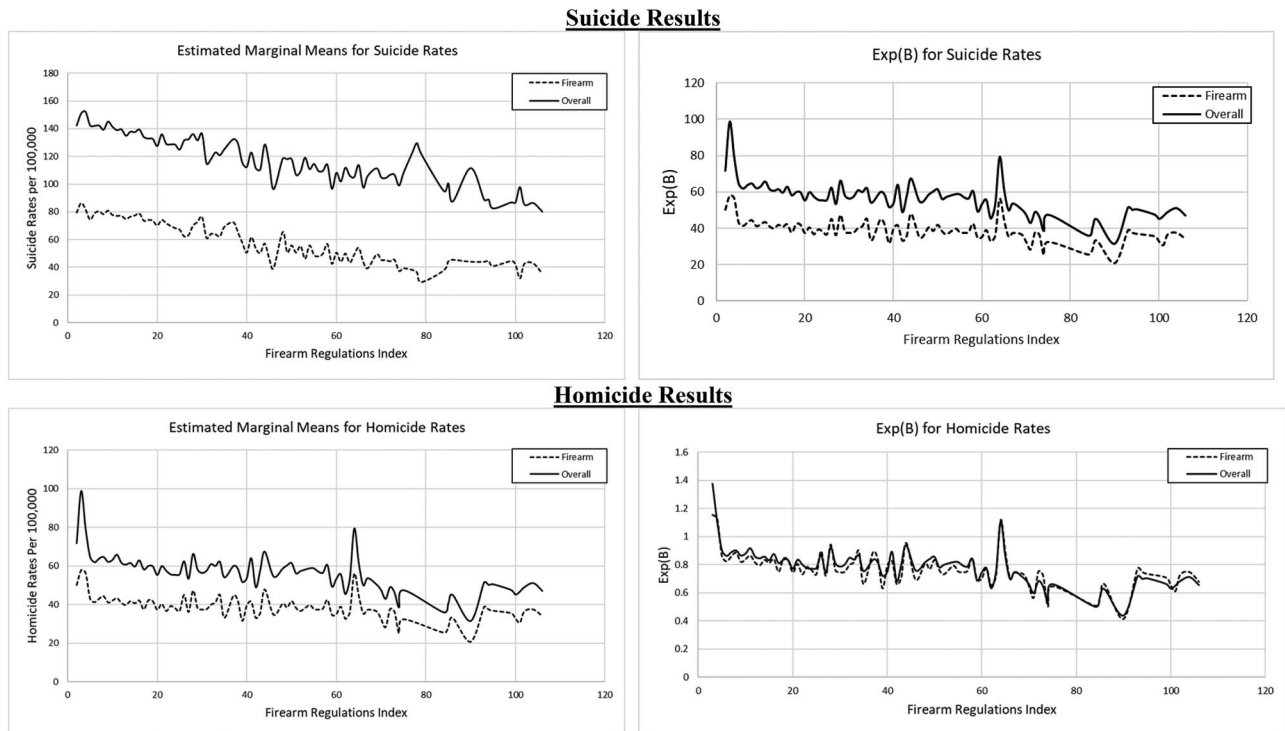


Fig. 1 Generalized estimated equation results for suicide & homicide rates, 1991–2017. Notes: solid lines represent overall rates; dotted lines represent firearm-specific rates.

limitation: the inability to ascertain whether firearm regulations are enforced. The current data only pertain to whether or not the states have those laws in place. For example, having a safe storage law in place might only impact suicide rates in states that enforce those safe storage laws consistently. This is a critical direction for future research on the effects of firearms laws on firearm crimes in general and homicide and suicide rates in particular. Until data can be explored that taps directly into the enforcement of firearm laws, our focus on total firearm regulations might be better equipped to pick up on this as the total number of firearm laws speaks more to the gun law culture of the specific states. Additionally, whereas we control for several potential confounding influences on suicide and homicide rates there is the potential that other unexplored confounding variables may influence the suicide and homicide rates of the states that enact firearm regulations.

Despite the study's limitations, this work points to the importance of firearm regulations in reducing overall and firearm suicide and homicide rates. The impact, while present for both, was strongest for suicide. As Fig. 1 shows, the suicide rates of states high in firearm regulations were close to half of those at the low end. Future work is needed to explore the relationship between firearm regulations and suicide and homicide rates more fully. Of particular interest would be studies exploring the impact of specific changes to firearm

laws over time—such as the introduction of extreme risk protection orders, which allow the removal of firearms in instances of concern by family members and/or law enforcement. These laws are becoming more commonplace and future work could explore their impact on state-level suicide and homicide rates following their introduction. It will also be important to explore the impact of firearm regulation strictness on suicide and homicide trends—including the extent to which, as suggested earlier, various laws are enforced. For example, given that suicide rates in the USA are on the rise (CDC²⁸), one question that could be explored by future research is whether states with more permissive or less consistently enforced firearm laws are seeing greater increases than those whose laws are stricter or more heavily enforced. Finally, future research should also examine trends in homicide more fully—given the inconsistencies in the literature with regards to homicide rates. One promising direction would be on examining the impact of firearm legislation on the declines in violent crime seen in the 1990s—a period included in the current analysis. Examining the passage of specific gun laws may provide a clearer picture of this drop in violent crime.

Conclusions

In the 1960s and 1970s, suicide rates in England dropped unexpectedly—an unintentional byproduct of the removal of

carbon monoxide from the public gas supply.²⁹ This unintended consequence highlighted how changes at societal levels can impact suicide mortality—and subsequently how this might be able to be applied to criminal behavior as well. The present work, as well as the growing body of evidence supporting the impact of firearm regulations on suicide and homicide mortality, also highlights what role legislation can play in reducing suicide and, to a lesser extent, homicide rates. With close to 40 000 deaths annually from firearm violence, regulations that can limit access to firearms appear to reduce state-level mortality. Evidence-based implementation of firearm regulations across the whole of the USA has the potential to significantly reduce the toll of firearm violence.

Supplementary data

Supplementary data are available at the *Journal of Public Health online*.

Funding

The present work was supported by a grant administered by New Jersey's Office of the Secretary for Higher Education (OSHE).

References

- Kochanek KD, Murphy SL, Xu J. *et al*. Deaths: final data for 2017. *Natl Vital Stat Rep* 2019;**68**(9):1–77.
- McClenathan J, Pahn M, Siegel M. *The Changing Landscape of U.S. Gun Policy: State Firearm Laws, 1991–2016*. 2016. http://www.statefirearmlaws.org/sites/default/files/2017-12/report_0.pdf (9 December 2019, date last accessed).
- Pirelli G, Wechsler H, Cramer RJ. Firearm, law, and policy. In: Pirelli G, Wechsler H, Cramer RJ (eds). *The Behavioral Science of Firearms: A Mental Health Perspective on Guns, Suicide, and Violence*. Oxford, UK: Oxford University Press, 2019, 72–124.
- Pirelli G, Wechsler H, Cramer RJ. Firearms: a primer. In: Pirelli G, Wechsler H, Cramer RJ (eds). *The Behavioral Science of Firearms: A Mental Health Perspective on Guns, Suicide, and Violence*. Oxford, UK: Oxford University Press, 2019, 3–70.
- Lester D, Murrell ME. The preventive effect of strict gun control laws on suicide and homicide. *Suicide Life-Threat Behav* 1982;**12**(3): 131–40.
- Lester D, Leenaars A. Suicide rates in Canada before and after tightening firearm control laws. *Psychol Rep* 1993;**72**(3):787–90.
- Anestis MD, Anestis JC. Suicide rates and state laws regulating access and exposure to handguns. *Am J Public Health* 2015;**105**: 2049–58.
- Anestis MD, Selby EA, Butterworth SE. Rising trajectories in suicide rates: the role of firearm suicide rates and firearm legislation. *Prevent Med* 2017;**100**:159–66.
- Webster D, Crifasi CK, Vernick JS. Effects of the repeal of Missouri's handgun purchaser licensing law on homicides. *J Urban Health* 2014;**92**(2):293–302.
- Rudolph KE, Stuart EA, Vernick JS *et al*. Association between Connecticut's permit-to-purchase handgun law and homicides. *Am J Public Health* 2015;**105**:e49–54.
- Andres AR, Hempstead K. Gun control and suicide: the impact of state firearm regulations in the United States, 1995–2004. *Health Policy* 2011;**101**:95–103.
- Anestis MD, Khazem LR, Law KC *et al*. The association between state laws regulating handgun ownership and statewide suicide rates. *Am J Public Health* 2015;**105**:2059–67.
- Kposowa A, Hamilton D, Wang K. Impact of firearm availability and gun regulation on state suicide rates. *Suicide Life-Threat Behav* 2016;**46**(6):678–96.
- Fleegler EW, Lee LK, Monteaux MC *et al*. Firearm legislation and firearm-related fatalities in the United States. *JAMA Internal Med* 2013;**173**(9):732–40.
- Siegel M, Pahn M, Xuan Z *et al*. The impact of state firearm laws on homicide and suicide deaths in the USA, 1991–2016: a panel study. *J Gen Internal Med* 2019;**34**(10):2021–8.
- Rihmer Z, Barsi J, Veg K, Katona CLE. Suicide rates in Hungary correlate negatively with reported rates of depression. *J Affect Disord* 1990;**20**(2):87–91.
- Stack S. The impact of divorce on suicide in Norway, 1951–1980. *J Marriage Family* 1989;**51**(1):229–38.
- Siegel M, Pahn M, Xuan Z *et al*. Firearm-related laws in all 50 US states, 1991–2016. *Am J Public Health* 2017;**107**(7):1122–9.
- Centers for Disease Control and Prevention. *Wide-Ranging Online Data for Epidemiologic Research (WONDER)*. Department of Health and Human Services, 2019. Atlanta, GA, USA. <https://wonder.cdc.gov/>.
- U.S. Bureau of the Census. *Statistical Abstract of the United States: 2012 (131st edn)*. U.S. Federal Statistical System, 2012. <https://www.census.gov/library/publications/2011/compendia/statab/131ed.html>.
- U.S. Bureau of the Census. *American Fact Finder*. 2019. <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.
- Bureau of Labor Statistics. *Local Area Unemployment Statistics*. U.S. Department of Labor, 2019. <https://www.bls.gov/lau/#tables>.
- Centers for Disease Control and Prevention. *National Vital Statistics System: Marriage and Divorces*. National Center for Human Statistics, 2019. https://www.cdc.gov/nchs/nvss/marriage-divorce.htm?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fnchs%2Fmardiv.htm.
- Bureau of Justice Statistics. *Publications & Products: Prisoners*. Office of Justice Programs, 2019. <https://www.bjs.gov/index.cfm?ty=pbse&sid=40>.
- Schell TL, Peterson S, Vegetabile BG, *et al*. *State-Level Estimates of Household Firearm Ownership*. Santa Monica, CA: Rand Corporation, 2020. <https://www.rand.org/pubs/tools/TL354.html>

- 26 Siegel M, Ross CS, King C III. The relationship between gun ownership and firearm homicide rates in the United States, 1981-2010. *Am J Public Health* 2013;**103**(11):2098–105.
- 27 Fridel EE. Comparing the impact of household gun ownership and concealed carry legislation on the frequency of mass shootings and firearms homicide. *Justice Quarterly* 2020. Online First. doi: 10.1080/07418825.2020.1789693.
- 28 Centers for Disease Control and Prevention. *CDC Vital signs*. National Center for Human Statistics, 2018. <https://www.cdc.gov/vitalsigns/pdf/vs-0618-suicide-H.pdf>.
- 29 Clarke RV, Mayhew P. The British gas suicide story and its criminological implications. *Crime Justice* 1988;**10**:79–116.