Examining the relationship between the prevalence of guns and homicide rates in the USA using a new and improved state-level gun ownership proxy

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ABSTRACT

Determining the relationship between gun ownership levels and firearm homicide rates is critical to inform public health policy. Previous research has shown that state-level gun ownership, as measured by a widely used proxy, is positively associated with firearm homicide rates. A newly developed proxy measure that incorporates the hunting license rate in addition to the proportion of firearm suicides correlates more highly with state-level gun ownership. To corroborate previous research, we used this new proxy to estimate the association of state-level gun ownership with total, firearm, and non-firearm homicides. Using state-specific data for the years 1981–2010, we modelled these rates as a function of gun ownership level, controlling for potential confounding factors. We used a negative binomial regression model and accounted for clustering of observations among states. We found that state-level gun ownership as measured by the new proxy, is significantly associated with firearm and total homicides but not with non-firearm homicides.

Firearms are responsible for approximately 31 000 deaths in the USA each year, of which approximately 11 000 are homicides.[1] In the wake of the Newtown tragedy, many states are considering legislation to regulate more stringently the availability of firearms. While some policy makers argue that reducing the prevalence of firearms will decrease firearm homicide, the National Rifle Association has argued that the opposite is true: more firearms in the hands of citizens will protect against violent crime.[2] Determining whether higher gun ownership is associated with increased or decreased firearm homicide is a critical public health research question.

Several cross-sectional studies have reported a positive and significant relationship between the prevalence of gun ownership at the state level and state-specific rates of firearm homicide.[3–15] Collectively, these studies examined the relationship between state-level gun ownership and firearm homicides during the period 1972–1999.

We recently published an updated analysis of the relationship between state-level gun ownership and firearm homicide rates in the USA that included data through the year 2010.[16] Using 30 years of panel data and controlling for a wide range of state-level factors known to influence homicide rates, we found a robust correlation between higher levels of gun ownership and higher firearm homicide rates, with each 1% point increase in gun ownership associated with a 0.9% increase in firearm homicide rate.[16]

A limitation noted in the paper was our use of a proxy measure (firearm suicides divided by all suicides, or FS/S) to estimate state-level gun ownership. Subsequently, we developed a new and more accurate proxy measure which incorporates a state's hunting license rate—obtained from the U.S. Fish & Wildlife Service[17]—in addition to FS/S. (Annual state-specific data on hunting license rates are included as an online-only supplementary appendix.) This new proxy measure, which is a weighted average of FS/S and the hunting license rate ((0.62×FS/S) +(0.88×hunting license rate)—4.478) improves the correlation with survey-measured gun ownership in Behavioral Risk Factor Surveillance System during 2001, 2002 and 2004 from 0.80 for FS/S to 0.95, and closely estimates absolute levels of gun ownership.[18] With the recent issuance by the National Institutes of Health (NIH) of a request for proposals to study the prevention of firearm violence,[19] a better understanding of the usefulness of existing proxies for state-level firearm ownership would be helpful.

In this paper, we reanalyse the data in our previous research using the new, more accurate proxy instead of FS/S. We also examine the relationship between gun ownership and firearm homicide rates, and total and non-firearm homicide rates as well. Our primary purpose is to investigate whether we can corroborate the findings of previous research while using the new proxy measure, thus addressing a criticism of prior research that the FS/S proxy measure is not a sufficiently strong correlate of household firearm ownership.[20] This research addresses the National Research Council's call for 'more rigorous evaluations on the impact of proxies.'(ref.[20] p. 42)

METHODS

Design overview

Essentially, we used the same data, model and statistical analysis described previously.[1] Briefly, we assembled a panel of annual data for the years 1981–2010 for each of the 50 states. The adjusted firearm, non-firearm, or total homicide rate in a given year for a given state was modelled as a function of the gun ownership level in that state during that year, while controlling for factors that could confound the association. A negative binomial regression model was used, entering fixed effects for each year. We accounted for clustering of observations among states using a generalised estimating equations (GEE) approach, and controlled for a wide range of factors that have been identified in previous literature as being related to homicide

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rates. We first ran a full model that included all variables, regardless of their contribution to the model. We then developed a final, more parsimonious model, which included only variables with significant regression coefficients, using a Wald test at a significance level of 0.05. Here, we report the results of the final models, which avoid over-specification. We also note that the results of the full models were similar.

Model refinements

We refined the model first by using the new proxy, which incorporates FS/S and the state's hunting license rate,[18] and second, by modelling the adjusted total homicide rate and the adjusted firearm homicide rate as the outcome variable. We also modelled non-firearm homicide as an additional outcome. The only other change in our model was that we did not control for the adjusted non-firearms homicide rate. We excluded this variable for two reasons. First, the model already includes four variables that capture what we aimed to capture by including non-firearm homicide rates: the violent crime rate, the non-violent crime rate, the hate crime rate, and the incarceration rate. Second, introducing this variable might actually introduce a bias away from the null hypothesis.

Variables

The outcome variable was the age-adjusted firearm or non-firearm homicide rate, obtained from the Centers for Disease Control and Prevention's Web-based Injury Statistics Query and Reporting Systems (WISQARS) database.[1] The main predictor variable was the prevalence of household firearm ownership, measured by either the old (FS/S) or new proxy. We controlled for the following state-level factors: proportion of young adults (ages 15–29 years), proportion of young males (ages 15–29 years), proportion of blacks, proportion of Hispanics, level of urbanisation, educational attainment, poverty status, unemployment, median household income, income inequality (the Gini ratio), per capita alcohol consumption, non-homicide violent crime rate (aggravated assault, robbery, and forcible rape), non-violent (property) crime rate (burglary, larceny-theft, and motor vehicle theft), hate crime rate, divorce rate, region, suicide rate, and incarceration rate.

State-level mortality data obtained through WISQARS for the years 2008–2010 do not include any states with fewer than 10 homicide deaths. This resulted in 13 missing data points; therefore, there was a total of 1487 observations in our dataset. Because of the small number of missing cases, we used case-wise deletion of these 13 records. We note that there was limited variation across time, and most of the variation was between the 50 states, thus limiting our effective sample size.

Model and statistical analysis

We modelled the outcome variable using negative binomial regression because the age-adjusted firearm and non-firearm homicide rates were not normally distributed, but skewed and overdispersed. We accounted for clustering in our data at the state level by using a GEE approach. We accounted for clustering at the year level by including year as a fixed effect.

All analyses were conducted using the xtnbreg procedure in STATA V.12 (College Station, Texas, USA: The Stata Corporation).

RESULTS

Adjusted firearm homicide rates

In the final model, gun ownership, as measured by FS/S, was positively associated with adjusted firearm homicide rates (IRR=1.010; 95% CI 1.006 to 1.014) (table 1). Gun ownership as measured by the new proxy also had a positive and significant association with firearm homicide (IRR=1.011; 95% CI 1.006 to 1.017). This indicates that for each 1% point increase in gun ownership, a state's firearm homicide rate increases by 1.1%.

Table 1 Effect of gun ownership level on age-adjusted firearm homicide rate

Proxy variable	Incidence rate ratio* (95% CI)	p Value
FS/S	1.010 (1.006 to 1.014)	p<0.001
New proxy	1.011 (1.006 to 1.017)	p<0.001

*Final model includes fixed effects for year, is adjusted for clustering within states, and controls only for state-level factors that are significant in the model at the 0.05 level.
FS/S, firearm suicides divided by all suicides

Adjusted total homicide rates

In the final model, gun ownership as measured by FS/S was positively associated with adjusted total homicide rates (IRR=1.006; 95% CI 1.003 to 1.010) (table 2). Gun ownership, as measured by the new proxy, also had a positive and significant association with total homicide (IRR=1.007; 95% CI 1.003 to 1.010). This indicates that for each 1% point increase in gun ownership, a state's total homicide rate increases by 0.7%.

Adjusted non-firearm homicide rates

In the final model, gun ownership as measured by FS/S was not significantly related to adjusted non-firearm homicide rates (IRR=0.999; 95% CI 0.996 to 1.003) (table 3). Gun ownership as measured by the new proxy also had no significant association with non-firearm homicide rates (IRR=0.998; 95% CI 0.994 to 1.003).

DISCUSSION

This study strengthens our previously published analysis of the relationship between firearm ownership and gun-related homicide rates among the 50 states by (1) using a new proxy measure for state-level gun ownership that correlates more highly with survey measures of gun ownership and (2) examining the relationship between gun ownership and firearm, non-firearm, and total homicide rates.

We found that the positive and significant association between gun ownership and firearm homicide was replicated with the new proxy. We also found that gun ownership, whether measured by the old or new proxy, is significantly associated with total homicide rates. Gun ownership has no significant relation to non-firearm homicide rates.

These findings make it less likely that the observed association between gun ownership and firearm homicide rates may be attributed to the use of a proxy measure for gun ownership. The results also demonstrate that an increased prevalence of firearms is associated with an increase in firearms homicides, and an increase in

Table 2 Effect of gun ownership level on age-adjusted total homicide rate

Proxy variable	Incidence rate ratio* (95% CI)	p Value
FS/S	1.006 (1.003 to 1.010)	p<0.001
New proxy	1.007 (1.003 to 1.010)	p<0.001

*Final model includes fixed effects for year, is adjusted for clustering within states, and controls only for state-level factors that are significant in the model at the 0.05 level.
FS/S, firearm suicides divided by all suicides

Table 3 Effect of gun ownership level on age-adjusted non-firearm homicide rate

Proxy variable	Incidence rate ratio* (95% CI)	p Value
FS/S	0.999 (0.996 to 1.003)	p=*0.78*
New proxy	0.998 (0.994 to 1.003)	p=*0.43*

*Final model includes fixed effects for year, is adjusted for clustering within states, and controls only for state-level factors that are significant in the model at the 0.05 level.
FS/S, firearm suicides divided by all suicides

total homicides as well. The finding of a specific relationship between gun ownership and firearm, but not non-firearm, homicide rates adds evidence to support the specificity of the observed relationship. Together, these results corroborate the findings of previous studies using data from earlier time periods.[3–15]

We are not arguing here that the new proxy is better than the old one because it better predicts firearm homicide rates. Our assertion that the new proxy improves upon the old comes solely from a previously published article in this journal, in which we showed that its correlation with survey-measured state gun ownership improves from 0.80 to 0.95.[18] No matter which proxy is used, there is a strong, positive correlation between gun ownership and firearm and total homicide rates. These results corroborate earlier research findings by making it less likely that they are attributable to the use of a proxy for gun ownership.

Despite the use of a 30-year panel of data, the analysis remains essentially cross-sectional, as the variation between states drives the findings. Of the overall variation in between state firearm homicide rates, most is due to differences across states, and only a small amount is due to variation within states over time. The possibility of reverse causation—increases in firearm homicide rates leading state residents to acquire more guns thus increasing gun ownership levels—remains a limitation. Further research, using longitudinal designs or analytic methods, is needed to determine the direction of the causal relationship. As Kleck has argued, however, accurate measures of longitudinal trends in gun ownership levels are lacking, making longitudinal research difficult.[21]

In addition to helping clarify the relationship between firearm availability and firearm homicide, this research may be helpful to researchers planning studies to examine the effect of measures to reduce firearms-related violence. Our research demonstrates the usefulness of an alternative proxy for state-level gun ownership.

What is already known on the subject

- Several previous studies have reported a positive and significant relationship between household gun ownership at the state level and state-specific firearm homicide rates.
- These studies have been criticised because they used a proxy for gun ownership—the proportion of suicides committed with a firearm (FS/S)—since there is no source for state-specific gun ownership data.
- We recently developed a new and improved proxy that increases the correlation between the proxy and survey-measured household gun ownership to 0.95 compared to 0.80 for the previous proxy, making it more useful for modelling the effects of gun ownership on homicide rates.
- No study has yet used this new proxy to examine its relationship with state-specific firearm, non-firearm, and total homicide rates.

What this study adds

- Using the new proxy, we found that higher levels of household gun ownership at the state level are significantly associated with increased state-specific firearm and total homicide rates, but not non-firearm homicide rates.
- These findings corroborate the results of previous studies and substantiate the conclusion that higher levels of gun ownership are associated with increased rates of firearm and total homicide.

Contributors All authors contributed to the conception and design, analysis and interpretation of data, and revising the article critically for important intellectual content, and approved the final version. MS acquired the data and drafted the manuscript.

Competing interests None.

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Data sharing statement The authors are happy to provide to other researchers the dataset used in this research. Please send a request to MS at mbsiegel@bu.edu.

REFERENCES

1 Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting Systems: Fatal Injury Reports. http://www.cdc.gov/injury/wisqars/fatal_injury_reports.html (accessed 30 Jan 2014).
2 National Rifle Association. *A post-Heller, post-McDonald question: does an increase in handguns increase crime?* Fairfax, VA: National Rifle Association, Institute for Legislative Action, 2010. http://www.nraila.org/news-issues/fact-sheets/2010/a-post-heller,-post-mcdonald-questionb.aspx?s=guns+lower+crime&st=&ps= (accessed 17 Dec 2013).
3 Cook PJ, Ludwig J. The social costs of gun ownership. *J Public Econ* 2006;90:379–91.
4 Miller M, Azrael D, Hemenway D. Rates of household firearm ownership and homicide across US regions and states, 1988–1997. *Am J Public Health* 2002;92:1988–93.
5 Miller M, Azrael D, Hemenway D. Firearm availability and suicide, homicide, and unintentional firearm deaths among women. *J Urban Health* 2002;79:26–38.
6 Miller M, Azrael D, Hemenway D. Firearm availability and unintentional firearm deaths, suicide, and homicide among 5–14 year olds. *J Trauma* 2002;52:267–75.
7 Price JH, Thompson AJ, Dake JA. Factors associated with state variations in homicide, suicide, and unintentional firearm deaths. *J Community Health* 2004;29:271–83.
8 Seitz ST. Firearms, homicides, and gun control effectiveness. *Law Soc Rev* 1972;6:595–614.
9 Lester D. Firearm availability and the incidence of suicide and homicide. *Acta Psychiatr Belg* 1988;88:387–93.
10 Lester D. Firearm deaths in the United States and gun availability. *Am J Public Health* 1993;83:1642.
11 Miller M, Hemenway D, Azrael D. State-level homicide victimization rates in the US in relation to survey measures of household firearm ownership, 2001–2003. *Soc Sci Med* 2007;64:656–64.
12 Murnan J, Dake JA, Price JH. Association of selected risk factors with variation in child and adolescent firearm mortality by state. *J Sch Health* 2004;74:335–40.
13 Rosenfield R, Baumer E, Messner SF. Social trust, firearm prevalence, and homicide. *Ann Epidemiol* 2007;17:119–25.
14 Ruddell R, Mays GL. State background checks and firearms homicides. *J Crim Justice* 2005;33:127–36.
15 Fleegler EW, Lee LK, Monuteaux MC, *et al*. Firearm legislation and firearm-related fatalities in the United States. *JAMA Intern Med* 2013;173:732–40.
16 Siegel M, Ross CS, King C. The relationship between gun ownership and firearm homicide rates in the United States, 1981–2010. *Am J Public Health* 2013;103:2098–105.
17 U.S. Fish & Wildlife Service. Historical hunting license data. http://wsfrprograms.fws.gov/Subpages/LicenseInfo/Hunting.htm (accessed 22 Jan 2013).
18 Siegel M, Ross CS, King C. A new proxy measure for state-level gun ownership in studies of firearm injury prevention. *Inj Prev* 2014;20:204–7.
19 U.S. Department of Health and Human Services. *Research on the health determinants and consequences of violence and its prevention, particularly firearm violence (R01). PA-13-363*. Bethesda, MD: National Institutes of Health, 2013. http://grants.nih.gov/grants/guide/pa-files/PA-13-363.html (accessed 7 Oct 2013).
20 Wellford CF, Pepper JV, Petrie EV, *et al*. *Firearms and violence: a critical review*. Washington, DC: The National Academies Press, National Research Council, 2005.
21 Kleck G. Measures of gun ownership levels for macro-level crime and violence research. *J Res Crime Delinq* 2004;41:3–36.