



## Original article

## Patterns of gun deaths across US counties 1999–2013

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## ABSTRACT

**Purpose:** We examined the socio-demographic distribution of gun deaths across 3143 counties in 50 United States' states to understand the spatial patterns and correlates of high and low gun deaths.**Methods:** We used aggregate counts of gun deaths and population in all counties from 1999 to 2013 from the Centers for Disease Control and Prevention's Wide-ranging Online Data for Epidemiologic Research (WONDER). We characterized four levels of gun violence, as distinct levels of gun death rates of relatively safe, unsafe, violent, and extremely violent counties, based on quartiles of 15-year county-specific gun death rates per 100,000 and used negative binomial regression models allowing clustering by state to calculate incidence rate ratios and 95% confidence intervals (95% CIs).**Results:** Most states had at least one violent or extremely violent county. Extremely violent gun counties were mostly rural, poor, predominantly minority, had high unemployment rate and homicide rate. Overall, homicide rate was significantly associated with gun deaths (incidence rate ratios = 1.08, 95% CI = 1.06–1.09). In relatively safe counties, this risk was 1.09 (95% CI = 1.05–1.13) and in extremely violent gun counties was 1.03 (95% CI = 1.03–1.04).**Conclusions:** There are broad differences in gun death rates across the United States representing different levels of gun death rates in each state with distinct socio-demographic profiles.

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## Introduction

Consistently high national gun death rates and recent visible mass shootings across the country have refocused public attention on gun violence as one of the most important public health challenges facing the United States (US) in the early 21st century [1,2]. Recent studies have shown that the endemic national gun death rates from 2001 to 2013 mask wide spatial variation in gun death rates across states [1,3]. Substantial between-state heterogeneity has been demonstrated between 2001 and 2010 with rates of gun deaths ranging from as low as 3.0 per 100,000 in Hawaii to as high as 21.7 per 100,000 in District of Columbia [1].

Smaller geographic areas such as counties have more homogenous socio-demographic characteristics compared with larger states [4,5]. We were interested in understanding intercounty

heterogeneity of gun death rates across the US to document the spatial distribution of different levels of gun death rates at county level and the socio-demographic characteristics associated with homogenous groupings.

## Methods

## Study design

Using county-specific data from 1999 to 2013, we assessed the spatial patterns of gun deaths across the US. We also assessed the relation of socio-demographic characteristics, informed by the previous literature [6,7], that could characterize differences between counties: race-specific population percentage, population density, urbanization status of the county (location), median household income, percentage of population in poverty, unemployment rate, and homicide rate. We did not use gun laws as potential confounders since gun laws were considered to be a part of the mechanistic pathway linking social, demographic characteristics, and gun death rates [7]. All the data used are from available public data sources, and this study is therefore considered exempt from federal regulations for the protection of human

No potential conflicts of interest relevant to this article were reported.

Authorship statement: Both authors equally contributed to the study. Both authors conceived the study, obtained data, performed the analyses and led the writing.

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research participants, and no ethics review application was required to conduct this study.

#### Data sources

Cumulative counts of gun deaths of all intents in each county (3143) between years 1999–2013 were obtained from querying the restricted version of Centers for Disease Control and Prevention's Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) [8]. Mortality data in CDC WONDER are compiled by the National Center for Health Statistics using data from the death registry. We also extracted 15-year homicide rates and the cumulative population in each county from CDC WONDER. Those counties with <10 events were not reported and was not analyzed in accordance with restrictions by CDC WONDER to avoid inadvertent identification of cases [8].

County-specific population density for years 2000 and 2010 was obtained from the U.S. Census program (<http://www.census.gov/prod/cen2010/doc/sf1.pdf>), American Fact Finder; we used the later data from 2010 to reflect the latest changes [9]. The latest urbanization status of the counties (2013) were obtained from CDC WONDER [8]. Median household incomes and percentage of people in poverty for each year were obtained from the U.S. Census program, Small Area Income and Poverty Estimates [10] and the mean of the annual values were computed for analysis. The annual averages of the employment status of the civilian noninstitutional population for the years 1999 to 2013 was obtained from the Bureau of Labor Statistics [11]. Annual data on employment and unemployment in the states and sub-groups within the United States are available from the Current Population Survey and the Local Area Unemployment Statistics program [12,13]. The Current Population Survey is conducted by the U.S. Census Bureau for the Bureau of Labor Statistics and samples about 50,000 households [12], whereas Local Area Unemployment Statistics is a Federal-State cooperative program in participation with State employment security agencies [13]. Using the annual rates, we computed 15-year average of each covariate for each county.

#### Outcome

Our primary outcome measure was overall gun death rates per 100,000 persons between 1999 and 2013, a 15-year time period. We averaged the annual rates from 1999 to 2013 for each county to obtain a 15-year gun death rate for each county. We define cumulative gun death rate as the mean annual gun death rate per 100,000/year over the 15 years. We categorized gun death rates into four categories based on quartiles of the 15-year cumulative rates. The four quartiles can be considered to be “relatively safe” with county-specific gun death rates ranging from 1.58 to 9.01 per 100,000, “unsafe” from 9.02 to 12.20 per 100,000, “violent” from 12.21 to 15.75 per 100,000, and “extremely violent”  $\geq 15.76$  per 100,000. We refer the four categories as “levels of gun deaths”.

#### Data analysis

First, we assessed the distribution of the total counts of firearm-related mortality rates during 15 years and categorized all the county-specific 15-year firearm-related mortality rates into four levels of gun death rates based on quartiles. Second, we graphically represented the spatial distribution of the quartiles of gun death rates from lowest to highest across the country, called “levels of gun deaths”. Third, we documented the spatial distribution of the different levels of gun deaths in each county within each state. Fourth, we described the social and demographic characteristics of each quartile. We used negative binomial regression modeling (since

the variance of our outcome was greater than the mean) with population as offset and allowed clustering around state to calculate robust standard errors, incidence rate ratios (IRRs), and 95% confidence intervals (95% CI) to determine the association between gun death rates and socio-demographic characteristics [14]. Model fit was assessed using deviance goodness-of-fit, McFadden's adjusted  $R^2$  and akaike information criteria [15]. We assessed multicollinearity and found that on removing the covariate “percentage of white population”, reduces the collinearity in the model. Fifth, we tested the difference across the quartiles in the association between gun death rates and homicide rates using appropriate interaction tests by adding interaction terms between homicide rates and the quartiles of gun deaths rates in the final model. STATA 14.1 (STATA Corp LP, College Station, TX, USA) was used to manage the data, to conduct the analyses. All statistical tests were two-sided.

#### Results

A total of 464,033 gun deaths occurred within 15 years, from 1999 to 2013, for a cumulative gun death rate of 10.4 per 100,000 in the US. National gun death rate ranged from 10.3 in 1999 to 10.6 per 100,000 in 2013. Of 3143 counties, 370 had gun deaths with <10 events. Among those counties with  $\geq 10$  gun deaths during the 15 years, the gun death rates ranged from 1.6 per 100,000 in Bristol County, Rhode Island to 66.1 per 100,000 in Wade Hampton (*now* Kasilvak) Census Area, Alaska.

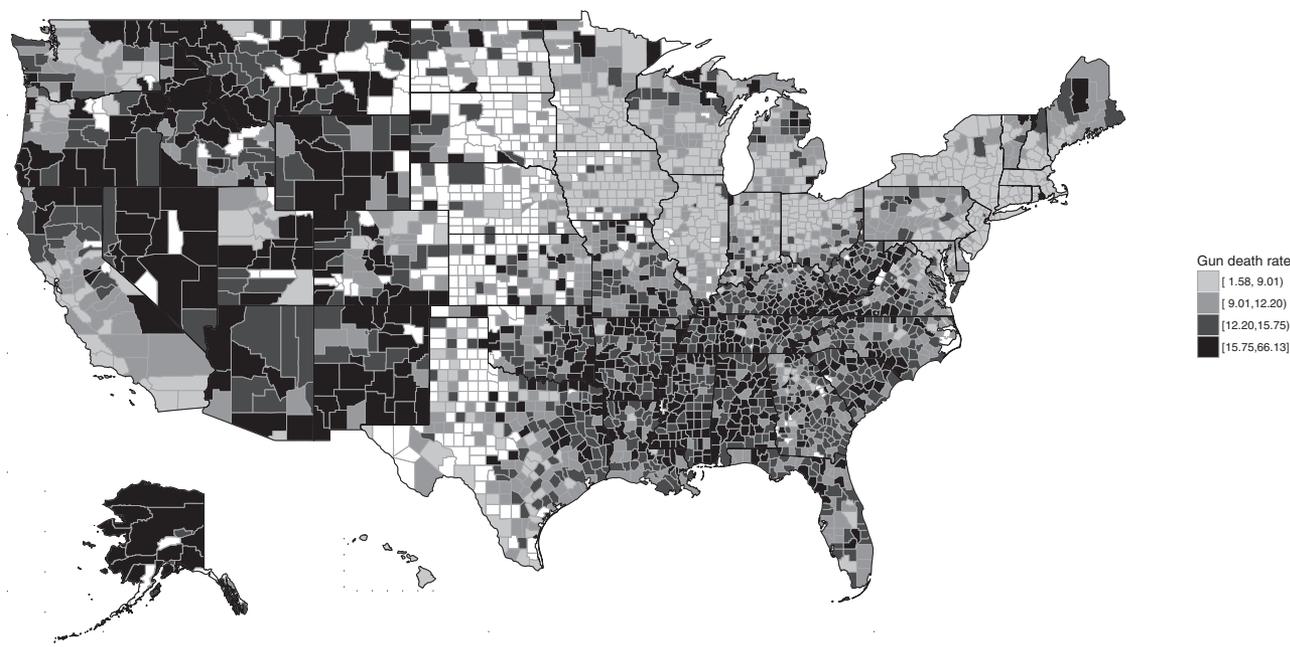
The 25th, 50th, and 75th percentile of 15-year county-specific gun death rates was 9.01, 12.20, and 15.75 per 100,000 respectively. Figure 1 presents the 15-year county-specific gun death rates categorized into four quartiles of gun death rates.

Supplementary Figures 1–4 presents counties in each quartile separately. Relatively safe gun counties are largely concentrated in the northeast areas with very few relatively safe counties in states of California, Texas, and Washington. Unsafe and violent gun counties are found throughout the country with very few unsafe and violent counties observed in the northeast regions. Extremely violent gun counties are mainly clustered in Alaska along with two distinct clusters in southeast regions and in the western region.

Figure 2 presents the percentage of each of the four levels of gun death rates represented in each state using the 15-year gun death rates. Connecticut and Rhode Island had 100% of all counties categorized as relatively safe gun counties, and 14 states had 50% of their counties included as the relatively safe gun counties. Seven states of Nevada, Mississippi, Alaska, Alabama, New Mexico, South Carolina and Wyoming, and District of Columbia had no counties belonging to the relatively safe level of gun deaths. Most states (except Connecticut and Rhode Island) had at least one county belonging to either the violent or extremely violent category.

Table 1 presents the socio-demographic characteristics in each level of gun deaths. The mean proportion of White, Asian, and Hispanic population declined from 90.8%, 2.3%, and 8.7% respectively in relatively safe counties to 80.3%, 0.5%, and 5.5% respectively in extremely violent counties, whereas the mean proportion of black and American Indian/Alaskan Native population increased from 6.7% to 3.2% in relatively safe counties to 19.8% and 10.5% in extremely violent gun counties. Relatively safe counties were more urban, had a higher median household income, had a lower proportion of the population in poverty, lower mean unemployment rate, and low mean homicide rate, whereas extremely violent gun counties were 76.5% rural, had a very low median household income (\$34,353), 18.8% were in poverty, mean unemployment rate was 7.5 per 1000, and the highest homicide rate of 8.9 per 100,000.

Supplementary Table 1 presents the association between gun deaths and socio-demographic characteristics for overall and for each quartile. For the entire country, homicide rate was significantly



**Fig. 1.** Gun death rates in each county, 1999 to 2013. Gun death rates per 100,000 are presented cumulatively over 15-years.

associated with gun deaths (IRR = 1.08, 95% CI = 1.06–1.09). In the relatively safe counties, the strength of association was even greater with 9% increased risk, IRR = 1.09, 95% CI = 1.05–1.13, whereas in the extremely violent gun counties there was a 3% increased risk IRR = 1.03 and 95% CI = 1.03–1.04.

## Discussion

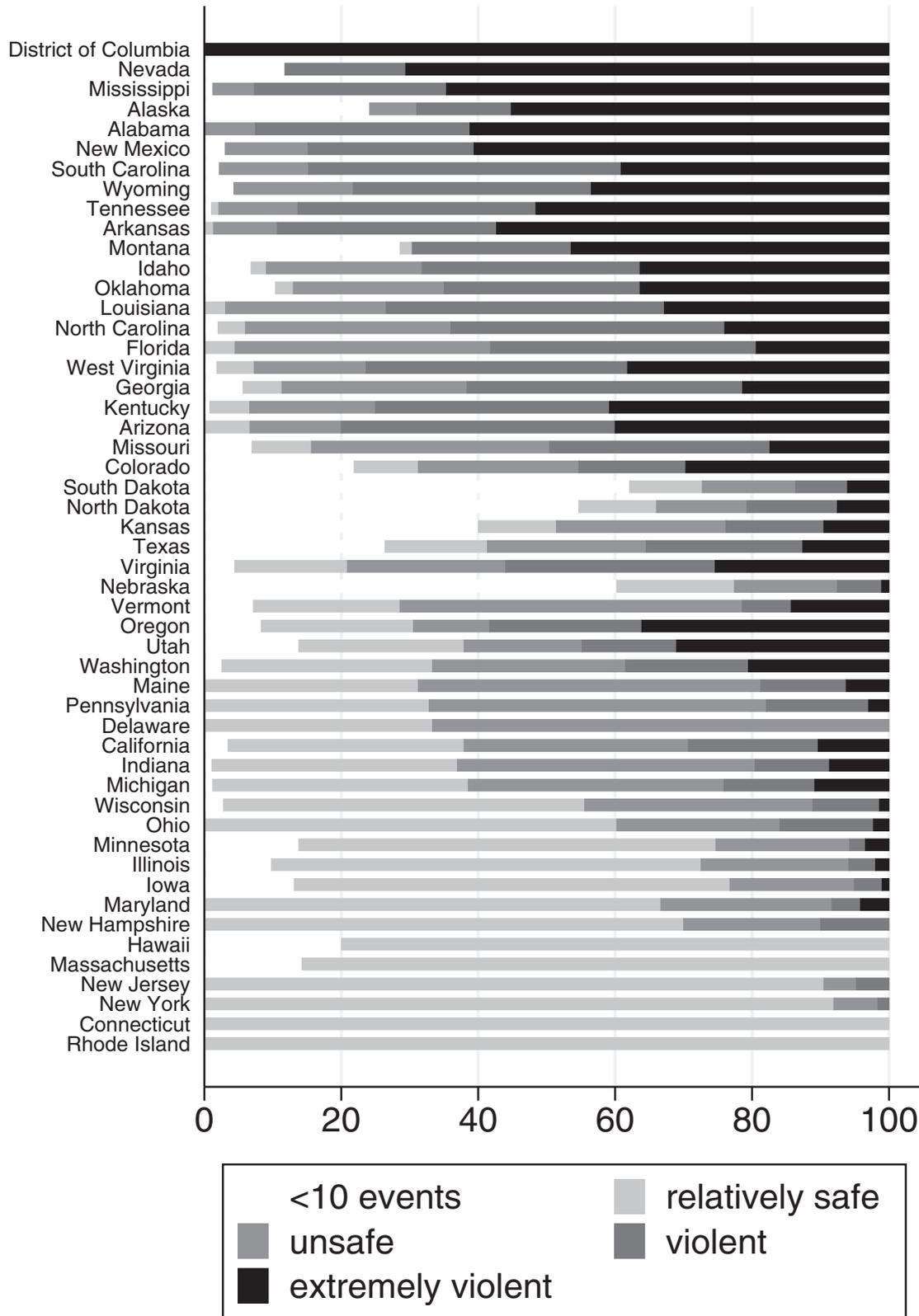
Using aggregate county-specific gun deaths across the country, we showed dramatically different levels of gun violence across counties in the US. In many ways, there are four rather distinct levels of gun death rates in the US characterized from relatively safe to extremely violent. We found, first, that relatively safe gun counties are primarily in the northeast part of the country with increasing gun death rates that spread throughout the country, culminating in two distinct clusters of extremely violent gun counties in the southeast states and more widely in the western half of the country. Second, the relatively safe gun counties were predominantly White, less poor, with higher household income, lower unemployment, and more likely to be urban, whereas increasingly violent gun counties had higher rates of minority population, greater poverty, lower unemployment, and were mostly rural. Third, homicide rates are significantly positively associated with gun death rates, both overall and in each level of gun death rates, although this association is stronger in the relatively safe counties.

We found lower gun death rates in the northeast region of United States, whereas extremely violent gun counties were concentrated in the southwest and in the western half of the US. Studies have shown such clustering of gun violence using trauma center data in much smaller areas [16]. To our knowledge, this is the first demonstration of such a definitive spatial pattern and clustering in distinct regions of the entire country based on county-specific data. This finding is an extension of state-specific heterogeneity in gun death rates reported using similar data from 2000 to 2010 that masked unchanging temporal trends indicative of endemic gun death rates [1]. Although we do not present temporal trends, we demonstrated a further layer of heterogeneity at the

county level. More recent reports of varying gun ownership rates between states also corroborates our evidence of high heterogeneity of gun death rates across the country, where gun ownership rates were found to be positively associated with gun death rates [17]. Furthermore, considering that gun laws are state-specific [7], our findings suggest that the spatial patterns of gun deaths are influenced by factors that extend beyond state-specific characteristics and also include county-level factors that might, if better understood, form the basis for efforts to mitigate gun-related violence.

The four levels of gun deaths were characterized by distinct socio-demographic characteristics with minority populations being represented to a greater degree in regions with higher rates of gun death. We also showed that the relatively safe counties were less poor, with higher household income, lower unemployment, and with largely urban counties as compared with violent and extremely violent counties, which were predominantly rural counties. Our results echo the well-documented increased risk of gun deaths among minority populations across the country [1,18]. A recent study using trauma registry data comparing a suburban and rural county of Lancaster with that of urban areas, Philadelphia found persistent gun violence rate in rural areas that mirrors our results [19]. Gun deaths in the US are mainly due to suicide, almost twice as many as homicides from 1999 to 2013 [1,8]. A recent study showed that suicide rates are higher in rural than in urban communities and the rural-urban differences increased over time [20]. In the context of this evidence, our finding that violent and extremely violent areas are largely in rural counties suggests that suicide gun deaths may contribute significantly to this increased risk in these rural counties.

Our finding that gun death rates are positively associated with homicide rates are in line with various studies that established a similar positive relationship with gun ownership and homicide rates [17,21–23]. Further, the association between gun ownership or availability and homicide rates have been demonstrated [24–26], there are few studies that have assessed the direct relationship between gun death rates and homicide rates. Using data from 1981 to 2010, gun ownership has been shown to be an



**Fig. 2.** Distribution of four levels of gun death rates in each state, 1999 to 2013. The horizontal bars represent the total percentage of counties in each state and the colored segments represent the four categories of gun death rates within each state.

important predictor in gun homicide rates [6,21], whereas gun ownership rates have been associated with gun death rates [17]. Violence and homicides are both separately associated with

neighborhood social factors, such as poverty, suggesting a set of common causal pathways underlying these observations [27–29].

**Table 1**  
Socio-demographic characteristics in counties characterized by gun death rates from 1999 to 2013

n	Total	Relatively safe	Unsafe	Violent	Extremely violent	<10
	3143	693	693	694	693	370
% White population, 1999–2013	86.3 (16.3)	90.8 (10.1)	87.5 (13.8)	83.1 (16.5)	80.3 (20.9)	93.0 (14.2)
% Black population, 1999–2013	9.0 (14.6)	4.6 (6.7)	8.1 (11.8)	12.8 (16.1)	14.2 (19.8)	2.5 (8.6)
% American Indian/Alaskan Native, population, 1999–2013	2.1 (7.7)	0.8 (3.2)	1.8 (7.3)	1.9 (6.0)	3.4 (10.5)	2.8 (10.2)
% Asian, population, 1999–2013	1.1 (2.5)	2.3 (4.1)	1.2 (2.2)	0.7 (1.1)	0.5 (0.6)	0.5 (2.1)
% Hispanic, population, 1999–2013	7.6 (12.8)	8.7 (14.3)	8.4 (13.4)	6.6 (9.7)	5.5 (9.9)	10.0 (17.0)
Population density	251 (12)	638 (3445)	199 (439)	140 (455)	150 (747)	25 (175)
Location, n (%)						
Large central metro	68 (2.2)	28 (4.0)	15 (2.2)	10 (1.4)	15 (2.2)	0 (0)
Large fringe metro	368 (11.7)	154 (22.2)	104 (15.0)	70 (10.1)	37 (5.3)	3 (0.8)
Medium metro	373 (11.9)	110 (15.9)	103 (14.9)	94 (13.5)	60 (8.7)	6 (1.6)
Small metro	358 (11.4)	104 (15.0)	94 (13.6)	97 (13.9)	48 (6.9)	15 (4.0)
Micropolitan (nonmetro)	641 (20.4)	172 (24.8)	94 (13.6)	144 (20.7)	138 (19.9)	32 (8.6)
Noncore (nonmetro)	1330 (42.3)	125 (18.0)	155 (22.4)	279 (40.2)	392 (56.6)	312 (84.1)
Median household income, 1999 to 2013	40,338 (10,125)	49,001 (12,097)	41,657 (8298)	37,976 (7518)	34,353 (6749)	37,291 (6829)
% in poverty, 1999 to 2013	15.1 (5.8)	11.3 (4.7)	14.4 (5.1)	16.5 (4.9)	18.8 (5.6)	14.2 (5.8)
Unemployment rate, 1999 to 2013	6.4 (2.0)	5.7 (1.6)	6.3 (1.8)	6.7 (1.8)	7.5 (2.1)	4.7 (1.9)
Homicide rate per 100,000, 1999 to 2013	5.5 (4.0)	2.6 (1.5)	4.3 (2.2)	6.0 (2.7)	8.9 (5.4)	—

All values are mean and standard deviation except location, which is frequency and percentage. The four groups are based on quartile cut-offs of the cumulative 15-year county-specific gun death rates.

We observed that high rates of gun deaths are present in largely rural areas and determined that the magnitude of the association between gun death rates and homicide rates decreases from relatively safe to extremely violent gun counties. These observations suggest a shift away from homicides to self-inflicted gun violence in the high gun violence counties, consistent with the observation about the rural-urban difference in gun counties noted above. The increased incidence in rural areas demonstrated in our study has also been shown in an Australian study where rate of suicides were highest among Australian men as compared with urban men or women [30]. Using data from 1999 to 2006 in the US, that investigated the relationship between unintentional firearm death and urbanicity among adults, the rates of unintentional firearm death were found to be significantly higher in rural counties than in urban counties [31].

Several limitations are to be considered when interpreting our findings. Our study design takes into consideration county characteristics but does not consider smaller scale factors such as neighborhood characteristics. There may be several other potentially confounding social and state-level factors along with gun laws, both known and unknown, that has not been considered in this study. The CDC requires no reporting of events <10 per county, therefore we did not attempt to obtain or analyze those counties with events <10, which may have led to either overestimation or underestimation based on the actual rates of the “missing” counties. In addition, the pattern of strength of association is also consistent with the phenomenon of weaker associations due to restriction of range. For example, we were unable to assess the difference in county-specific gun death rates before and after the Great Recession in 2007 due to larger and unbalanced number of counties with events <10 events in the two time-periods. The limited variability in gun death rates across counties in the two middle quartiles affords much less opportunity for strong associations to occur compared with the much wider ranges in the two extreme quartiles.

In conclusion, we demonstrate distinct levels of gun death rates across the US with safer counties concentrated in the northeast, and extremely violent gun counties concentrated in the southeast and western half of the US. The existence of substantial intercounty heterogeneity in gun violence suggests that comprehensive efforts to reduce gun violence in the US will require action not only at the national and state level but also at the local and community level.

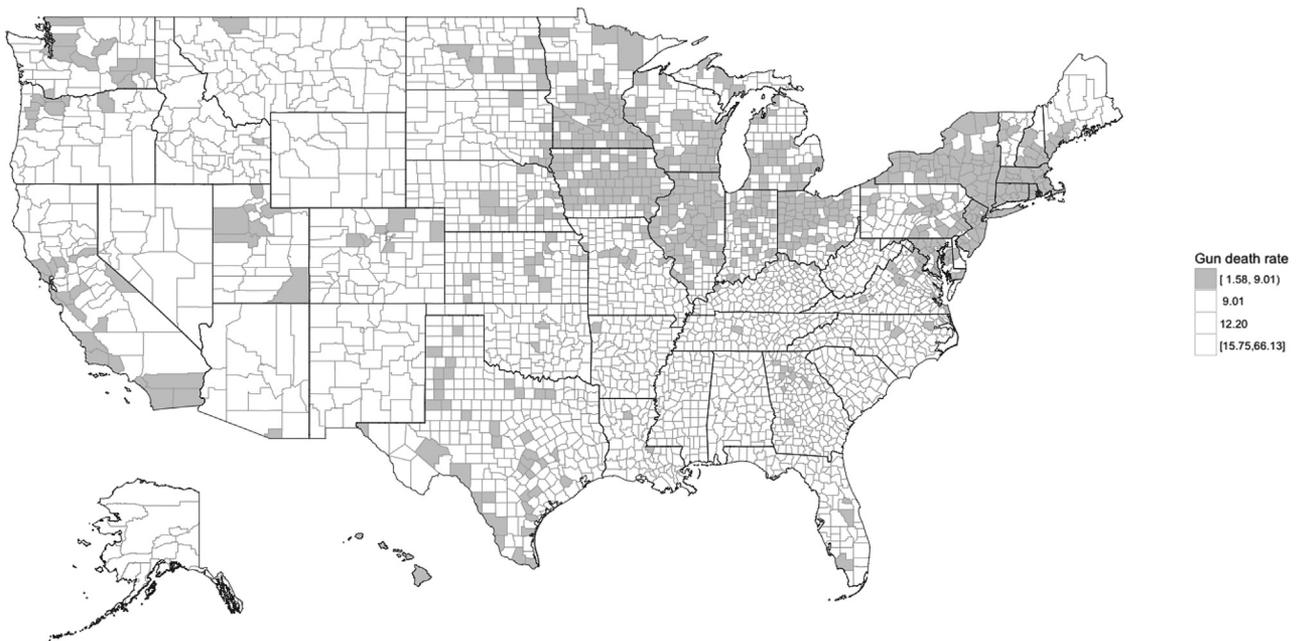
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The corresponding author had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. The authors thank Elizabeth Pino for editing of the manuscript. There was no funding for this study.

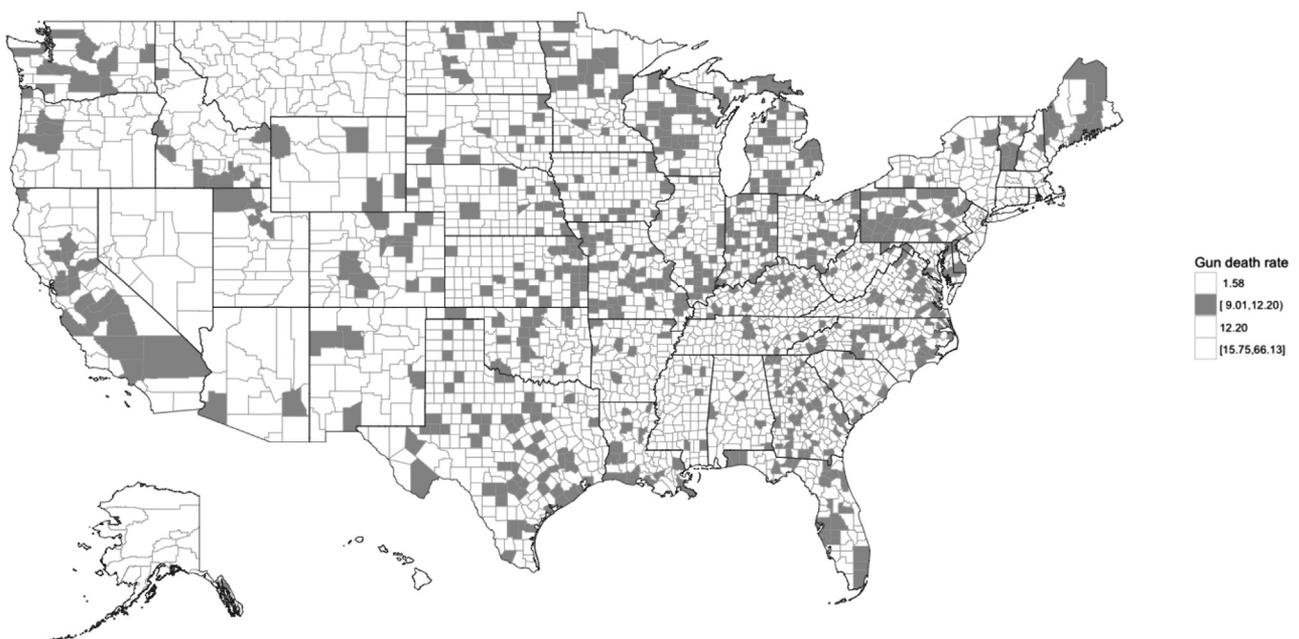
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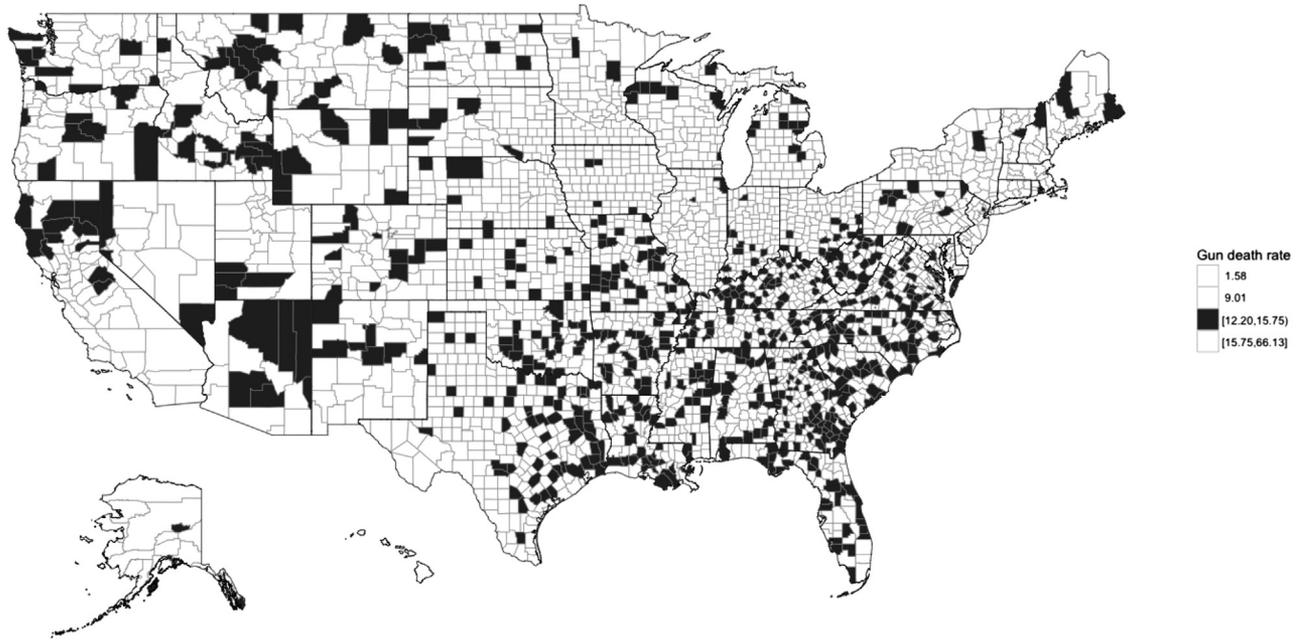
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**Appendix**

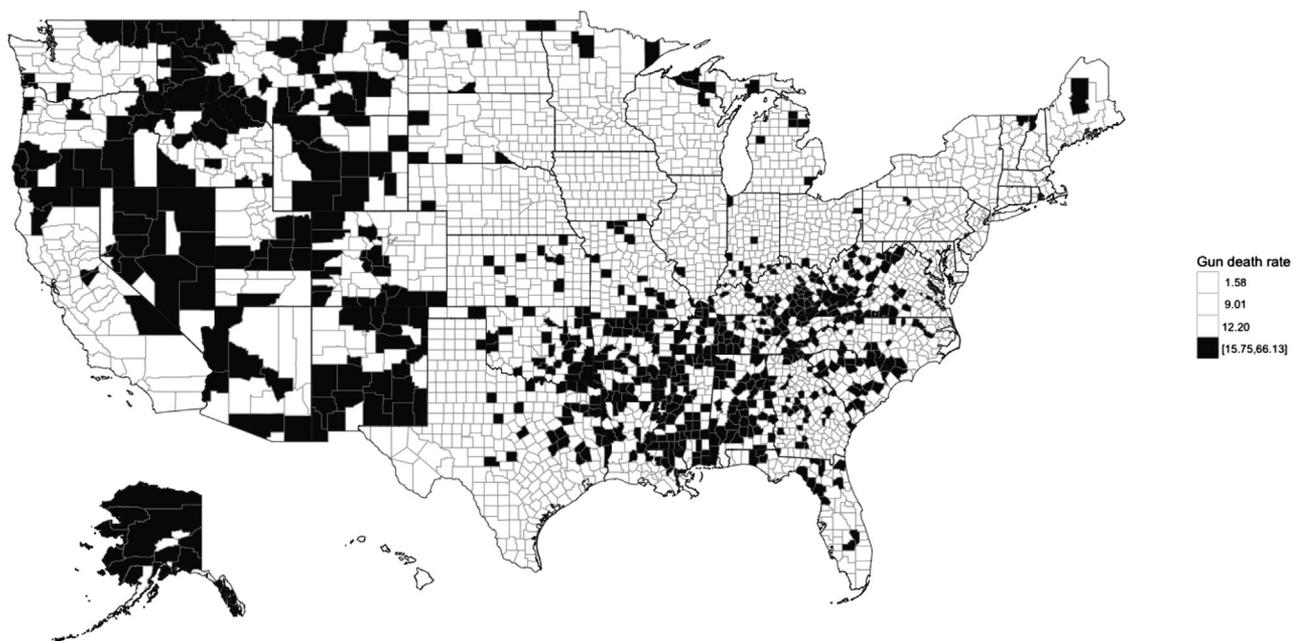
**Supplementary Figure 1.** Gun death rates in relatively safe counties (1.58 to 9.01 per 100,000) from 1999 to 2013.



**Supplementary Figure 2.** Gun death rates in unsafe counties (9.01 to 12.20 per 100,000) from 1999 to 2013.



**Supplementary Figure 3.** Gun death rates in violent counties (12.20 to 15.75 per 100,000) from 1999 to 2013.



**Supplementary Figure 4.** Gun death rates in extremely violent counties (15.75 to 66.13 per 100,000) from 1999 to 2013.

**Supplementary Table 1**

Association between gun deaths and socio-demographic characteristics, overall and counties characterized by different levels of gun death rates, 1999–2013

Variable	Total	Relatively safe	Unsafe	Violent	Extremely violent
	IRR (95% CI)				
<b>Population</b>					
% Black	0.99 (0.99–1.00)	1.00 (0.99–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (0.99–1.00)
% American Indian/Alaskan Native	1.00 (0.99–1.01)	1.00 (0.99–1.01)	1.00 (0.99–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.01)
% Asian	0.98 (0.97–1.00)	0.99 (0.98–0.99)	1.00 (0.99–1.00)	1.01 (1.00–1.02)	0.98 (0.96–1.00)
% Hispanic	1.00 (0.99–1.00)	1.00 (0.99–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)
Population density	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)
<b>Location</b>					
Large central metro	Ref	Ref	Ref	Ref	Ref
Large fringe metro	1.07 (0.98–1.17)	0.99 (0.89–1.10)	0.97 (0.92–1.01)	1.01 (0.96–1.07)	1.01 (0.95–1.07)
Medium metro	1.04 (0.96–1.13)	0.97 (0.88–1.06)	0.95 (0.91–0.99)	0.99 (0.95–1.03)	1.01 (0.96–1.06)
Small metro	1.03 (0.94–1.14)	0.96 (0.85–1.09)	0.96 (0.91–1.01)	1.00 (0.96–1.05)	1.07 (0.99–1.16)
Micropolitan (nonmetro)	1.06 (0.96–1.17)	0.96 (0.84–1.10)	0.95 (0.91–1.00)	1.02 (0.98–1.07)	1.03 (0.95–1.11)
Noncore (nonmetro)	1.17 (1.06–1.30)	0.99 (0.87–1.14)	0.97 (0.92–1.02)	1.02 (0.96–1.07)	1.09 (1.01–1.16)
Median household income	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)	1.00 (1.00–1.00)
% in poverty	0.98 (0.97–0.99)	0.99 (0.97–1.00)	1.00 (1.00–1.01)	1.00 (0.99–1.00)	1.00 (0.99–1.00)
Unemployment rate	1.00 (0.99–1.02)	0.99 (0.96–1.01)	1.00 (0.99–1.00)	1.00 (0.99–1.01)	1.02 (1.00–1.03)
Homicide rate per 100,000	1.08 (1.06–1.09)	1.09 (1.05–1.13)	1.02 (1.01–1.03)	1.02 (1.02–1.03)	1.03 (1.03–1.04)

IRR = incidence rate ratios; CI = confidence interval.

Counties were nested within states. All data were from 1999 to 2013. Multivariable negative binomial regression generalized estimating equations models for count responses were used allowing clustering by state to account for correlation. *P*-interaction for homicide rate < .0001.