

# Firearm Ownership and Violent Crime in the U.S.

## An Ecologic Study

Michael C. Monuteaux, ScD, Lois K. Lee, MD, David Hemenway, PhD, Rebekah Mannix, MD,  
Eric W. Fleegler, MD

**Introduction:** Although some view the ownership of firearms as a deterrent to crime, the relationship between population-level firearm ownership rates and violent criminal perpetration is unclear. The purpose of this study is to test the association between state-level firearm ownership and violent crime.

**Methods:** State-level rates of household firearm ownership and annual rates of criminal acts from 2001, 2002, and 2004 were analyzed in 2014. Firearm ownership rates were taken from a national survey and crime data were taken from the Federal Bureau of Investigation Uniform Crime Reports. Rates of criminal behavior were estimated as a function of household gun ownership using negative binomial regression models, controlling for several demographic factors.

**Results:** Higher levels of firearm ownership were associated with higher levels of firearm assault and firearm robbery. There was also a significant association between firearm ownership and firearm homicide, as well as overall homicide.

**Conclusions:** The findings do not support the hypothesis that higher population firearm ownership rates reduce firearm-associated criminal perpetration. On the contrary, evidence shows that states with higher levels of firearm ownership have an increased risk for violent crimes perpetrated with a firearm. Public health stakeholders should consider the outcomes associated with private firearm ownership.

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### Introduction

Firearm violence is a persistent public health concern in the U.S., with more than 10,000 American firearm homicides annually,<sup>1</sup> which is the highest rate among developed, industrialized nations.<sup>2</sup> Firearms are used in 68% of homicides in the U.S.<sup>1</sup> Firearms are also frequently used in the commission of other violent crimes, such as robbery and assault (44.7 and 50.9 events per 100,000 people, respectively, in 2013).<sup>3</sup>

In the wake of recent mass shootings, gun control debates have intensified. Firearm safety supporters suggest increasing the regulation of firearms to reduce violent firearm-related crime, whereas others promote

more widespread firearm availability as a deterrent to crime and to enhance personal defense. However, the empirical evidence for the relationship between the level of firearm ownership and the incidence of criminal activity, albeit extensive, remains controversial. When considering homicide, one summary of the literature claimed that “levels of general gun ownership appear to have no significant net effect on rates of homicide.”<sup>4</sup> By contrast, other studies have demonstrated an association between firearm availability and homicide,<sup>5,6</sup> with a review concluding that “the available evidence is consistent with the hypothesis that increased gun prevalence increases the homicide rate.”<sup>7</sup>

The literature on the association between firearm ownership rates and non-fatal assault and robbery is smaller, characterized by methodologic variability and marked by inconsistent findings. Some evidence shows that higher levels of gun ownership are associated with higher rates of robbery with guns, but not with overall robbery levels.<sup>8,9</sup> In regions with higher levels of gun

From Boston Children’s Hospital (Monuteaux, Lee, Mannix, Fleegler); and the Harvard School of Public Health (Hemenway), Boston, Massachusetts

Address correspondence to: Michael C. Monuteaux, ScD, Boston Children’s Hospital, 300 Longwood Avenue (GL 144), Boston MA 02115. E-mail: michael.monuteaux@childrens.harvard.edu.

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ownership, there are higher levels of gun assault, but not always higher levels of non-gun assault.<sup>10</sup> One study reported a positive association between household firearm ownership and gun-related assault across 21 countries,<sup>11</sup> whereas another country-level study found mixed evidence for a link between firearm ownership and non-lethal violence.<sup>12</sup> A county-level study found no link between a firearm ownership proxy measure and gun crime,<sup>13</sup> but another study found that individuals living in cities with high levels of gun availability have higher odds of being the victim of gun assault or gun robbery.<sup>14</sup>

Given the ongoing public debate about firearm policy at the both the federal and state levels, it is important to commit additional research efforts to examining firearm ownership in the U.S. and its relationship with violent criminal outcomes. The association between household firearm ownership prevalence and non-lethal violent crimes where a firearm was used is of particular interest. The objective of this study is to investigate the link between levels of self-reported U.S. household gun ownership and crimes committed with a firearm, including robbery and non-fatal assault.

## Methods

### Study Sample

Data were aggregated on household firearm ownership and criminal perpetration in each of the 50 states for the years 2001–2002 and 2004 (the only years with available state-level firearm ownership data). State-level data on firearm ownership were taken from the Behavioral Risk Factor Surveillance System (BRFSS), a large, nationally representative, annual survey of the U.S. population, administered by CDC.<sup>15</sup> BRFSS includes >200,000 respondents annually and provides representative national- and state-level prevalence estimates for health-related behaviors and risk factors. In each of the years 2001, 2002, and 2004, BRFSS included this question: *Are any firearms now kept in or around your home? Include those kept in a garage, outdoor storage area, car, truck, or other motor vehicle* (the 2004 survey did not include the second sentence). This question was not administered in California in 2002 or Hawaii in 2004; therefore, these state-year observations were excluded from the analysis. When generating state-level estimates, the survey design was taken into consideration by specifying the primary sampling units and the sampling weights (denoting the inverse of the probability that the observation is included), to ensure accuracy.<sup>16</sup>

### Measures

Criminal data were taken from the Uniform Crime Reports (UCR), a national, annually updated database of reported crimes across the U.S., administered by the Federal Bureau of Investigation (FBI).<sup>3</sup> The UCR gathers data on reported crimes submitted by city, university and college, county, state, tribal, and federal law enforcement entities.

Although the data are subjected to a rigorous quality control regimen by the FBI, quality issues have been noted with UCR data.<sup>17,18</sup> First, not all law enforcement agencies report data, leading to portions of the population that are not represented. In 2001, 2002, and 2004, the law enforcement agencies participating in the UCR Program represented 92%, 93% and 94%, respectively, of the U.S. population, with a median state-level coverage of 98.5% (interquartile range=92.5%, 99.8%). Also, the data only represent criminal events that are reported to law enforcement agencies. The nationally representative National Crime Victimization Survey indicates that, for many crimes, a proportion of victims do not report the incident to authorities.<sup>19</sup>

To mitigate these issues, this investigation was limited to crime outcomes that: (1) are most likely documented by law enforcement<sup>20</sup>; (2) are compiled from law enforcement agencies that submitted complete data throughout the year under study; and (3) have a hypothesized relationship to firearm ownership. These were robberies committed with a firearm and assault committed with a firearm. Thus, these analyses assumed that for each observation (i.e., each state-year), the populations within jurisdictions that did not provide data to the UCR did not differ from those that did in terms of the prevalence of firearm ownership. The potential impact of this assumption increased as the proportion of state-level populations represented by UCR data decreased.

UCR estimates of the annual, state-level populations (derived from the U.S. Census) represented by the agencies that contributed data to compile the count of the given outcome were used. Census data were used to capture annual, state-level estimates of demographic factors previously associated with firearms,<sup>21</sup> including age (percentage aged <25 years), race (percentage of blacks), ethnicity (percentage of Hispanics), sex, median household income, population density (population per square mile of land area), education (percentage completing at least high school), poverty (percentage below the federal poverty level), and urbanicity (percentage living in an urban area).<sup>22</sup>

### Statistical Analysis

The number of each specific crime type reported for each state in each year of the study was obtained. A negative binomial regression model was estimated, with the state-level count of criminal offenses as the dependent variable and the log of the population values as the offset (coefficient constrained to 1). A negative binomial model was chosen to account for the overdispersion in the outcome variable, a condition that can lead to underestimated standard errors in Poisson models. To verify the model selection, a likelihood ratio test of the overdispersion parameter,  $\alpha$ , was performed. Evidence to reject the null hypothesis that  $\alpha=0$  indicates that the negative binomial model is preferred over Poisson. For each of the four models (outcomes of assault, robbery, homicide, and homicide with a firearm), the likelihood ratio test supported the use of negative binomial models over Poisson models (all  $p$ -values <0.001).

Gun ownership (divided into quintiles and estimated as dummy variables with the lowest quintile set as the referent) was modeled as the independent variable. Dummy variables, as opposed to a continuous variable, were chosen to capture relationships between firearm ownership and crime rates that may not be linear. Demographic factors (age, race, ethnicity, sex, median household income, population density, education, poverty, and urbanicity)

that have previously been shown to be associated with violent crime and firearm ownership were included as covariates. Models were also adjusted for year and geographic region (Northeast, Midwest, South, and West). Finally, to account for spatial associations among states, adjustment was made for the firearm ownership levels of neighboring states. That is, for each state, the mean ownership rate of all geographically adjacent states was calculated, and this variable was included as a covariate in the model. For states without adjacent geographic neighbors (Alaska and Hawaii), the value of the closest state (Washington for Alaska and California for Hawaii) was used. Each state provided year-specific values for all terms in the model.

As a secondary analysis, two additional outcomes were also examined: overall homicide and homicide committed with a firearm. These were secondary outcomes because the data were compiled from a subset of jurisdictions within each state from which supplementary homicide data were available. Specific population estimates for these were not provided. Overall state-level population estimates from the Census were used for these outcomes.

Given that these data included multiple observations for each state (i.e., one observation per state per year), the assumption of independent observations may not hold. To accommodate these data, clustered sandwich SE estimates were used, which allow for intrastate correlation. All data analyses were performed using STATA SE, version 12.1.

## Results

The rates of reported violent crimes in the U.S. during the study period (2001, 2002, and 2004) were 505, 495, and 464 per 100,000 individuals, respectively. Overall violent crime rates ranged from 78.2/100,000 (North Dakota, 2002) to 822.6/100,000 (South Carolina, 2002), with a median of 371.7/100,000. Homicide rates ranged from 0.8/100,000 (North Dakota, 2002) to 13.3/100,000 (Louisiana, 2002), with a median of 4.6/100,000.

There was wide variability across states in the percentage of households with a firearm (Table 1), ranging from 65.5% in Wyoming in 2004 to 8.7% in Hawaii in 2001. Across time, there was little change in gun ownership rates within states, and only a 0.6% change nationally from 2001 to 2004. The 148 observations that had firearm ownership data available (i.e., each state, by year, except California in 2002 and Hawaii in 2004) were categorized into quintiles according to firearm ownership rates: 8.7%–25.5% ( $n=28$ ), 26.2%–37.1% ( $n=30$ ), 37.5%–42.8% ( $n=31$ ), 42.9%–48.6% ( $n=29$ ), and 50.7%–65.5% ( $n=30$ ).

### Association Between State-Level Firearm Ownership and Violent Crime Rates

Results from the multivariate regression models predicting state-level crime rates are summarized in Table 2.

**Table 1.** Self-Reported Household Firearm Ownership Prevalence Across States in the U.S., by Year

State	Percentage of households with a firearm			Change (delta), 2001–2004
	2001	2002	2004	
Alabama	51.7	57.9	52.2	0.5
Alaska	57.8	60.9	59.8	2.1
Arizona	31.1	37.0	32.3	1.3
Arkansas	55.3	58.7	58.8	3.5
California	21.3	—	20.1	–1.2
Colorado	34.7	34.8	34.6	–0.1
Connecticut	16.8	16.4	18.1	1.3
Delaware	25.5	27.1	26.3	0.8
Florida	24.5	26.6	25.2	0.8
Georgia	40.3	41.5	40.3	0.0
Hawaii	8.7	10.2	—	1.5
Idaho	55.3	57.1	55.7	0.4
Illinois	20.2	21.2	20.7	0.5
Indiana	39.1	39.6	38.5	–0.6
Iowa	42.8	44.4	45.7	2.9
Kansas	42.1	44.2	42.8	0.7
Kentucky	47.7	48.6	47.7	0.0
Louisiana	44.1	46.3	45.0	0.9
Maine	40.5	41.5	40.3	–0.2
Maryland	21.3	22.5	21.7	0.4
Massachusetts	12.6	12.9	11.5	–1.1
Michigan	38.4	40.7	40.8	2.4
Minnesota	41.7	45.0	41.2	–0.5
Mississippi	55.3	55.0	54.6	–0.7
Missouri	41.7	45.8	44.2	2.5
Montana	57.7	62.1	62.6	4.9
Nebraska	38.6	42.3	45.4	6.8
Nevada	33.8	32.6	34.0	0.2
New Hampshire	30.0	31.1	31.0	1.0
New Jersey	12.3	11.5	11.4	–0.9
New Mexico	34.8	40.1	39.7	4.9
New York	18.1	18.4	18.5	0.5

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**Table 1.** Self-Reported Household Firearm Ownership Prevalence Across States in the U.S., by Year (*continued*)

State	Percentage of households with a firearm			Change (delta), 2001–2004
	2001	2002	2004	
North Carolina	41.3	41.6	39.4	–1.9
North Dakota	50.7	54.5	56.2	5.5
Ohio	32.4	32.2	34.0	1.6
Oklahoma	42.9	45.0	46.5	3.6
Oregon	39.8	40.3	39.8	0.0
Pennsylvania	34.7	36.7	35.1	0.4
Rhode Island	12.8	13.5	12.4	–0.4
South Carolina	42.3	45.6	43.3	1.0
South Dakota	56.6	60.4	59.9	3.3
Tennessee	43.9	47.0	46.6	2.7
Texas	35.9	36.4	37.1	1.2
Utah	43.9	45.5	44.8	0.9
Vermont	42.0	45.7	43.8	1.8
Virginia	35.1	36.5	37.5	2.3
Washington	33.1	36.7	34.0	0.9
West Virginia	55.4	58.2	58.5	3.0
Wisconsin	44.4	44.5	43.0	–1.5
Wyoming	59.7	63.1	65.5	5.8
Overall	32.2	34.9	32.8	0.6

Note: Values in table represent estimated prevalence.

Higher rates of firearm ownership were positively associated with rates of firearm-related assault, with each quintile exhibiting a significantly increased risk relative to the lowest, referent quintile. Relative to the states in the lowest quintile of ownership (i.e., the lowest firearm ownership category), states in the highest quintile had a rate of firearm-related assaults that was 6.8 times higher. Likewise, higher rates of firearm ownership were associated with significantly increased rates of firearm-related robbery across the second, third, and fourth quintiles. Three-year averages of state-level firearm ownership and firearm-related robbery and assault rates are depicted in [Figure 1](#).

Higher levels of firearm ownership were also associated with a significantly increased risk for overall homicide. Furthermore, firearm ownership was significantly associated with increased firearm-related homicide, with each quintile associated with successively higher risk ([Table 2](#)).

These analyses were repeated with the proportions of state-level populations represented by UCR data included as an additional covariate. The results for firearm-related assault and robbery did not change, continuing to show a significant positive association with firearm ownership, except that for robbery, the estimate for the fifth quintile became significant as well (incidence rate ratio [IRR]=3.92, 95% CI=1.34, 11.44). For the overall homicide outcome, the comparison of the fifth quintile to the referent quintile failed to achieve statistical significance (IRR=1.93, 95% CI=0.94, 3.98). The remaining results were unchanged, indicating increased risk for overall and firearm-related homicide with higher levels of state-level firearm ownership.

### Longitudinal Prediction of State-Level Violent Crime Rates Using Firearm Ownership

Although the association between firearm ownership and an increased risk for firearm-related assault and robbery is consistent with the hypothesis that firearm availability contributes to firearm-related crime, it is also plausible that increased rates of crime motivate the acquisition of firearms in the interest of protection. As one approach to address this ambiguity, another model was estimated using firearm ownership in 2001 to predict violent crime rates in 2002 and 2004, adjusting for the same demographic factors. As shown in [Table 3](#), firearm ownership in 2001 was significantly associated with increased rates of firearm-related assault, robbery, and homicide, as well as overall homicide.

### Discussion

This study tested the hypothesis that private firearm ownership at the state level serves as a deterrent to criminal activity, with firearm ownership measured by a nationally representative self-report survey and crime measured by official law enforcement agency reports. These results do not support the hypothesis that higher rates of firearm ownership are associated with lower firearm-related assault, robbery, or homicide rates. To the contrary, evidence was found for a positive association, in which states with greater levels of private firearm ownership experienced greater rates of firearm-related violent crimes.

These results are consistent with studies finding a positive association between city-level gun availability, the individual risk for gun-related assault and robbery,<sup>14,23</sup> and an increased risk for firearm assault victimization and possessing a firearm at the time of the crime.<sup>24</sup> The present findings are partially consistent with a study of gun availability in South Carolina in 1991–1994,<sup>13</sup> which found an association between illegal

**Table 2.** Association Between State-Level, Self-Reported Firearm Ownership and Violent Crime Reported to Law Enforcement, 2001–2002, 2004

State-level covariates <sup>a</sup>	Violent crime outcome			
	Assault with a firearm <sup>a</sup>	Robbery with a firearm <sup>a</sup>	Homicide <sup>b</sup>	Homicide with a firearm <sup>b</sup>
Firearm ownership				
1 <sup>st</sup> Quintile (least)	ref	ref	ref	ref
2 <sup>nd</sup>	<b>2.88 (1.31, 6.22)</b>	<b>2.89 (1.46, 5.75)</b>	<b>1.56 (1.09, 2.23)</b>	<b>1.87 (1.21, 2.91)</b>
3 <sup>rd</sup>	<b>4.23 (1.44, 12.41)</b>	<b>3.33 (1.39, 8.00)</b>	<b>1.81 (1.18, 2.78)</b>	<b>2.22 (1.29, 3.81)</b>
4 <sup>th</sup>	<b>5.91 (1.78, 19.57)</b>	<b>3.75 (1.55, 9.09)</b>	<b>2.18 (1.44, 3.29)</b>	<b>2.74 (1.62, 4.63)</b>
5 <sup>th</sup> (greatest)	<b>6.77 (1.53, 29.92)</b>	2.72 (0.87, 8.57)	<b>2.08 (1.18, 3.66)</b>	<b>2.84 (1.34, 6.04)</b>
Year	0.97 (0.91, 1.03)	<b>0.92 (0.87, 0.98)</b>	0.99 (0.95, 1.03)	0.99 (0.95, 1.04)
Household income	0.99 (0.94, 1.04)	1.01 (0.96, 1.07)	1.01 (0.98, 1.04)	1.01 (0.98, 1.04)
Percent male	1.02 (0.62, 1.68)	1.12 (0.74, 1.71)	1.14 (0.85, 1.52)	1.06 (0.74, 1.53)
Percent black	<b>1.04 (1.01, 1.06)</b>	<b>1.05 (1.03, 1.08)</b>	<b>1.05 (1.03, 1.06)</b>	<b>1.05 (1.04, 1.07)</b>
Percent Latino	<b>1.02 (1.00, 1.05)</b>	1.01 (0.99, 1.04)	1.01 (1.00, 1.03)	1.01 (1.00, 1.03)
Percent <25 years	0.94 (0.85, 1.04)	0.95 (0.89, 1.01)	<b>0.94 (0.90, 0.98)</b>	<b>0.93 (0.89, 0.98)</b>
Percent ≥HS education	0.99 (0.91, 1.06)	<b>0.90 (0.84, 0.97)</b>	0.95 (0.89, 1.01)	<b>0.93 (0.87, 0.99)</b>
Percent urban	<b>1.03 (1.00, 1.06)</b>	<b>1.03 (1.01, 1.06)</b>	<b>1.02 (1.00, 1.04)</b>	<b>1.03 (1.00, 1.05)</b>
Percent poverty	1.01 (0.90, 1.12)	0.97 (0.85, 1.11)	1.01 (0.94, 1.08)	0.98 (0.91, 1.06)
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)
Region				
Northeast	ref	ref	ref	ref
Midwest	1.87 (0.95, 3.68)	1.91 (0.98, 3.70)	1.25 (0.77, 2.02)	1.32 (0.75, 2.32)
South	<b>2.34 (1.15, 4.78)</b>	1.36 (0.59, 3.14)	1.00 (0.53, 1.88)	1.01 (0.50, 2.05)
West	2.30 (1.00, 5.28)	1.44 (0.56, 3.66)	1.36 (0.77, 2.39)	1.42 (0.74, 2.72)
Border ownership <sup>c</sup>	0.98 (0.96, 1.01)	0.99 (0.95, 1.02)	0.99 (0.97, 1.01)	0.99 (0.97, 1.01)

Note: Values in table represent incidence rate ratio (95% CI); boldface indicates statistical significance ( $p < 0.05$ ).

<sup>a</sup>Illinois did not contribute crime data to this analysis; rates are based on Uniform Crime Reports population estimates of reporting jurisdictions.

<sup>b</sup>Florida did not contribute crime data to this analysis; rates are based U.S. Census annual state-level population estimates.

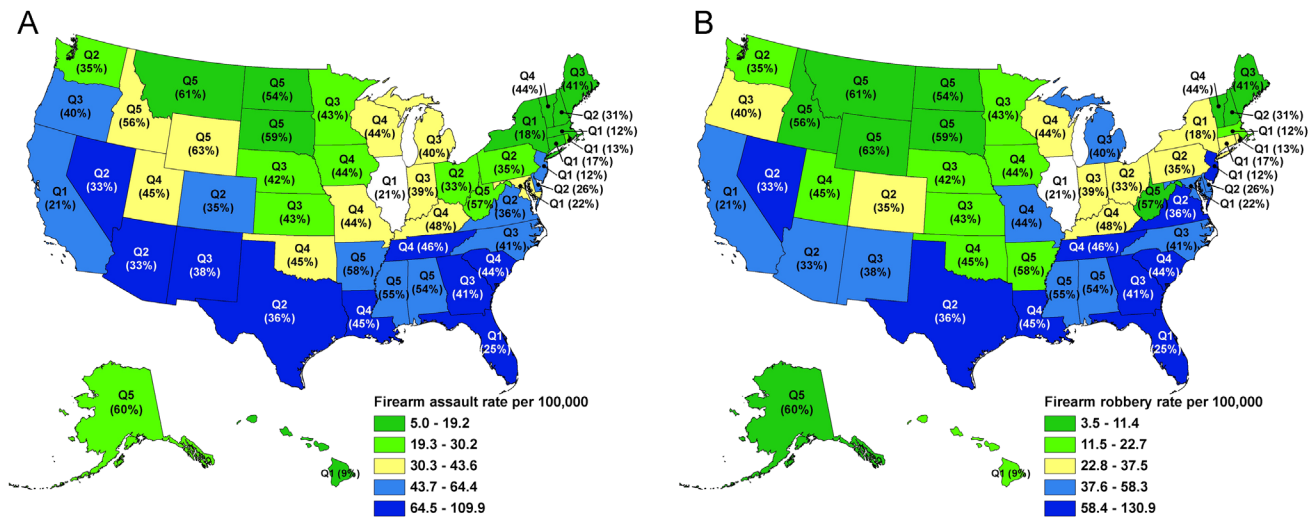
<sup>c</sup>Mean firearm ownership rate of all geographically adjacent states.

HS, high school

gun availability and gun crime, but not with lawful gun availability. This discrepancy may be the result of methodologic differences in the measures of gun prevalence (a survey measure of ownership versus a count of concealed weapon permits). These findings are also partially consistent with a study of 21 developed countries (including the U.S.) that found an association between firearm ownership and rates of gun-related assault, but not robbery.<sup>11</sup>

These findings are similar to studies examining the link between firearm ownership and firearm-related homicide, despite methodologic differences. Miller and

colleagues<sup>5,6</sup> reported a positive relationship between firearm ownership and overall homicide as well as firearm homicide across states and regions. Another study found that stronger state-level firearm control legislation was associated with decreased firearm-related suicides and homicides.<sup>25</sup> Whereas homicides were measured using death certificate data in Miller et al.<sup>5,6</sup> and Fleegler and colleagues,<sup>25</sup> law enforcement crime reports were used in the present study. This study is also consistent with that of Siegel et al.,<sup>26</sup> which found a positive association between state-level non-stranger homicide and firearm ownership. Another study found



**Figure 1.** Adjusted mean firearm-related assault and robbery rates per 100,000 persons (over years 2001, 2002, and 2004). No data available for firearm-related assault or robbery rates in Illinois. Colors represent quintiles of specific firearm-related crimes. Labels demonstrate quintiles of mean firearm ownership rates with mean percent ownership in parentheses.

an association between the repeal of Missouri’s handgun purchaser licensing law (thereby increasing firearm availability) and an increase in firearm homicides, using both death certificate data and UCR data to measure homicide.<sup>27</sup> Also, a study using a proxy of state-level firearm ownership (i.e., a composite of a firearm suicide measure and the hunting license rate) found an association with total homicides and firearm-related homicides.<sup>28</sup>

There was a slight increase in overall firearm ownership in 2002 (35%) relative to 2001 (32%), with 45 states reporting an increase in ownership. These data do not seem to be indicative of a national upward trend in ownership, given that the overall prevalence dropped back to 32.8% in 2004. It is difficult to infer what might have instigated the increase in 2002, especially given that

the observed delta is compatible with the margin of error inherent in the survey design from which the data are derived.

**Limitations**

These results should be considered in the context of methodologic limitations. First, the results are susceptible to the biases and limitations inherent to ecologic studies.<sup>29</sup> However, consistent with the ecologic findings, evidence from an individual-level study found an association between carrying a firearm and being injured in a firearm-related assault.<sup>24</sup> Second is the use of state-level data as opposed to more granular data (e.g., county- or city-level data) that better account for differences between urban and rural areas in violent crime and

**Table 3.** State-Level, Self-Reported Firearm Ownership in 2001 Predicting Violent Crime Reported to Law Enforcement in 2002 and 2004

Quintiles of firearm ownership	Assault with a firearm <sup>a</sup>	Robbery with a firearm <sup>a</sup>	Homicide <sup>b</sup>	Homicide with a firearm <sup>b</sup>
1 <sup>st</sup> (least)	ref	ref	ref	ref
2 <sup>nd</sup>	<b>3.26 (1.42, 7.48)</b>	<b>3.72 (2.04, 6.80)</b>	<b>1.97 (1.44, 2.71)</b>	<b>2.19 (1.46, 3.28)</b>
3 <sup>rd</sup>	<b>5.06 (1.17, 21.9)</b>	<b>3.84 (1.54, 9.58)</b>	<b>2.03 (1.19, 3.47)</b>	<b>2.36 (1.26, 4.42)</b>
4 <sup>th</sup>	<b>5.68 (1.18, 27.4)</b>	<b>6.86 (2.72, 17.3)</b>	<b>2.69 (1.33, 5.46)</b>	<b>3.35 (1.52, 7.36)</b>
5 <sup>th</sup> (greatest)	<b>7.25 (1.16, 45.2)</b>	<b>5.23 (1.62, 16.9)</b>	<b>2.37 (1.08, 5.20)</b>	<b>3.09 (1.15, 8.26)</b>

Note: Values in table represent incidence rate ratio (95% CI); boldface indicates statistical significance ( $p < 0.05$ ). All models adjusted for year, median household income, sex, race, ethnicity, age, education, urbanicity, poverty, population density, region, and bordering state ownership.

<sup>a</sup>Illinois did not contribute crime data to this analysis; rates are based on Uniform Crime Reports population estimates of reporting jurisdictions.

<sup>b</sup>Florida did not contribute crime data to this analysis; rates are based U.S. Census annual state-level population estimates.

firearm ownership. To account for this, models were adjusted for state-level urban population residence. Also, these data, though more recent than other published studies, are still almost a decade old as of this writing. This study was limited to the use of 10-year-old data because BRFSS stopped including firearm questions in 2004. However, it is unlikely that temporal changes would alter the pattern of results if repeated with contemporaneous data. Also, the use of UCR data only allows evaluation of the occurrence of reported crimes. The present study examined serious violent crimes (aggravated assault, robbery, and homicide) that are most likely to be reported to law enforcement authorities. Though the attenuation, if any, of crime rates as a result of non-reporting could have caused a reduction in precision, it was unlikely to be differential with respect to firearm ownership, and should not invalidate the results. Although a wide range of demographic and social factors were controlled to account for interstate differences, it is possible that, as in all observational research, residual confounding remained in the model estimates, such that the associations reported herein may have been spurious. However, it is unlikely that residual confounding could account for the magnitude of some effects reported. To adjust for geographic effects, an attempt was made to control for U.S. census region. Although this is a gross geographic measurement, more specific measures could not be used, given that data were analyzed at the state level. Finally, these data do not allow investigation of the temporal association between firearm ownership and crime rates. Elevated crime rates could have motivated the private acquisition of firearms in the interest of self-defense and protection. The longitudinal analysis showing that firearm ownership in 2001 predicts crime in later years provides some assurance about the direction of the effect, but is not adequate to completely rule out the possibility of reverse causation. Given the methodologic limitations of this study, especially those inherent in its ecologic design, this study should be replicated with more recent, individual-level data, as recently proposed by President Obama's Executive Action on gun violence.<sup>30</sup>

## Conclusions

These analyses do not support the hypothesis that firearm ownership deters violent firearm crime. Instead, this study shows that higher levels of firearm ownership are associated with higher rates of firearm-related violent crime. Public health and legislative stakeholders should consider these results when responding to or engaging in the gun control debate. Further individual-level, epidemiologic research is needed to confirm these results.

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## References

1. Web-based Injury Statistics Query and Reporting System (WISQARS). CDC, National Center for Injury Prevention and Control; 2012. <http://wisqars.cdc.gov:8080/cost/>.
2. Hemenway D, Miller M. Firearm availability and homicide rates across 26 high-income countries. *J Trauma*. 2000;49(6):985-988. <http://dx.doi.org/10.1097/00005373-200012000-00001>.
3. Uniform Crime Reports (UCR). Federal Bureau of Investigation, 2013. [www.fbi.gov/about-us/cjis/ucr](http://www.fbi.gov/about-us/cjis/ucr).
4. Kleck G. *Targeting Guns: Firearms and Their Control*. New York, NY: Aldine de Gruyter; 1997.
5. Miller M, Azrael D, Hemenway D. Rates of household firearm ownership and homicide across U.S. regions and states, 1988-1997. *Am J Public Health*. 2002;92(12):1988-1993. <http://dx.doi.org/10.2105/AJPH.92.12.1988>.
6. Miller M, Hemenway D, Azrael D. State-level homicide victimization rates in the U.S. in relation to survey measures of household firearm ownership, 2001-2003. *Soc Sci Med*. 2007;64(3):656-664. <http://dx.doi.org/10.1016/j.socscimed.2006.09.024>.
7. Hepburn LM, Hemenway D. Firearm availability and homicide: a review of the literature. *Aggress Violent Behav*. 2004;9:417-440. [http://dx.doi.org/10.1016/S1359-1789\(03\)00044-2](http://dx.doi.org/10.1016/S1359-1789(03)00044-2).
8. Cook P. The effect of gun availability on robbery and robbery murder. In: Haverman R, Zellner R, eds. *Policy Studies Review Annual*. Beverly Hills, CA: Sage; 1979:743-781.
9. Cook P. Robbery violence. *J Crim Law Criminol*. 1987;78:357-376. <http://dx.doi.org/10.2307/1143453>.
10. Felson RB, Pare PP. Firearms and fisticuffs: region, race and adversary effects on homicide and assault. *Soc Sci Res*. 2010;39:272-284. <http://dx.doi.org/10.1016/j.ssresearch.2009.07.004>.
11. Killias M, van Kesteren JN, Rindlisbacher M. Guns, violent crime and suicide in 21 countries. *Can J Criminol*. 2001;43(4):429-448.
12. van Kesteren JN. Revisiting the gun ownership and violence link: a multilevel analysis of victimization survey data. *Br J Criminol*. 2014; 54(1):53-72. <http://dx.doi.org/10.1093/bjc/azt052>.
13. Stolzenberg L, D'Alessio SJ. Gun availability and violent crime: new evidence from the National Incident-Based Reporting System. *Soc Forces*. 2000;78(4):1461-1482. <http://dx.doi.org/10.1093/sf/78.4.1461>.
14. Altheimer I. Do guns matter? A multi-level cross national examination of gun availability on assault and robbery victimization. *West Crim Rev*. 2008;9(2):9-32.
15. Behavioral Risk Factor Surveillance System (BRFSS). CDC; 2013. [www.cdc.gov/brfss/index.htm](http://www.cdc.gov/brfss/index.htm).
16. Levy PS, Lemeshow S. Strategies for design-based analysis of sample survey data. *Sampling of Populations: Methods and Applications*, 3rd ed. New York: John Wiley & Sons; 1999: 481-494.
17. Martin RA, Legault RL. Systematic measurement error with state-level crime data: evidence from the "More Guns, Less Crime" debate. *J Res Crime and Delinq*. 2005;42(2):187-210. <http://dx.doi.org/10.1177/0022427804270052>.
18. Maltz MD. *Analysis of missingness in UCR crime data*. Criminal Justice Research Center, Ohio State University; 2006.

19. Criminal Victimization in the United States – Statistical Tables, 2004. Bureau of Justice Statistics, U.S. Department of Justice; 2013. [bjs.ojp.usdoj.gov/index.cfm?ty=pbdetail&iid=1102](http://bjs.ojp.usdoj.gov/index.cfm?ty=pbdetail&iid=1102).
20. *Crime in the United States, 2004: Uniform Crime Reports*. Washington DC: U.S. Department of Justice, Federal Bureau of Investigation; 2005.
21. Hemenway D. *Private Guns, Public Health*. Ann Arbor, MI: The University of Michigan Press; 2004.
22. United States Census Bureau. U.S. Department of Commerce, 2013. [www.census.gov/](http://www.census.gov/).
23. Jung RS, Jason LA. Firearm violence and the effects of gun control legislation. *Am J Community Psychol*. 1988;16(4):515–524 <http://dx.doi.org/10.1007/BF00922768>.
24. Branas CC, Richmond TS, Culhane DP, Ten Have TR, Wiebe DJ. Investigating the link between gun possession and gun assault. *Am J Public Health*. 2009;99(11):2034–2040. <http://dx.doi.org/10.2105/AJPH.2008.143099>.
25. Fleegler EW, Lee LK, Monuteaux MC, Hemenway D, Mannix R. Firearm legislation and firearm-related fatalities in the United States. *JAMA Intern Med*. 2013;173(9):732–740. <http://dx.doi.org/10.1001/jamainternmed.2013.1286>.
26. Siegel M, Negussie Y, Vanture S, Pleskunas J, Ross CS, King C 3rd. The relationship between gun ownership and stranger and nonstranger firearm homicide rates in the United States, 1981–2010. *Am J Public Health*. 2014;104(10):1912–1919. <http://dx.doi.org/10.2105/AJPH.2014.302042>.
27. Webster D, Crifasi CK, Vernick JS. Effects of the repeal of Missouri’s handgun purchaser licensing law on homicides. *J Urban Health*. 2014;91(2):293–302. <http://dx.doi.org/10.1007/s11524-014-9865-8>.
28. Siegel M, Ross CS, King C. Examining the relationship between the prevalence of guns and homicide rates in the USA using a new and improved state-level gun ownership proxy. *Inj Prev*. 2014;20(6):424–426. <http://dx.doi.org/10.1136/injuryprev-2014-041187>.
29. Morgenstern H. *Ecologic Studies. Modern Epidemiology*, 3rd ed, Philadelphia, PA: Lippencott Williams & Wilkins; 2008.
30. Now is the time to do something about gun violence. The White House, President Barack Obama; 2013. [www.whitehouse.gov/issues/preventing-gun-violence#what-we-can-do](http://www.whitehouse.gov/issues/preventing-gun-violence#what-we-can-do).