

Household Firearm Ownership and Rates of Suicide Across the 50 United States

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Background: The current investigation explores the association between rates of household firearm ownership and suicide across the 50 states. Prior ecologic research on the relationship between firearm prevalence and suicide has been criticized for using problematic proxy-based, rather than survey-based, estimates of firearm prevalence and for failing to control for potential psychological risk factors for suicide. We address these two criticisms by using recently available state-level survey-based estimates of household firearm ownership, serious mental ill-

ness, and alcohol/illicit substance use and dependence.

Methods: Negative binomial regression was used to assess the relationship between household firearm ownership rates and rates of firearm, nonfirearm, and overall suicide for both sexes and for four age groups. Analyses controlled for rates of poverty, urbanization, unemployment, mental illness, and drug and alcohol dependence and abuse.

Results: US residents of all ages and both sexes are more likely to die from suicide when they live in areas where

more households contain firearms. A positive and significant association exists between levels of household firearm ownership and rates of firearm and overall suicide; rates of nonfirearm suicide were not associated with levels of household firearm ownership.

Conclusion: Household firearm ownership levels are strongly associated with higher rates of suicide, consistent with the hypothesis that the availability of lethal means increases the rate of completed suicide.

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In the United States, suicide consistently ranks as one of the 15 leading causes of death for the population overall and ranks as one of the three leading causes of death for persons less than 30 years old.¹ In 2002, of the 31,655 Americans who committed suicide, 17,108 (54%) used a firearm. Although men account for 80% of all suicides and 88% of all firearm suicides in the United States, firearm use accounts for over 40% of all completed suicides by women and children as well.¹

According to the National Academy of Sciences (NAS) report “Firearms and Violence: A Critical Review” released in December of 2004,² a central and unresolved question in the public health approach to preventing suicide is whether restricting access to highly lethal and commonly used means, such as firearms, will result in a complete shift to other equally lethal suicide acts, such as jumping off tall buildings. Complete substitution, as this complete shift is called, assumes that suicidal intent is all that matters; opportunity or the ready availability of different means of suicide is irrelevant.

Case control studies in the United States suggest that substitution is incomplete, consistently finding that the presence of a gun in the home^{3–14} (and the purchase of firearms

from a licensed dealer^{15,16}) are risk factors for suicide, not only for the gun owners but for all members of the household. Drawing causal inferences about the gun-suicide connection from existing case-control studies has, however, been questioned on the grounds that these studies do not adequately control for the possibility that members of gun-owning households are inherently more suicidal than members of nongun-owning households and that the association may be spurious, because of differential recall of firearm ownership and comorbid conditions (by cases compared with controls).²

Ecologic studies provide a complementary approach to study the relationship between firearm ownership and suicide. Ecologic analyses have consistently found a positive association between cross-sectional measures of firearm prevalence and firearm suicide.^{17–26} Findings with respect to the association between firearm prevalence and rates of overall suicide, however, have been mixed, depending largely on the way firearm prevalence has been measured, especially on the particular proxy used to assess firearm prevalence.^{2,27}

Ecologic studies of the firearm-suicide connection have been criticized, most recently in the NAS report, for using problematic proxy-based, rather than survey-based, estimates of firearm prevalence. The report, although published in 2004, was apparently written before the release of state-level firearm ownership data from the 2001 Behavioral Risk Factor Surveillance System (BRFSS) because it explicitly calls for the future inclusion of household firearm ownership questions on this annual survey.² Although two prior nationally representative studies^{21,28} used survey estimates of firearm prevalence, both were limited relatively imprecise estimates afforded by the annual General Social Survey (GSS),²⁹ which consisted of fewer than 2,000 respondents nationally (com-

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pared with the BRFSS, which has over 200,000 respondents annually) and was designed to be representative at the census region level ($n = 9$) rather than at the state level. Consequently, these analyses could not control for more than one covariate at a time.

Another critique of existing ecologic and case-control studies is that the associations found between firearm ownership and rates of suicide, even if unbiased, might not be causal if gun owners are inherently more suicidal (e.g., people who own guns may have higher rates of mental illness or other risk factors for suicide, such as alcohol or drug dependence). There are no data to support this contention. Two ecologic studies of firearm levels and rates of suicide have attempted to control for mental illness;^{28,30} both found that the firearm-suicide association was not confounded by these factors. One of these studies was nationally representative but limited its evaluation to the nine census regions;²⁸ the other study was limited to seven states in the Northeast.³⁰ Both studies were restricted in their ability to control for other potential confounders because of the small number of units of observation.

The present investigation addresses these two ecologic critiques by using: (1) recently available state-level survey-based estimates of household firearm ownership from the BRFSS and (2) recently available estimates of serious mental illness and of alcohol and illicit substance use and dependence from the 2002 National Survey on Drug Use and Health.³¹ The association between household firearm ownership and suicide is examined while controlling for these covariates, as well as for three other potential confounders: urbanization, unemployment, and poverty. In addition, we conducted sensitivity analyses to explore whether the associations between firearm ownership and suicide for men, women, and children are materially affected when rates of household firearm ownership are derived respectively from male respondents in the BRFSS, female respondents, and respondents living in households with children.

MATERIALS METHODS

Mortality Data

Suicide mortality data for each state were obtained through the Centers for Disease Control and Prevention (CDC)'s Web-based Injury Statistics Query and Reporting System.¹ Suicide data, grouped by firearm (ICD-10 E-codes X72–X74) and nonfirearm methods (E-codes X60–X71, X75–X84, Y87.0, and U03), were further stratified by sex and age (5–19, 20–34, 35–64, and 65 years of age and older). Analyses use mortality data aggregated during the 3-year period of 2000 to 2002 to allow comparisons across our age groupings.

Independent Variables

State level data on the percentage of individuals living in households with firearms (gun prevalence) were obtained from the 2001 BRFSS.³² The BRFSS, the world's largest

telephone survey (more than 200,000 adult respondents annually), is an ongoing data collection program sponsored by the CDC, with all 50 states participating. Data collected are representative at the state and national level. BRFSS questionnaires and data are available on the Internet (www.cdc.gov/brfss); the BRFSS uses a complex sampling and weighting scheme described in detail elsewhere.³² Estimates were also calculated for female respondents and male respondents separately and for respondents who live in households with children. Firearm prevalence estimates presented in the tables and text exclude respondents who did not know or refused to answer the BRFSS firearm questions.

State-level measures of alcohol and illicit substance abuse and dependence, and of serious mental illness, were obtained from the 2002 National Survey on Drug Use and Health.³¹ The survey-weighted hierarchical Bayes (SWHB) methodology used to arrive at state estimates is described in detail elsewhere.^{33,34}

Serious mental illness (SMI) is defined as having a diagnosable mental, behavioral, or emotional disorder that met the criteria found in the 4th edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) and resulted in functional impairment that substantially interfered with or limited one or more major life activities. Data for SMI estimates were available only for respondents aged 18 years or older.

Rates of alcohol or illicit substance dependence or abuse are based on definitions found in the DSM-IV. Estimates of illicit substance abuse and dependence were the percentage of respondents reporting having used any illicit drug other than marijuana in the year before the survey and includes cocaine, crack, heroin, hallucinogens, inhalants, or any prescription-type psychotherapeutic used nonmedically. Estimates of alcohol abuse and dependence pertain to the percentage of respondents reporting abuse or dependence in the year before the survey. Illicit drug and alcohol dependence and abuse data were available for ages 12 to 17 years and for the population overall.

Unemployment data were downloaded from the Bureau of Labor Statistics;³⁵ poverty and urbanization data came from Census 2000.³⁶ Unemployment, poverty, and the inverse of urbanization are ecologic characteristics that have been associated with higher rates of suicide in various studies.^{37–41}

Statistical Analyses

Multivariate analyses adjust for the percentage of a state's population with serious mental illness, alcohol dependence or abuse, illicit substance dependence or abuse, and the percentage unemployed, living below the poverty level, and in urban areas. Suicide death rates across the United States demonstrate a skewed distribution, with variance greater than the mean. Accordingly, we use a negative binomial regression model instead of Poisson to assess the association between household firearm ownership and suicide deaths. The

primary outcome is the number of suicides per state during the 3-year study period.

Incidence rate ratios (IRR), derived by exponentiating beta coefficients in the negative binomial regressions, express the magnitude of the association between death rates and measures of firearm prevalence. Incidence rate ratios measure the percentage difference in the outcome of interest (e.g., firearm suicide rate, nonfirearm suicide rate, and overall suicide rate) for each one-percentage absolute point difference in the rate of household firearm prevalence (e.g., the relative difference in the rate of firearm suicide comparing states where 33% of individuals live in households with firearms to states where 34% of individuals live in households with firearms).

To illustrate our main findings more concretely, we compare suicide deaths during our study period in states most extreme in their firearm prevalence. The group of high-prevalence and the group of low-prevalence states are matched so that the numbers of person-years in the two groupings are approximately equal: 15 states with the highest firearm prevalence are compared with the 6 states with the lowest firearm prevalence. Similar mortality rate ratios are obtained when comparing the 10 states most extreme in firearm prevalence (not shown).

RESULTS

In cross-sectional analyses, a one-percentage point absolute difference in household firearm prevalence was associated with a 3.5% (95% confidence interval [CI]: 2.4% to 4.7%) relative difference in the rate of firearm suicide, no significant difference in the rate of nonfirearm suicide, and a 1.4% (95% CI: 0.6% to 2.2%) difference in the rate of suicide overall (Table 1). Because approximately 33% of individuals in the United States live in households with a firearm, a one-percentage point difference in household firearm ownership corresponds to a relative difference of 3% (in relative terms, we found that a 3% difference in household firearm ownership corresponds to a 3.5% difference in rates of fire-

arm suicide). The magnitude of association between household firearm ownership and rates of suicide overall did not differ significantly across sex or age groups, although the magnitude of the association was highest for women and our youngest age group (5–19 years).

Almost twice as many individuals completed suicide in the 15 states with the highest levels of household firearm ownership (14,809) compared with the 6 states with the lowest levels of household firearm ownership (8,052; Table 2). For each age group and for both sexes, there were close to twice as many suicide victims in the high-gun prevalence states, a finding that was driven by differences in firearm suicides (i.e., nonfirearm suicides differed little). Overall, people living in high-gun states were 3.8 times more likely to kill themselves with firearms. As in multivariate results, the mortality rate ratio for firearm suicides was highest for women and for our youngest age group.

State-level estimates of household firearm ownership derived from male respondents, female respondents, and respondents who lived in homes with children were highly correlated (correlation coefficient: 0.99) even though estimates from female respondents were consistently and proportionately lower than estimates from male respondents in a given state. Consequently, measures of association between rates of suicide among men, women, and children and measures of household firearm ownership were virtually identical regardless of which measure of firearm prevalence was chosen. For simplicity of explication, all results presented use estimates of household firearm prevalence derived from all respondents to the BRFSS. Similarly, incidence rate ratios relating suicide and firearm ownership were virtually identical for our youngest age group regardless of whether analyses used alcohol and substance abuse/dependence rates reported for 12- to 17-year-olds alone or measures pertaining to all ages. Again, for simplicity of presentation and to allow comparisons across age groups in our tables, results presented for each age group and both sexes derive from analyses using identical covariates.

Table 1 Difference in Suicide Rates for a One-Percentage Point Difference in Household Firearm Ownership, 2000 to 2002

| | Percent Difference in Suicide Rate (95% CI) | | |
|------------------|---|-----------------|----------------|
| | Firearm | Nonfirearm | Overall |
| Total population | 3.5 (2.4–4.7)* | −0.5 (−1.3–0.3) | 1.4 (0.6–2.2)* |
| Men, all ages | 3.3 (2.2–4.4)* | −0.6 (−1.4–0.1) | 1.4 (0.6–2.2)* |
| Women, all ages | 4.9 (3.0–6.9)* | 0.0 (−1.0–1.1) | 1.3 (0.3–2.3)† |
| 5–19 year olds | 4.9 (3.4–6.4)* | 0.7 (−0.5–2.0) | 2.5 (1.4–3.6)* |
| 20–34 year olds | 3.6 (2.4–4.9)* | −0.5 (−1.3–0.2) | 1.3 (0.5–2.1)† |
| 35–64 year olds | 3.7 (2.5–4.9)* | −0.3 (−1.2–0.6) | 1.5 (0.6–2.3)† |
| 65+ year olds | 3.4 (1.9–5.0)* | −1.0 (−2.1–0.2) | 1.8 (0.7–3.0)† |

Analyses control for rates of unemployment, urbanization, poverty, serious mental illness, and alcohol and illicit drug dependence and abuse.

* $p < 0.001$.

† $p < 0.01$.

DISCUSSION

Consistent with previous empirical work from individual-level^{3–13,15,16} and with most^{17,18,20–24,28} but not all^{19,25} ecologic studies, we find that higher rates of firearm ownership are associated with higher rates of overall suicide. The magnitude of this association is particularly marked in our youngest age group (5–19 years), consistent with other studies^{11,19,21,42} and with the hypothesis that the ready availability of firearms is likely to have the greatest effect on suicide rates in groups characterized by more impulsive behavior.^{43,44} We found no significant association between household firearm ownership and nonfirearm suicide, although most coefficients relating firearm ownership and nonfirearm suicide were negative, suggesting the possibility of some (i.e., incomplete) substitution, particularly for men and the elderly.

Table 2 Suicides by Age Group, 2000 to 2002

| | High-Gun States | Low-Gun States | Mortality Rate Ratio (High Gun:Low Gun) |
|-------------------------|-----------------|----------------|--|
| Total population | 116 million | 119 million | |
| Household gun ownership | 47% | 15% | |
| Total population | | | |
| Firearm suicide | 9,749 | 2,606 | 3.8 |
| Nonfirearm suicide | 5,060 | 5,446 | 1.0 |
| Total suicide | 14,809 | 8,052 | 1.9 |
| Men | | | |
| Firearm suicide | 8,489 | 2,430 | 3.6 |
| Nonfirearm suicide | 3,572 | 4,007 | 0.9 |
| Total suicide | 12,061 | 6,437 | 1.9 |
| Women | | | |
| Firearm suicide | 1,260 | 176 | 7.3 |
| Nonfirearm suicide | 1,488 | 1,439 | 1.1 |
| Total suicide | 2,748 | 1,615 | 1.7 |
| 5- to 19-year-olds | | | |
| Firearm suicide | 654 | 121 | 5.5 |
| Nonfirearm suicide | 417 | 339 | 1.3 |
| Total suicide | 1,071 | 460 | 2.4 |
| 20- to 34-year-olds | | | |
| Firearm suicide | 2,407 | 580 | 4.3 |
| Nonfirearm suicide | 1,443 | 1,376 | 1.1 |
| Total suicide | 3,850 | 1,956 | 2.0 |
| 35- to 64-year-olds | | | |
| Firearm suicide | 4,674 | 1,316 | 3.6 |
| Nonfirearm suicide | 2,775 | 2,992 | 1.0 |
| Total suicide | 7,449 | 4,308 | 1.8 |
| 65+-year-olds | | | |
| Firearm suicide | 2,011 | 589 | 3.5 |
| Nonfirearm suicide | 423 | 736 | 0.6 |
| Total suicide | 2,434 | 1,325 | 1.9 |

High-gun states were the 15 states with the highest average gun levels as measured by percent of adults living in households with guns (based on BRFSS 2001): Wyoming, South Dakota, Alaska, West Virginia, Montana, Arkansas, Mississippi, Idaho, North Dakota, Alabama, Kentucky, Wisconsin, Louisiana, Tennessee, and Utah. Low-gun states were the six states with the lowest average gun levels: Hawaii, Massachusetts, Rhode Island, New Jersey, Connecticut, and New York.

Our finding that the firearm-suicide association persists even after controlling for differences in serious mental illness, alcohol dependence and abuse, and illicit drug dependence and abuse (as well as while controlling for differences in state-level urbanization, poverty, and unemployment) is consistent with previous ecologic work that controlled for different measures of suicidal tendencies: rates of major depression, serious suicide thoughts,²⁸ and medically serious suicide attempts.³⁰

Our results suggest that, if the relationship between household firearm ownership and suicide were causal, an increase in the prevalence of household firearm ownership from 33% to 34% (i.e., a relative change of 1/33 or 3%) would increase firearm suicide by 3.5% and overall suicide by 1.5%. Our findings are consistent with arguably the most successful, if unintended, suicide prevention story to date: the coincident decline in carbon monoxide-producing coal-burning furnaces used to heat English homes before the late 1950s and declines in not only carbon monoxide suicides (which constituted about half of all suicides in England prior to the 1950s), but in overall suicides.⁴⁵ In the United States,

where firearms constitute over 50% of all suicides, even small relative declines in the use of firearms in suicide acts could result in large reductions in the number of suicides annually, depending on what method would be substituted in lieu of firearms. For example, because over 90% of all suicidal acts with firearms prove fatal (but as a group constitute only 5% of all attempts: fatal plus nonfatal), whereas fewer than 3% of all suicide acts with drugs prove fatal (which as a group constitute 90% of all attempts),⁴⁶ if 1 in 10 individuals who attempted suicide with firearms in 2002 were to have attempted with drugs instead, the number of suicides in the United States would decrease by approximately 1,700 suicides per year.

In our analyses, we have the advantage of being able to use survey measures of household firearm ownership, a reasonable measure of exposure because most firearm suicides use firearms from the victim's home.¹¹ However, even this measure does not provide potentially important information about many characteristics of firearm availability that may be related to the rate of suicide deaths. For example, our measure does not provide information about the relative prevalence of

handguns and long guns (though handgun prevalence and all-gun prevalence are highly correlated across the US Census regions: correlation coefficient, 0.93);⁴⁷ the number of firearms in a gun-owning household; firearm storage practices; the caliber of gun(s); how often guns are used for hunting, target shooting, or other activities; or other measures of availability that may be relevant to the likelihood that a suicide attempt proves fatal. Similarly, although we control for the percentage of individuals in each state who have a history of serious mental illness and the percentage who have a history of illicit substance and/or alcohol abuse or dependence, we are unable to control for severity within these categories. In addition, we control for other possible proxies for suicidal tendencies, such as suicidal plans or attempts.

Our study has other limitations. Firearm prevalence data for this cross-sectional study come from 2001, whereas mortality data come from 2000 to 2002. The effect of this temporal discrepancy on our results is likely to be small because guns are highly durable. In fact, existing data show that the cross-sectional pattern of household firearm ownership tends to be quite constant over time.⁴² In addition, we find that firearm prevalence estimates from the 2001 BRFSS are significantly and independently related to the cross-sectional pattern of suicide rates for *each* of the 3 years of our study period (not shown); we chose to aggregate data during a span of 3 years so that we would have the power to analyze the firearm-suicide relation across age groups. For example, using contemporaneous mortality and firearm prevalence data from 2001, we find that each 1% difference in household firearm ownership is associated with a 3.5% (95% CI: 2.3% to 4.7%) difference in the rate of firearm suicide, a 1.3% (0.4% to 2.1%) difference in the rate of overall suicide, and is not associated with the rate of nonfirearm suicide. These relations are almost identical to those we report in Table 1, where mortality data are aggregated from 2000 to 2002.

Although our approach avoids the case-control problem of recall bias, it is important to avoid the ecologic fallacy in interpreting our findings (i.e., drawing causal inferences about individual risk factors from aggregate level data).⁴⁸ The greatest threat to the validity of our findings in this respect is that we do not know whether firearm suicide victims actually lived in homes with guns (even if they lived in high-gun states). Although it is possible that persons who actually lived in homes with guns in a high-gun state might have lower rates of firearm suicide than persons in that state who lived in homes without guns, findings from case-control studies suggest this is unlikely. For example, in one study of suicides in the home and in another of adolescent suicides in and out of the home,⁸ approximately 90% of victims used a gun if they lived in a home with a gun. Moreover, fewer than 10% of all firearm suicides involved a firearm from a home other than the victim's household.¹¹

Despite these limitations, our finding that Americans of all ages and both sexes are more likely die from suicide when they live in areas where household firearms are more preva-

lent is consistent with the hypothesis that substitution is incomplete: where ready access to household firearms is less likely, suicidal acts are, on average, less likely to prove lethal. Although our study cannot demonstrate causality, our results lend support to the hypothesis that the availability of lethal means affects the rate of completed suicide.

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EDITORIAL COMMENT

Most people who attempt suicide survive to receive hospital treatment because the vast majority choose pharmacologic means. Those who choose firearms are more likely to die at the scene (over 250 times more likely than those who overdose) and rarely make it to the hospital for treatment. However, a few of them do, most often with dramatic presentations. Over the years, one such case in particular stands out in my mind both for its medical aspect and its message about those who attempt suicide. This 35-year-old man took a rifle to his head, but because of the length of the gun succeeded only in shattering his face and missing his brain entirely.

In this article Miller et al. elegantly analyze two different national data sets to demonstrate the association between firearm ownership and firearm suicide. Although this ecologic analysis can only show the association for whole state populations, the literature is filled with case control studies that also demonstrate the association at the individual level. Although both case control studies and ecologic analyses can be criticized for merely demonstrating an association, not a cause (firearm ownership) and effect (firearm suicide), the face validity, magnitude, and consistency of this association, after controlling for possible confounding variables such as depression and substance abuse, strongly support the causal nature of the association.

Many medical professionals maintain the false impression that those who attempt suicide with a firearm are “dead set” on killing themselves, and that if they were somehow interrupted from this attempt they would surely find another way and ultimately succeed. This idea fosters resentment in caring for such patients and feelings that time and medical resources are being wasted on a person who will eventually volitionally end his or her life. Nothing could be further from the truth. Suicide is most often an impulsive act in response to an acute situation; most persons who attempt suicide and survive never repeat the attempt. Unfortunately, those who reach for a readily available firearm almost never get a second chance. More than 90% of them die with the first attempt.

My 35-year-old patient was one of the few to survive. Despite his shattered jaw which forced him to maintain a prone position to breath without aspirating the torrent of blood coming from his face, he was alert, cooperative, and communicated well using gestures. The staff assumed he must have had a long and severe history of depression. Three months later, I was privileged to hear the real story. This young man, a father of two small children, had no history of depression or suicidality, but had recently received some very bad news. The instant he realized he survived the attempt, he was grateful. Surgeons successfully reconstructed his face

and, a decade later, he is living a productive and fulfilling life. This patient was one of the lucky few to survive a firearm suicide attempt that every year takes more than 16,000 American lives. Miller's article provides one more piece of evidence on a national level that supports the notion that readily available firearms are the major cause of this tragically large number of deaths.

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Erratum

In *Panagiotis T, Elias P, Constantinos M, Minos T, Panagiotis D, Elias L. Long-term results in surgically treated acetabular fractures through the posterior approaches. J Trauma. 2007;62:378–82.* The names were incorrectly inverted.

The correct list of names is as follows:

Panagiotis G. Triantaphilopoulos, MD, Elias Christos Panagiotopoulos, PhD, Constantinos Mousafiris, PhD, Minos Tyllianakis, PhD, Panagiotis Dimakopoulos, PhD, and Elias E Lambiris, PhD.