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Impact of Firearm Availability and Gun Regulation on State Suicide Rates

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Past studies on suicide have investigated the association of firearm ownership and suicide risk in the United States. The aim of the present study was to build on previous work by examining the impact of firearm storage practices and the strictness of firearm regulation on suicide rates at the state level. Data were compiled from primarily three sources. Suicide and firearm ownership information was obtained from the Centers for Disease Control and Prevention. Strictness of handgun regulation was derived from figures available at the Law Center to Prevent Violence, and controls were taken from the US Bureau of the Census. Mixed models were fitted to the data. Household firearm ownership was strongly associated with both suicide by all mechanisms, and firearm suicide. Storage practices had especially elevated consequences on suicide rates. Percent with loaded guns and gun readiness increased suicide rates, and strictness of gun regulation reduced suicide rates. Ready access to firearms can make a difference between life and death. Loaded and unlocked firearms within reach become risk factors for fatal outcomes from suicidal behavior. Future research might want to examine ways of obtaining more recent data on individual firearm ownership. This study proposes several policy recommendations for suicide prevention.

Worldwide, 800,000 people die of intentional self-harm annually (World Health Organization [WHO], 2014, p. 10). The global age-adjusted death rate in 2012 was 11.5 per 100,000 population (WHO, 2014, p. 14). Given variations in reporting across nations, differences in data quality, and persistent cultural sensitivities about the topic, these numbers are most likely underestimates of the true global prevalence of suicide. In the United States in 2012, 40,600 people died by their own hands, and the suicide mortality rate was 12.5 per 100,000 (Centers for Disease Control and Prevention [CDC], 2015a). By 2011, the U.S. rate, rising steadily since 2004, matched the average for all 36 Organization of Economic Cooperation and Development (OECD) nations (OECD, 2013, p. 35) and now slightly exceeds it (CDC, 2015a). From 2005 through 2012, suicide was the tenth leading cause of death among all U.S. residents (CDC, 2015b).

Firearms were the cause of nearly 51% of U.S. suicide deaths from 2004 to 2012, never falling below 50% in any year (CDC, 2015a). This is a percentage far higher than in any other advanced industrial nation. Among other English-speaking countries, Canada, where guns accounted for 14.9% of

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suicides in 2010, is closest to the United States. In the United Kingdom, the number was only 2.5% that year. Sweden (27.3%), Norway (21.9%), and Finland (17.5%), followed by France (17.4%), are the Western European nations where guns are most frequently used for intentional self-harm; elsewhere, the percentage is 10% or less (WHO, 2015). Among all these countries, only France and Sweden have higher overall suicide rates than the United States (OECD, 2015). Given the far greater lethality of firearms compared with all other means of self-harm, these numbers reveal that Americans are undoubtedly less suicidal than other English-speaking or European peoples with similar or even lower suicide mortality; they just choose more effective means. If firearms were less available, fewer people would succeed in killing themselves, even if many would seek substitute ways of trying.

Sweden, Norway, Finland, France, and Canada all have far fewer guns in the hands of private citizens than the United States, which ranks first in the world with an estimated civilian ownership rate of 88.8 firearms for every 100 persons. Yet all rank among the top 15 in the world, with rates of possession ranging from 30.8 in Canada, 31.2 in France, 31.3 in Norway, and 31.6 in Sweden to 45.3 in Finland—well above the OECD median of 12.5. To match its strikingly low firearm suicide rate, the United Kingdom stands out for having approximately half the OECD median number of privately owned guns (Small Arms Survey, 2007).

Compared with all but a handful of U.S. states, all of the aforementioned countries impose more restrictions on the purchase and possession of firearms, particularly handguns—none more so than the United Kingdom. In addition to more expansive mental health disqualifications, all require licensing of owners and registration of guns, procedures that inhibit impulsive purchases and have particular relevance to suicide risk (Small Arms Survey, 2011).

National figures for the United States mask significant variations in overall suicide rates and the frequency with which guns are the instrument across the 50 states and nine U.S. Census divisions. Suicide rates are lowest in the Northeast and highest in the West (Drapeau & McIntosh, 2015). In 2013, when the overall age-adjusted suicide rate was 12.6, and the firearm suicide rate was 6.4, state rates ranged from over 20 in Alaska, Montana, New Mexico, Utah, and Wyoming to less than 10 in Connecticut, Illinois, Maryland, Massachusetts, New Jersey, and New York.

The aim of this study was to examine the impact of household firearms on suicide mortality in 49 states. We address the following specific questions: (1) Is the prevalence of firearms in the home associated with state-level suicide rates? (2) Do loaded and unlocked firearms at home increase suicide risk? (3) Do state firearm regulations deemed most relevant to mitigating suicide risk affect mortality rates? (4) What are the implications of our answers to these questions for future research and public health policy?

Past Research

Gun Ownership and Storage Practices. With a single notable exception (Konty & Schaeffer, 2012), research in recent years (Hepburn, Miller, Azrael, & Hemenway, 2007; Kellermann et al., 1992; Miller, Azrael, & Barber, 2012; Miller, Azrael, & Hemenway, 2013; Miller, Azrael, Hepburn, Hemenway, & Lippman, 2002; Miller, Lippmann, Azrael, & Hemenway, 2007; Wiebe, 2003) has consistently shown that home firearm availability is associated with elevated suicide risk. In their comprehensive survey of the literature on gun ownership and suicide mortality, Miller et al. (2012) observed a strong relationship, regardless of study design. Kposowa (2013), however, noted that studies based on individual-level data, like his own, find smaller effects than those typically reported in ecological studies based on aggregated data. The risks of ownership,

while widely shared, vary greatly among demographic groups defined by sex, age, race/ethnicity, marital status, and place of residence, including region, state, and urban or rural area (Miller et al., 2013; Wiebe, 2003). Research on the effects of ownership is hampered by the lack of current data below the national level on the number and types of weapons in American households and the abiding methodological challenge of accounting for all factors that may influence suicidal behavior.

The effect of storage practices on suicide has been less studied and with less consistent results. Extensive literature reviews by Miller et al. (2012) and Brent and Bridge (2003) find support for the conclusion that while guns in the home, however stored, are a risk factor for suicide, the level of risk is enhanced when they are kept loaded or unlocked. A 2005 case-control study (Grossman et al., 2005) concurred, but two other studies (Dahlberg, Ikeda, & Kresnow, 2004; Shenassa et al., 2003), applying similar analytic techniques to data from the same national survey, drew opposite conclusions about whether unsafe storage does or does not add to the dangers associated with ownership itself. Both rely on data that are now more than 20 years old.

Gun Control Laws. Attempts to gauge the impact of gun regulation on suicide mortality have yielded similarly mixed results (Andres & Hempstead, 2011; Fleegler, Lee, Monuteaux, Hemenway, & Mannix, 2013; Miller et al., 2012). In their own studies, both Andres and Hempstead (2011) and Fleegler et al. (2013) found positive effects after controlling for possibly confounding factors. Miller et al. (2002) likewise concluded from their review of the earlier literature that restricting access to lethal means is one of the most effective suicide prevention strategies. Gerney, Parson, and Posner (2013) and Hamilton and Kposowa (2015), comparing rates of ownership and mortality in states, reached the same conclusion. Both studies found as well that gun controls have a greater impact on suicide than homicide rates, a conclusion also reached by Ludwig and Cook (2000) in their research on the effects of the federal Brady Handgun Violence Prevention Law enacted in 1994. Price, Thompson, and Duke (2004), in contrast, saw no effects on either suicide or homicide, once other factors are taken into account. According to Andres and Hempstead (2011), regulations that limit or delay gun purchases generally are the only type of restriction that are effective in preventing suicide; attempting to exclude whole categories of persons from acquiring guns because of their mental health or substance abuse histories does little or nothing to reduce risk.

Assessing the effectiveness of gun control laws depends on how they are classified and scored, inescapably a somewhat subjective, even arbitrary, process. None of the several classification schemes devised by researchers establish discrete categories (Andres & Hempstead, 2011; Fleegler et al., 2013; Law Center to Prevent Gun Violence [LCPGV], 2015; Miller & Hemenway, 1999). None of the methods for assigning scores and ranks to measure the comprehensiveness and strictness of state regulations account for the possible interaction among laws, nor have any been validated (Wintemute, 2013). Only Andres and Hempstead (2011) attempted to disentangle the effects of specific kinds of regulation on particular violent outcomes, another serious limitation.

This study adds a number of dimensions to the existing body of research on firearms and suicide, applying advanced multivariate techniques to the most current mortality data in 49 of the 50 states. The District of Columbia and Hawaii were omitted in multivariate analyses because information is lacking on gun-related variables in both. We take advantage here of a form of hierarchical linear analysis that is capable of accounting for clustering of states within census divisions, thereby providing more reliable estimates. We fit separate models to estimate the effects not only of household ownership of firearms but also

of gun storage practices known to enhance suicide risk. In addition, we model the impact on suicide by all mechanisms and by firearms alone on a subset of state gun regulations, selected for their relevance to fatal self-harm.

By virtue of its comprehensive design, our study's findings go beyond previous work, most importantly with respect to the effect of firearm storage practices on suicide risk. Our results contribute to the existing literature on the complex phenomenon of suicide, while raising new questions about the influence of certain population characteristics on suicide mortality.

METHODS

Data

Data on *suicides*, defined as intentional self-harm, are based on the tenth revision of the *International Classification of Diseases (ICD)* with cause codes X60-X84, Y87.0 (WHO 2015). Suicide rates for each state are adjusted for age using the U.S. 2000 standard population via the WONDER web-based inquiry system available from the CDC (CDC, 2015c). To bring stability into the estimates, suicide rates for the analysis were summed and averaged over 3 years, 2011, 2012, and 2013. The second dependent variable is firearm suicides, which were summed and averaged for the same 3 years.

There are four key explanatory variables: firearm ownership; loaded guns; loaded guns that are stored unlocked, which we term *gun readiness*; and strictness of gun regulation. Estimates of household firearm ownership rates by state are based on the first of three firearm questions asked in the 2002 and 2004 Behavioral Risk Factor Surveillance System (BRFSS) surveys (CDC, 2004, 2005). Respondents were asked, "Are any firearms kept in or around your home?" They were instructed to include "weapons such as pistols, shotguns, and rifles but not BB guns, starter pistols, or guns that cannot fire" if they were "kept in a garage, outdoor storage area, or motor vehicle" as well as the home. In 2004, the response rate on this question was 94.1%, with 2.3% refusing to answer and 3.3% of responses missing, the remaining 0.3% saying they were "not sure" or "did not know." The 104,952 respondents who answered "yes" (35.7%; 31.1% weighted) were then asked, "Are any of these firearms now loaded?" 22,794 (21.7%; 22.0% weighted) answered "yes" and 80,102 said "no," a response rate of 98%. Positive responders were then asked "Are any of these loaded guns also unlocked?" Interviewers explained that "unlocked" means "you do not need a key or combination to get the gun or fire it" and that "we don't count safety as a lock." The response rate on this final question was 99%, including 14,137 who answered affirmatively (62%; 60.1% weighted). State-level responses used in the analysis were estimated in Stata, version 13 (Stata Corporation, College Station, TX, USA), using design and poststratification weights provided in the data set.

The *loaded gun* variable is based on responses to the question, "Are any of these guns now loaded?" In view of the complex design of the BRFSS, positive responses were first weighted as described earlier to reflect the U.S. population of households. We then calculated the percentage of all households with loaded guns in the home by multiplying the percentage of all gun-owning households by the percentage keeping them loaded.

Gun readiness, defined as the percentage of all respondent households who possessed a loaded and unlocked gun in or around their homes, was calculated by multiplying the percentage of owners with loaded guns by the number of those who reported keeping them unlocked in each state. Methods of storage are included because of their known association with suicide risk (Grossman, Reay, & Baker, 1999; Shenassa, Rogers, Spalding, & Roberts, 2004; Vernick et al., 2003) and because we observed that state household ownership rates are not predictably related

with how owners keep their guns, especially whether they keep them loaded (data not shown).

The explanatory variable *strictness of gun regulation* was developed from data on state gun laws compiled and summarized by the Law Center to Prevent Gun Violence (LCPGV, 2015). Several types of laws were selected for inclusion in the analysis, based on their special relevance to suicide risk and prevention. Our criteria for selection were the potential for denying or delaying access to firearms by persons at heightened risk for self-harm by virtue of their mental state, substance use, or age. The categories we selected include the following: (1) regulation of private sales as well as sales by licensed dealers; (2) use of state records, which are likely to be more current and complete than federal records, to carry out background checks; (3) broader definitions of mental health disqualifications for purchase and possession than provided in federal law; (4) collection of mental health records from professional sources, not courts alone; (5) stricter prohibitions on purchase by substance abusers, including their extension to alcohol abusers; (6) provision for disarming newly prohibited persons; (7) safe storage requirements; and (8) child access prevention, establishing civil or criminal liability for either "negligent storage" or "reckless transfer" of guns to minors. Scores were then assigned in each category, applying a point system devised by the authors (available upon request), but similar to the method used by LCPGV. A single point was awarded for the presence of a law and an additional point given if the law applied to all firearms, not handguns alone, with further adjustments up or down, in the safe storage and child access prevention categories. Scores were then summed across categories and the states ranked in descending order of comprehensiveness and strictness.

Five additional independent variables are included as controls, based on past research. The first three are state-level variables: long-term unemployment, calculated from Bureau of Labor Statistics data (Anderson, 2012) as the ratio of mean to median weeks unemployed, 2007–2009. Higher ratios are indicative of extreme long-term unemployment, the particular labor market experience we deemed most likely to lead to suicidal behavior; *religious adherents*, defined by the U.S. Religious Census as "people affiliated with a congregation," including children, members, and attendees who are not members (Association of Statisticians of American Religious Bodies (ASARB), 2010a), and represented as the percent of total state population (ASARB, 2010b); and prevalence of a serious mental illness (SMI) in 2008–2009 is likewise a percentage of state population as estimated from survey data by the Substance Abuse and Mental Health Services Administration (SAMHSA, 2014). SAMHSA defines SMI as "having a diagnosable mental, behavioral, or emotional disorder . . . that results in serious functional impairment" for an adult 18 years or older (2014, p. 10).

The last two are U.S. Census Division-level variables: divorce rates in 2009, based on Census data by state, aggregated by division; and percent of the Census division population residing in rural areas (U.S. Bureau of the Census, 2012). In bivariate analysis only, we compute a series of dummy variables for divisions with one each for mid-Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific. The New England division was used as the reference group for comparison.

Statistical Estimation

For the present analysis, we employed a mixed model approach (Raudenbush & Bryk, 2002; Singer, 1998). Due to the fact that we collected information on states nested within nine census divisions, there are two levels of analysis in the data. The lowest level (Level 1) comprises states and their characteristics, and the second level (Level 2) consists of divisions and their

attributes. To maintain scarce degrees of freedom, we have kept independent variables to six, four at the state level, and two at the division level. Our model may be summarized as follows:

$$Y_{ij} = \gamma_{00} + \gamma_{10}X_{ij} + \gamma_{01}W_j + u_{0j} + u_{1j}X_{ij} + r_{ij},$$

where Y_{ij} = the score on the dependent variable for a given state ($_i$) located in census division ($_j$); γ_{00} = grand mean (average intercept); X_{ij} = a state's ($_i$) score on explanatory variable X in division $_j$; W_j = a division-level explanatory variable; r_{ij} = a state-level random effect (state error term); u_{0j}, u_{1j} = division-level random effects, where u_{0j} is the intercept residual, and u_{1j} is the slope residual.

The underlying assumptions in the model include the following: $E(r_{ij}) = 0$; Var $(r_{ij}) = \sigma^2$; Cov(u_{0j}, r_{ij}) = Cov$(u_{1j}, r_{ij}) = 0$. In addition to fixed effects at either level, interaction effects including cross-level ones may be specified and estimated if theoretically warranted. The various fixed effect coefficients are represented by the γs in the equation. The equation has been truncated for esthetic purposes, so not all variables and effects are shown. Parameters for the model were estimated via maximum likelihood using the MIXED procedure in SAS 9.4 (SAS Institute, Cary, NC, USA). All covariates were grand mean centered to aid in the interpretation of the intercept term. Following mean centering, the intercept reflects the mean suicide rate for all divisions.

We started the analysis by estimating an unconditional means model which allows for the decomposition of variability in the response variable into within-group and between-group components (Raudenbush & Bryk, 2002; Snijders & Bosker, 1999). The dependent variable, which is the suicide rate for state $_i$ nested in division $_j$ (Y_{ij}), is equal to the average suicide rate in division $_j$ plus a state-level error term represented by r_{ij}. The variance of r_{ij} may be denoted as σ^2, and the variance of u_{0j} may be represented as τ_{00}. It can be seen that $\tau_{00} = \text{var}(u_{0j})$ provides an estimate of the between-division variability, and $\sigma^2 = \text{var}(r_{ij})$ gives the within-division variability in suicide. We may then calculate the percentage of observed variation in suicide rates that is attributable to clustering or division membership by computing ρ, the intraclass correlation coefficient, where $\rho = \tau_{00}/(\tau_{00} + \sigma^2)$.

Results of the unconditional means model (not shown) revealed that the covariance parameter estimates (random effects) were both statistically significant. The between-division estimate is 6.28 ($z = 1.73$, $p < .041$), and the within-division estimate is 8.22 ($z = 4.61$, $p < .0001$). These estimates suggest that Census divisions in the United States differ in suicide rates. There is, however, even greater variation in suicide within divisions. To determine what portion of variance in suicide rates is attributable to division differences, we next computed an intraclass correlation coefficient, which indicates the proportion of variance in suicide rates that is due to division membership. The calculation (6.28/[8.22 + 6.28]) yields a result of 0.433, meaning that 43.3% of the total variance in state suicide rates can be explained by shared characteristics of states in the same Census division. In other words, and as might be expected, there is a lot of clustering in the data. The single fixed effect in the null model, the overall intercept or grand mean (γ_{00}), was 14.12, which indicates the average division suicide rate in the nine divisions. The significant variance component for divisions (τ_{00}) suggests the need to incorporate variables at Level 2 in an effort to account for some of the division-level variation in suicide rates. We thus included the divorce rate and percent in rural areas at the division level.

Procedure of Analysis

First, we present descriptive statistics of the variables (Table 1). We follow with results of bivariate correlations (Table 2),

TABLE 1
Descriptive Statistics[a] of the Variables in the Analysis (N = 49)

Variable	Mean	*SD*	Skew	Min.	Max.
Suicide Rate, 2011–2013	14.38	3.94	0.39	7.83	25.00
Firearm Suicide Rate, 2011–2013	7.452	2.83	0.20	1.80	14.46
Level 1 (State)					
Pct Gun ownership, 2004	39.10	13.62	−0.27	11.10	65.00
Pct Gun loaded, 2004	8.05	4.59	0.36	1.50	17.30
Pct Gun loaded and unlocked, 2004	4.96	2.94	0.35	0.60	10.80
Strictness of gun regulation, 2013	28.48	23.94	1.47	6.00	89.00
Long-term unemployment, 2010	1.62	0.21	0.57	1.29	2.18
Pct Religious adherents, 2010	48.47	10.27	0.19	27.60	79.10
Pct with SMI, 2010	4.73	0.80	1.00	3.50	7.20
Level 2 (Division)					
Pct rural population, 2009	21.010	8.135	0.738	8.100	40.10
Divorce rate 2009	3.616	0.519	0.233	2.700	4.60
New England division	0.118			0	1
Middle Atlantic division	0.059			0	1
East North Central division	0.098			0	1
West North Central division	0.137			0	1
South Atlantic division	0.176			0	1
East South Central division	0.078			0	1
West South Central division	0.078			0	1
Mountain division	0.157			0	1
Pacific division	0.098			0	1

Pct, percentage; SMI, serious mental illness.
[a]For the division variable, the mean is the proportion of states within a given division. Due to rounding errors, the sum may not add to exactly 1.00 (or 100).

and then move to multivariate results, presented in Tables 3 and 4. Table 3 displays results for suicide rate by all mechanisms summed and averaged for three years as the outcome variable; Table 4 does the same for firearm suicide rates, similarly summed and averaged. Both tables separately model the effects of each of the four gun-related variables—firearm ownership, gun loaded, gun readiness, and gun regulation. All variables in the models were subjected to normality tests using the univariate procedure in SAS (SAS Institute, Cary, NC, USA). A combination of summary measures and visual displays (including inspection of quantile–quantile plots, stem-and-leaf plots, and histograms) showed that dependent and independent variables were approximately normal.

We assessed the presence of multicollinearity by calculating variance inflation factors in each of the four potential models for each variable using ordinary least squares regression. Values ranged from 1.06 (percent religious adherents), 1.15 (divorce rate), 1.22 (percent serious incidents of mental illness), and 1.62 (long-term unemployment) to 2.39 (percent of households with firearms). All estimates were below suggested thresholds in the econometric and sociological literature (Greene, 2003; Hanushek & Jackson, 1977), and the hierarchical linear modeling results do not appear to have been bedeviled by multicollinear inefficiencies. Tests of significance are reported for both bivariate and multivariate analyses, but we do so with the understanding that nearly the entire universe of U.S. states is used. Therefore, traditional interpretations of "significance" in terms of generalizing sample statistics to population parameters are not applicable; rather, statistical significance is best understood in terms of a derived coefficient being different from

TABLE 2
Pearson Correlation Coefficients of the Variables (N = 49)

	SUI1113	GUNSU1113	GUNHOME	GUNLOAD	GUNLOCK	LAWSCORE	UNEMP	RELIG	MENTAL	RURAL	DIV	MIDATL	EAST NC	W NC	S ATL	E SC	W SC	MOU	PAC
SUI1113	1.00																		
GUNSU1113	.87**	1.00																	
GUNHOME	.73**	.71**	1.00																
GUNLOAD	.52**	.73**	.63**	1.00															
GUNLOCK	.57**	.77**	.66**	.99**	1.00														
LAWSCORE	−.69**	−.75**	−.79**	−.63**	−.63**	1.00													
UNEMP	.49**	.41**	.60**	.04	.09	−.36**	1.00												
RELIG	−.26*	−.19	.06	−.01	−.04	.04	.02	1.00											
MENTAL	.28**	.27*	.15	.11	.07	−.21	.19	.03	1.00										
RURAL	−.13	−.02	.30**	.18	.13	−.32**	.02	.46**	.01	1.00									
DIVORCE	.21	.37**	.32**	.74**	.73**	−.27*	.03	.02	.06	.09	1.00								
MID-ATLANTIC	−.30**	−.23	−.34**	−.27*	−.27	.39**	−.12	.11	−.18	−.45**	−.23*	1.00							
E NORTH CENTRAL	−.16	−.17	−.10	−.22	−.24*	.04	−.17	−.02	.18	−.39**	.02	−.08	1.00						
W NORTH CENTRAL	.01	−.14	.26*	−.27*	−.23	−.16	.39**	.29*	−.11	−.33**	.44**	−.09	−.13	1.00					
S ATLANTIC	−.26*	−.12	−.10	.11	.09	.01	−.36**	−.14	−.23	.16	.02	−.11	−.15	−.18	1.00				
E SOUTH CENTRAL	.01	.16	.23	.43**	.38**	−.19	−.16	.25*	.01	.39**	.69**	−.07	−.09	−.12	−.13	1.00			
W SOUTH CENTRAL	.01	.17	.16	.39**	.38**	−.17	.26*	.27*	.20	.56**	−.01	−.07	−.09	−.16	−.13	.08	1.00		
MOUNTAIN	.66**	.52**	.21	.20	.23	−.27*	.16	−.10	.18	−.01	−.31**	−.10	−.13	−.17	−.19	−.12	.11	1.00	
PACIFIC	.07	−.01	−.02	.07	.11	.23	−.01	−.36**	−.13	.31**	−.52**	−.08	−.10	−.13	−.15	−.09	−.09	−.09	1.00

*Significant at $p < 0.10$; **significant at $p < .05$ ($N = 49$).

TABLE 3
Hierarchical Linear Regression Results of the Effects of Household Gun Ownership, Gun Readiness, and Strictness of State Firearm Regulation on Suicide Rates, 2011–2013

	Model 1		Model 2		Model 3		Model 4	
Variables	β	*t*	β	*t*	β	*t*	β	*t*
Intercept (γ_{00})	14.42**	27.94	14.23**	23.91	14.24**	24.86	14.37**	26.69
Level 1 (States)								
Pct Gun ownership, 2004	0.19**	7.93						
Pct Gun loaded, 2004			0.514**	5.39				
Pct Gun loaded, unlocked, 2004					0.81**	5.91		
Strictness of gun regulation, 2013							−0.08**	−7.03
Long-term unemployment, 2010	−0.78	−0.51	6.90**	4.84	6.41**	4.65	4.36**	3.30
Pct Religious adherents, 2010	−0.06**	−2.40	−0.05	−1.57	−0.04	−1.50	−0.03	−1.13
Pct with SMI, 2010	0.27	0.96	0.34	1.02	0.47	1.43	0.27	0.91
Level 2 (Divisions)								
Divorce rate, 2009	0.48	0.53	−1.40	−1.18	−1.44	−1.27	0.69	0.73
Pct Rural, 2009	−0.11*	−1.79	−0.05	−0.82	−0.05	−0.67	−0.11	−1.60
Variance Components								
Intercept (τ_{00}) (between division)	1.99*	1.80^{+}	2.61**	1.73^{+}	2.41**	1.72^{+}	2.16**	1.78^{+}
Level 1 variance (σ^2) (within division)	1.99**	4.50^{+}	2.85**	4.47^{+}	2.65**	4.47^{+}	2.24**	4.54^{+}
Intraclass correlation	0.50		0.47		0.47		0.49	
−2 log likelihood	189.3		206.2		202.6		198.7	
LRS	77.6**		60.7**		64.3**		68.2**	
df	6		6		6		6	
Number of states	49		49		49		49	
Number of divisions	9		9		9		9	

Pct, percentage; SMI, serious mental illness; LRS, likelihood ratio statistic.
Significance tests for variance components are based on the *z* test.
*Significant at $p < 0.10$; **significant at $p < .05$; ^{+}z value.

zero in the population of states. We are also conservative in presenting results by employing threshold *p* values of .10 and .05; .10 is included because our "universe" of 49 states is rather small, leading to reduced statistical power of rejecting the null hypotheses. Finally, to detect possible violations of regression assumptions we perform postestimation diagnostics using the REG procedure in SAS (SAS Institute, Cary, NC, USA) for each of the eight models generated. Examination of visual displays (plots) and summary statistics reveals no violations. Plots of residuals, leverage, and Cook's *D* show no evidence for any state(s) exerting undue influence on the parameter estimates or the overall integrity of results.

RESULTS

Descriptive Findings

Descriptive statistics of all variables employed in the analyses are shown in

TABLE 4
Hierarchical Linear Regression Results of the Effects of Household Gun Ownership, Gun Readiness, and Strictness of State Firearm Regulation on Firearm Suicide Rates, 2011–2013

	Model 5		Model 6		Model 7		Model 8	
Variables	β	*t*	β	*t*	β	*t*	β	*t*
Intercept (γ_{00})	7.67**	26.18	7.56**	31.48	7.56**	31.58	7.56**	23.82
Level 1 (States)								
Pct Gun ownership, 2004	0.14**	6.17						
Pct Gun loaded, 2004			0.51**	8.15				
Pct Gun loaded, Unlocked, 2004					0.76**	8.03		
Strictness of gun regulation, 2013							−0.07**	−7.09
Long-term unemployment, 2010	−0.80	−0.59	4.53**	4.96	3.98**	4.30	2.37**	2.16
Pct Religious adherents, 2010	−0.04*	−1.80	−0.03	−1.55	−0.03	−1.47	−0.02	−0.08
Pct with SMI, 2010	0.08	0.32	0.12	0.50	0.24	1.01	0.14	0.56
Level 2 (*Divisions*)								
Divorce rate, 2009	1.24**	2.24	−1.02*	−1.73	−0.87	−1.50	1.10*	1.90
Pct Rural, 2009	−0.07*	−1.81	−0.44	−1.41	−0.03	−0.96	−0.06	−1.48
Variance Components								
Intercept (τ_{00}) (between division)	0.42	1.21^{+}	0.24	0.99^{+}	0.24	0.95^{+}	0.58*	1.31^{+}
Level 1 Variance (σ^2) (within division)	1.79**	4.52^{+}	1.41**	4.48^{+}	1.44**	4.48^{+}	1.68**	4.52^{+}
Intraclass correlation	0.19		0.15		0.14		0.26	
−2 log likelihood	174.9		161.7		157.7		177.3	
LRS	66.8**		80.0**		79.0**		64.4**	
df	6		6		6		6	
Number of states	49		49		49		49	
Number of divisions	9		9		9		9	

Pct, percentage; SMI, serious mental illness; LRS, likelihood ratio statistic.
Significance tests for variance components are based on the *z* test.
*Significant at $p < .10$; **significant at $p < .05$; ^{+}z value.

Table 1. The age-adjusted state mean suicide rate over the 2011–2013 period was nearly 14.4 per 100,000 population (*SD* = 3.9). New Jersey has the lowest rate (7.8) and Wyoming the highest (25.0). The national average firearm suicide rate was 7.5 (*SD* = 3.1), ranging from 1.8 in New Jersey to nearly 15.3 in Wyoming.

The U.S. average for percentage of households with firearms in 2004 was 39.1 (*SD* = 13.6), with values ranging from 11.1 in New Jersey to 65.0 in Wyoming. Mean percent of households with loaded guns was 8.0 (*SD* = 4.5), with the lowest value (1.5) observed in Massachusetts and the highest (17.3) in Alabama. The mean percentage of households with guns loaded and unlocked (gun readiness) across states was nearly 5.0 (*SD* = 2.9). Massachusetts had the lowest prevalence of gun readiness (0.6%) and Alaska and Arkansas shared the highest (10.8).

There are also wide disparities in strictness of state gun controls related to suicide risk, as we have defined and scored it. The average state score was 28.5 (SD = 23.9), ranging from 89.0 in California to only 6.0 in Arizona. Apart from California, the top five states with the strictest firearm regulations are in the Northeast and Middle Atlantic divisions: Connecticut (84.0), New Jersey (82.5), Maryland (80.5), New York (79.5), and Massachusetts (74.5). The remaining variables are all used as controls. The skewness column in Table 1 shows that in general, there are no major departures from normality among any of the independent variables, and thus, no transformations were necessary.

Bivariate Findings

Bivariate results in the form of Pearson's correlation coefficients are presented in Table 2. As may be seen, states with higher household gun ownership tend to have higher overall suicide rates (r = .73, p < .05). Those states also tend to have higher firearm suicide rates (r = .71, p < .05). The higher the percentage of households with loaded and unlocked guns in a state, the higher the overall suicide rate (r = .57, p < .05), an association even stronger for firearm suicides (r = .77, p < .05). Percentage of households with loaded guns is significantly associated with suicide by all mechanisms (r = .52, p < .05) and with firearm suicides (r = .73, p < .05).

Stricter state regulation of firearms is significantly associated with lower suicide rates (r = −.69, p < .05), lower firearm suicide rates (r = −.75, p < .05), as well as with lower firearm ownership (r = −.79, p < .05) and reduced gun readiness (r = −.63, p < .05). Among control variables, long-term unemployment is moderately but significantly associated with suicide (r = .49, p < .05), firearm suicides (r = −.41, p < .05), and higher gun ownership (r = .60, p < .05). Percent population in rural areas is not significantly associated with overall suicide rate or firearm suicides in states, but it is positively correlated with state-level gun ownership (r = .30, p < .05), and negatively linked to stricter state gun regulation (r = −.32, p < .05). Rural residence is further associated significantly with increased church membership in states (r = .46, p < .05). Division divorce rate is not significantly associated with overall suicide rate, but it does elevate firearm suicides (r = .37, p < .05). Divorce is also strongly and positively associated with loaded guns (r = .74, p < .05), with gun readiness (r = .73, p < .05), and with weaker gun regulation (r = −.27, p < .10), albeit modestly. Percent religious adherents is weakly associated with suicide rate in the negative direction (r = −.26, p < .10), but with no other variable. The higher the percentage of the population reporting SMI, the higher the suicide rate, but this association is modest for both overall suicides (r = .28, p < .05) and firearm suicides (r = .27, p < .10).

States in the mid-Atlantic division tend to have lower suicide rates (r = −.30, p < .05) than those in New England; they have lower gun ownership (r = −.34, p < .05), but score higher on strictness of firearm regulation (r = .39, p < .05). By far the highest divisional associations with suicide appear in the Mountain division. Compared with New England, that division has significantly higher suicide rate (r = .66, p < .05), higher firearm suicide rate (r = .52, p < .05), and weaker gun regulation (r = −.27, p < .10).

Multivariate Findings

The remainder of our analysis concentrates on the effect of our four gun measures on total and firearm suicide rates, adjusted for other variables. Relevant findings on the impact of household gun ownership on the total suicide rate (2011–2013) are shown in Model 1 of Table 3. As may be seen, gun ownership significantly elevates the suicide rate (β = 0.19, t = 7.93). For every unit increase in the percent of households with firearms, the suicide rate rose by .19 points, taking

into account the effects of other variables in the equation. With the exception of percent state population that is religious adherents, no other variable reached statistical significance. It is important to note that the variance components showed substantial variation in suicide between Census divisions, and also across states within divisions, but adding the divorce rate and rural population at Level 2 does not reduce the impact of divisional membership. This is not surprising, as neither variable reaches statistical significance at the 95% confidence level.

In Model 2, percent firearm ownership is replaced with percent of households with loaded guns. As shown in Table 3, a higher percentage of households with guns loaded is associated with significantly higher rates of suicide by all mechanisms ($\beta = 0.514$, $t = 5.39$). In this model, long-term unemployment emerges as a powerful influence on suicide rates ($\beta = 6.90$, $t = 4.84$), lifting them by nearly seven points per 100,000 for each fractional increase in the ratio of mean to median weeks of joblessness in a state, the most for any model.

In Model 3, percent firearm ownership is replaced in the equation with gun readiness (percent of households with loaded and unlocked guns). As evident in the table, this variable is highly significant, such that for every 1% increase in the percentage of households with guns unsecured and ready to fire, the suicide rate increases by .81 points ($\beta = 0.81$, $t = 5.91$). In this model, long-term unemployment again greatly increases state suicide rates ($\beta = 6.41$, $t = 4.65$), but no other control variables achieve significance. As in previous models, the between-division variance component (intercept τ_{00}) remained significant, suggesting that despite adding variables at Level 2, at least when it comes to overall suicide rates in the United States, there are some divisional differences.

Model 4 substitutes strictness of gun regulation for gun readiness. As shown in Table 3, every unit increase in state gun law scores reduces suicide nearly 0.1 point on average ($\beta = -0.08$, $t = -7.03$), a small but still significant effect, after controlling for the potentially confounding effects of all other variables in the equation. As in the previous models, long-term unemployment appears to have a relatively strong effect on suicide: in this instance, each unit increase in long-term unemployment raises a state's suicide rate by nearly 4.4 points.

In none of the models in Table 3 does the incidence of SMI reach statistical significance, which is consistent with bivariate results showing only a weak association with suicide. In all of them, a rather high proportion of variation in overall suicide rates is attributable to unmeasured characteristics of the Census divisions in which states are located. Given that neither of the divisional variables we included—divorce rate and rural population—reached statistical significance, and the interclass correlations remained high, future analysts might consider alternative theoretically relevant variables when replicating our study regarding overall suicide rates.

We turn next to models predicting firearm-related suicides. Relevant results are shown in Table 4. In Model 5, every percent increase in households with firearms is associated with an increase in firearm suicides of 0.14 points ($\beta = 0.14$, $t = 6.17$). Number of religious adherents has a small negative impact on firearm suicides ($\beta = -0.04$, $t = -1.80$) that is significant at the 90% level. At the division level, rural population appears to have a similar effect at the same marginal level of significance as it does in the other ownership model (Model 1). To a degree unique to this model, divorce, the other divisional control, has a significant impact on state firearm suicide rates ($\beta = 1.24$, $t = 2.24$). The variance components showed that 19% of variation in state firearm suicide rate is attributable to Census division membership. It appears that while the division divorce rate and division percent rural population did not significantly explain overall suicide rate in prior models, they predict the firearm

suicide rate, and including them reduced the intraclass correlation from 0.303 in the unconditional means model (not shown) to 0.19 in model 5.

Model 6 estimates the influence of loaded guns on firearms suicides. The estimated regression coefficient is 0.51 ($t = 8.15$), indicating that increases in the percent households with loaded guns in a state significantly raise the state's firearm suicide rate. Long-term unemployment ($\beta = 4.53$, $t = 4.96$) and the divorce rate ($\beta = -1.02$, $t = -1.73$) are also associated with firearm suicide rates at different levels of significance.

Model 7 provides estimates of the impact of loaded and unlocked guns (gun readiness) on firearm suicides, adjusted for the same controls. As may be seen, percentage of households with loaded and unlocked guns has a significant effect on firearm suicides, increasing the rate by an average of 0.76 points for every 1% rise in households with guns loaded and unlocked ($\beta = 0.76$, $t = 8.03$). Long-term unemployment again has an effect of greater magnitude ($\beta = 3.98$, $t = 4.30$). Other variables did not reach statistical significance. The intraclass correlation coefficient indicates that only 14% of variation in state suicide rate is attributable to census division location.

Model 8 estimates the effect of gun regulation on firearm suicides. As shown, a one unit increase in strictness score lowers the firearm suicide rate by 0.07 points. ($\beta = -0.07$, $t = -7.09$), matching the effect on overall suicide (Model 4). In this model, as in all others, long-term unemployment has a powerful effect ($\beta = 2.37$, $t = 2.16$). The division divorce rate also increases the state firearm suicide rate ($\beta = 1.10$, $t = 1.90$).

The intraclass correlation coefficient indicates that only 26% of variation in state suicide rate is attributable to Census division location. These findings indicate that when the rate of firearm suicides instead of all suicides is used as the outcome variable, there is less variation between Census divisions, and much more variation among states within divisions.

DISCUSSION

The aim of our study was to assess the impact of firearm ownership, firearm storage practices, and strictness of gun regulation on overall suicide and firearm suicide in the United States. In general, findings are consistent with the proposition that household gun ownership and keeping guns in the home that are loaded, and especially loaded guns that are unlocked, are significant contributors to U.S. suicide rates at the state level.

After controlling for possible confounders, including one (long-term unemployment) that has quite large effects in most models and two (religious adherents in states and divisional divorce rates) that reach some level of significance in at least one, we have found that all four gun variables are significantly related to suicide mortality, raising risk in all models. Household gun ownership modestly increases both all suicides and gun suicides, somewhat more in the former (0.19) than the latter (0.14) case, the reverse of what might be expected if the absence of guns leads to substitution of means. The increase in all suicide deaths appears to be largely but not completely driven by the increase in firearm fatalities. How guns are stored appears to be even more consequential than that they are present in the home. The increase in firearm suicide mortality almost triples if a gun in the home is kept loaded, going from 0.14 to 0.51, and rises another 50% to 0.76 when the loaded gun is left unlocked. This finding is consistent with the observation that attempted suicide is most often an impulsive act whose outcome very much depends on immediate access to lethal means. The effect of storage practices on the frequency of all suicides is almost exactly parallel, advancing from 0.19 to 0.51 to 0.81, further undercutting the assumption of substitution of means while

strengthening the conclusion firearms influence overall suicide rates. Finally, we have found that state gun regulations of the type we have selected for relevance to suicide appear to moderate suicide risk to a small but still significant extent, and that this effect is the same, regardless of means.

An interesting, but not unexpected finding, except in its magnitude, is the influence of long-term unemployment on suicide outcomes. In all but Models 1 and 5, in which gun ownership is the key explanatory variable, suicide rates jump dramatically when greater numbers of the unemployed are out of work for extremely long periods. In all four of the storage practice models, the increase is significant and large, ranging from 4.4 to 6.9 in the suicide by all mechanisms models and a somewhat lower 2.4 to 4.5 per 100,000 population, relative to a state average of 14.4 for all suicides and 7.5 for firearm suicide. Recent studies using measures that reveal only level but not duration of unemployment conflict in their findings on its association with suicide (Phillips, 2013; Phillips, Robin, Nugent, & Idler, 2010; Smith & Kawachi, 2014). How particular groups respond to spells of unemployment of varying dimension at different stages of working life demands further attention.

Of the remaining covariates, only religious adherents in states and divorce rates in divisions have any significant effect, and in both cases only in a few models. Number of religious adherents, as expected from previous and current research (Case & Deaton, 2015; Kposowa, 2013; Phillips, 2013), is negatively related to fatal outcomes in all models, but only in the two ownership models does it reach any level of significance. In both instances, the effect in reducing mortality is modest, comparable in magnitude to the effect of gun regulation. That the effect is greater on suicides by all mechanisms than by firearms alone suggests that religious affiliation may discourage suicidal intent more than it influences choice of means.

Divisional divorce rates have no significant influence on overall suicide rates in states, but they do appear to increase mortality in three of four firearm suicide models, achieving significance at the 5% level only in one, the ownership model. Many prior studies have found a more robust, consistent association, both at the individual (Kposowa, 2000, 2003) and aggregate (Breault, 1986; Kposowa, 2009) levels. Perhaps our finding is due to period or historical events: our divorce data were collected during the 2008–2009 recession. During economic downturns, divorce rates may decline as couples hold off filing, and this may affect suicide. It is important to note that even at the bivariate level divorce was weakly associated with suicide.

Contrary to much but not all previous work, our analysis shows no suicide mortality effects from the prevalence of serious mental illness in states, and only isolated, weak, and marginally significant effects due to the number of rural residents in states. Mental illness is well established as a risk factor for suicide in individuals, determined, ex post facto, to be antecedent to as many as 90% of such deaths according to one frequently cited source (American Psychological Association [APA], 2013). But determinations of this sort may not be generalizable to populations: individual and aggregate risk may not be the same, particularly when the event is relatively rare. There may be an "individual fallacy" no less problematic than the more commonly referred to "ecological fallacy." In fact, at least two ecological studies that, like ours, include both serious mental illness and gun ownership in their predictive models of suicide mortality agree that at the state level the one does not account for the other (Hemenway & Miller, 2002; Smith & Kawachi, 2014). The discrepancy in findings by type of study may well be practical as well as conceptual. A diagnosis of major depression, the condition most linked to suicide, is less likely than one of schizophrenia to lead to civil commitment

or other legal triggers to denial of access to firearms, it has been noted (APA, 2013).

Percent rural population, elsewhere found to be positively correlated with suicide rates (Miller et al., 2013; Betz, Barber & Miller, 2011), is in our models consistently negative in sign, although marginally significant only in Model 1, relating overall suicide to rates of household gun ownership. This is all the more surprising in light of a bivariate analysis that shows, as others have (Case & Deaton, 2015; Smith & Kawachi, 2014), that residence in the largely rural Mountain district by itself elevates suicide risk. In their multivariate analysis, Smith and Kawachi (2014) found that heightened mortality in these "suicide belt" states is not explained by their rural character or generally high rates of gun ownership. Analysis directly comparing rural with nonrural areas within divisions or states might generate more definitive results than our or theirs.

Analyses revealed divisional differences in suicide rates and firearm suicide rates, leading us to conclude that perhaps the often heard claim that suicide rates are higher in the West than in the East may in reality be a bit more complicated. As seen in Figure 1, at least in 2013 there did not seem to be a clear monotonic increasing gradient as we move from East to West.

New England has the lowest rate of both all-cause and firearm suicide rates, but that division is followed by the West North Central and East South Central divisions. We then have to return to the East North Central, which has higher rates than the West South Central. Thus, if a direct East–West gradient in suicide once existed, as observed by Breault (1986), it appears to have been lost, and we are left with a much

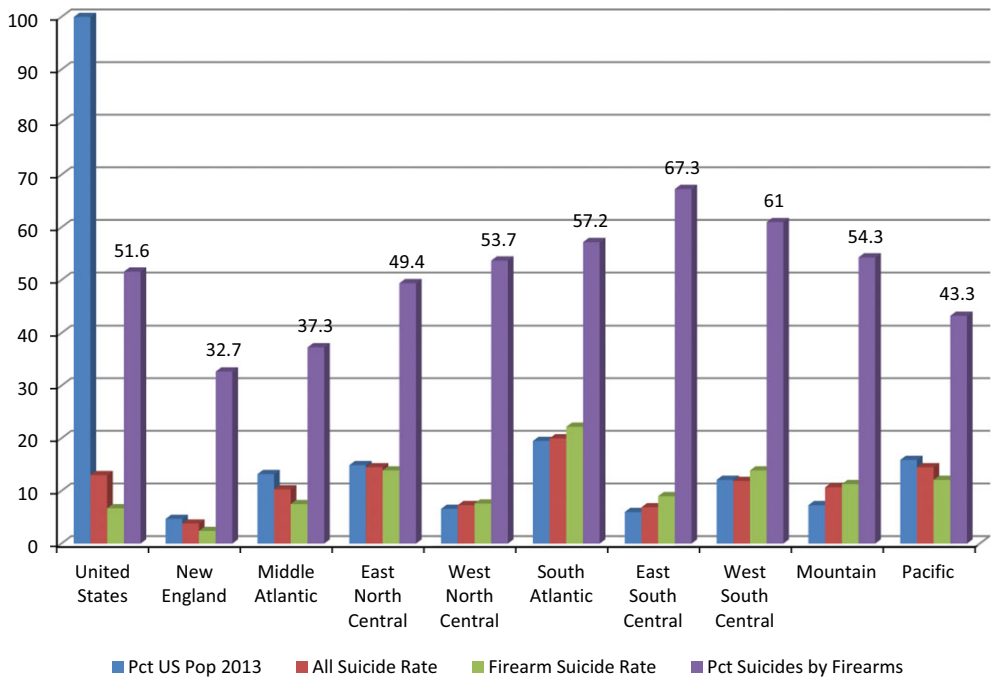

Figure 1. Percent share of U.S. population, all suicide rate, firearm suicide rate, and percent of suicides by firearms: Census divisions, 2013. *Notes:* Pop2010 from 2010 Census; Pop2013 from WISQARS, Fatal Injury Reports, accessed November 27, 2005, from http://www.cdc.gov/injury/wisqars/fatal_injury_reports.html. Hawaii and the District of Columbia were omitted for consistency with the rest of the analyses.

more complicated pattern of suicide and firearm suicide distributions. The South Atlantic division seems to have exceptionally high suicide and firearm suicide rates. We are not prepared to declare at this point whether there has emerged gun and suicide cultural zones in the United States, but we invite other scholars to explore this possibility in future research. The divisions to watch appear to be the South Atlantic, East South Central, Mountain, and West South Central, for in all of them, the percentage of suicides attributable to firearms is much higher than the 51.6 U.S. average.

With respect to the explanatory variables we have modeled, our findings are consistent with the many prior studies that have observed a positive connection between household gun ownership and suicide mortality (Miller et al., 2012; Smith & Kawachi, 2014; Wiebe, 2003). On the additional influence of storage practices on risk, our results support those investigators who have detected an enhancement effect (Brent & Bridge, 2003; Grossman et al., 2005; Miller et al., 2012; Shenassa et al., 2003) against those who find none (Dahlberg, Ikeda & Krewnow, 2004).

With regard to gun regulation, like Andres and Hempstead (2011) and Fleegler et al. (2013), our models show a significant, if modestly beneficial effect of more comprehensive and stringent state laws. Using a more complex form of analysis that controls for other factors potentially affecting outcomes, our findings confirm what some investigators claim about the efficacy of gun control (Gerney et al., 2013). We include in our measure laws that disqualify persons deemed to be at risk for suicide by virtue of mental illness or substance abuse from purchasing firearms along with more general provisions for waiting periods on all firearm purchases, but unlike Andres and Hempstead, we do not attempt to assess their relative effectiveness.

The study has some limitations. First, the information available to us on guns in the home is not current. The BRFSS survey, the only source of state-level data on the subject, has not asked any questions about guns in the home and how they are kept since 2004. It stopped asking about number and type of firearms in households or reasons for their possession in the 1990s, and it has never distinguished personal from household ownership, as does the smaller General Social Survey. The lack of current state-level data on firearm ownership and storage practices severely inhibits the research community's ability to provide new information on which to base effective suicide prevention strategies. It represents a failure of federal government policy that can only be addressed by Congress and the president. We have nonetheless advanced the discussion of the relationship between household firearms and suicide risk by giving equal attention to ownership and storage in the same analysis.

Our gun regulation measure, if in no way arbitrary, is necessarily subjective and certainly lacking validation. However, by focusing on particular regulations that are mostly likely to mitigate suicide risk, we have attempted to introduce balance into a debate that is too often focused on preventing homicide and other forms of interpersonal violence.

POLICY IMPLICATIONS

The contribution of firearms to suicide is a crucial public health and psychiatric issue to address as many suicides may be impulsive and thus unpredictable behaviors (APA, 2013). Many might occur through no prior ideation or planning, but may be due to spur of the moment feelings that arise in times of crisis; for example, a relationship loss, sudden job loss, sudden status loss, the death of a loved one, betrayal on the job or in other places by trusted ones, and unexpected financial loss. At these and similar moments, the immediate urge is to believe that life is not worth living; ready access to a suicide method can make a difference between life and death. It is in this context that loaded and unlocked firearms within

reach become especially risk factors for suicidal behavior.

Self-harm is one face of the gun violence problem in America; interpersonal violence (including intimate partner violence) is the other. Suicide is less often the focus of public debate over solutions than homicide, although it claims more than twice as many victims each year. Firearms, by far the most lethal means of self-harm, are responsible for half of these deaths, and firearm suicides account for over 60% of all firearm deaths—19,932 of 31,672 in 2010 (APA, 2013). Perceptions of the problem are further distorted by the fact that different forms of gun violence afflict different segments of the population, making agreement on a solution all the more difficult. Homicide risk is greatest for young Black men, but suicide risk is highest among older White men, among whom it is one of the leading causes of death.

As there is more than one gun violence problem and more than one population affected, so there must be more than one solution. If the objective is preventing self-harm (and intimate partner violence and accidental death along with it), encouraging safe storage may be more effective and less controversial than discouraging or banning gun ownership itself, which may require a constitutional amendment. Similarly, it is surely more feasible, and possibly more effective, to require waiting periods for gun sales than to attempt to assess purchasers' mental health status in order to keep guns out of the hands of those deemed likely to turn them on themselves. Delaying if not curtailing access to guns is itself but one facet of suicide prevention. As noted in the introduction, despite singularly high rates of firearm suicide and private firearm possession in the United States, it does not have an unusually high overall suicide rate, implying that alongside a "gun culture" that elevates risk of self-destruction are other elements of our culture, society, and institutions that suppress it. These must be identified and, where possible, fortified.

Public debate about "gun rights" versus "gun control" will not soon end, much less be resolved, but in the meantime, defining more discriminately the risks associated with private ownership of firearms and how widely but unevenly they are distributed among us may help us find common ground on ways to mitigate dangers specific to particular groups of Americans.

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