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Longitudinal Associations Between Healthcare Resources, Policy, and Firearm-Related Suicide and Homicide from 2012 to 2016



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BACKGROUND: Firearm-related violence is a leading cause of mortality in the United States (US). Prior research suggests that public policy plays a role in firearm mortality, but the role of healthcare resources (physicians, insurance coverage) within the US policy context has not yet been studied.

OBJECTIVE: To examine how healthcare resources and social/firearm policy affect firearm-related suicide and homicide rates in the US.

DESIGN: Longitudinal, ecological study.

SETTING: US.

PARTICIPANTS: US states from 2012 to 2016 ($N = 242$).

MEASUREMENT: The outcome variables were age-adjusted, firearm-related suicide and homicide rates. Predictor variables were healthcare resources (physicians, Medicaid benefits generosity) and policy context (social policy, firearm policy) with covariates for sociodemographic factors.

RESULTS: Healthcare provider variables did not have significant associations to firearm-related suicide or homicide. In fully saturated models, more worker protection laws, greater average population density, more alcohol regulation, and more firearm prohibition policies were associated with fewer firearm-related suicides. Higher generosity of Medicaid benefits was associated with fewer firearm-related homicides. Poverty rate was a predictor of both outcomes.

LIMITATIONS: This state-level study cannot make individual-level inferences. Only proxy variables were available for measuring gun ownership and actual gun ownership rates may not have been ideally captured at the state level.

CONCLUSIONS: At the state level, there are protective associations of certain social, healthcare, and firearm policies to firearm-related suicide and homicide rates. Healthcare resources play a role in population-level

firearm outcomes but alone are not sufficient to decrease firearm-related homicide or suicide.

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INTRODUCTION

Firearm-related violence is a leading cause of mortality and significant public health problem in the United States (US)¹. More than half of suicides in the US are related to firearms². Between 2003 and 2010, 82% of individuals killed by firearms in high-income countries were in the US³. Evidence suggest that policies restricting firearm access decrease suicide and homicide rates, but there remains controversy over whether firearm policy directly affects these rates, or whether they tend to be passed in communities with other policies that are more directly responsible for reduced mortality^{4–6}.

There has been research on state social and firearm policy and their impact on firearm-related public health outcomes, but these studies have not accounted for how the healthcare system may influence firearm violence within this policy context^{7,8}. The converse problem also exists. Studies have found that more healthcare resources (e.g., physicians, mental health spending) are associated with fewer suicides, but do not account for the policy context⁹. There are no recent studies examining suicide and homicide that simultaneously test the roles of healthcare factors and of firearm and social policies. There is strong evidence that the context in which people live, including available health resources, is central to predicting health outcomes. This is often referred to as *social determinants of health*, and the ecology of healthcare (i.e., providers, payers, facilities) is one such social determinant¹⁰. Studying the healthcare system context more fully in relation to firearm policy may illuminate areas for intervention.

To address this gap, we conducted a five-year, longitudinal analysis on associations between firearm policy, healthcare

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resources, and firearm-related suicide and homicide rates in the US. The purpose of the study was to examine how variables under state policy control affect firearm-related suicide and homicide rates in the US between 2012 and 2016. Our analysis builds on recent studies of these outcomes by exploring the effect of healthcare factors and social policy in addition to firearm policy²¹.

METHODS

Design

This ecological study used state-level data from 2012 to 2016. We selected this time period to capture the ACA Medicaid expansion implementation period¹¹. The Centers for Disease Control and Prevention (CDC) Social-Ecological Framework for Violence Prevention set the conceptual framework for our study, where we explored state-level effects of healthcare factors, social/community factors, and firearm policy factors¹². The study was determined to be exempt from Institutional Review Board regulation at the University of California, Los Angeles because it used publicly available, state-level data.

Data Sources and Variables

OUTCOME VARIABLES

The outcome variables for this analysis were firearm-related suicide and homicide rates. Data were obtained from the CDC Web-based Injury Statistics Query and Reporting System (WISQARS)¹³. We extracted age-adjusted fatality rates that were classified as having a violence-related intent and firearm-related mechanism for all 50 states over the five-year study period.

Predictor Variables. The main predictor variables were healthcare resources (physicians, Medicaid), social policy context, and firearm policy context. We selected two physician predictor variables that we hypothesized to have a relationship with the outcomes: primary care provider rate and psychiatrist rate (rate was defined as 1000 person-units per provider; primary care providers included family and general medicine physicians). We selected these physician types because their specialties have placed a particular emphasis on addressing firearm-related risk in policy and patient care^{14,15}. The variables were counts of employed providers in each category from the Bureau of Labor Statistics (higher values denote fewer providers)¹⁶. We also examined generosity of Medicaid benefits, based on evidence that Medicaid expansion may have increased access to primary and specialty care and thus affected our study outcomes¹⁷. Generosity of Medicaid benefits was measured as percentage of the Federal Poverty Line (FPL) that qualified a parent for Medicaid benefits based on income in each state¹⁸.

For state social policy variables, we used an alcohol regulations variable and a worker protections index variable. These variables were selected with the assumptions that inadequate worker protections may function as part of a matrix of socioeconomic deprivation that increases firearm-related risk and that substance use may increase firearm-related risk. The alcohol regulations and worker protections variables were derived from the Cato Institute Freedom in the 50 States data project, which ranks US states by policies that may affect personal and economic freedom¹⁹. The Cato Institute's "alcohol freedom" variable gives the percent contribution of a state's alcohol-related laws to degree of personal freedom. We standardized the alcohol freedom values for our analysis and conceptualized the variable in reverse, such that higher values indicate higher levels of alcohol regulation. To create a worker protections index, we counted whether or not a state's minimum wage exceeded the federal minimum wage, the presence of a short-term disability insurance program, the presence of a right-to-work law (conceptualized for this analysis as non-protective of workers²⁰), and a mean cutoff for the worker compensation mandated coverage index^{21,22}. Our worker protections index was the sum of these 4 items, with higher scores indicating more worker protections.

For state firearm policy, we used a count of firearm-related laws that we hypothesized to have a relationship with the study outcomes. The State Firearm Laws Database compiles data on state firearm policy from 1991 to 2016 on 133 firearm laws in 14 categories^{23,24}. Our analysis used count of laws by state for 2 categories that were conceptually linked to our outcomes: (1) prohibitions for high-risk gun possession related to mental illness or substance abuse and (2) prohibitions for high-risk gun possession related to history of violent crime. The first category consisted of 6 possible laws prohibiting firearm possession for mental health or substance use reasons. The second category consisted of 4 possible laws prohibiting firearm possession for felony convictions or violent misdemeanors.

Covariates. The covariates for this analysis were state sociodemographic characteristics that could influence our outcome variables, including poverty rate²⁵; hunting license rate as a partial proxy for gun ownership rate²⁶; and county-weighted state average density as a proxy for the average urbanity of the state. The hunting license rate variable is part of a proposed proxy measure of gun ownership that incorporates both hunting license rate and firearm-related suicide rate, but because firearm-related suicide rate was our outcome variable, we used only hunting license rate as a partial proxy²⁶. The density variable was derived by summing the average density for all counties in a given state, for each year: (county population / county land area) × (county population / state population).

Analysis

We used linear regression models to explore relationships between predictors and outcomes in four model stages. All models were adjusted for covariates, as well as US Census Division and year to account for secular trends and regional clustering in outcomes. We used frequencies, descriptive statistics, and heat maps to examine study variables. Our first model examined associations between healthcare factors firearm-related suicide and homicide rates, beginning with medical provider rates as predictors. Next, we added Medicaid benefits generosity to the model, followed by a third model adding alcohol regulations and the worker protections index. Finally, we added firearm policy variables. To verify the results of the fully saturated models, we estimated identical models predicting non-firearm-related suicide and homicide rates and compared the findings with those of the firearm-related outcomes.

For state-years that were missing homicide outcomes data (Hawaii, North Dakota, South Dakota, Maine, New Hampshire, Wyoming), we imputed the homicide rate using murder rate as a proxy (homicide includes murder, manslaughter, and self-defense-related homicide). For state-years that were missing data on number of physicians, we imputed missing provider counts by taking the mean of the preceding and following year. Two states (Idaho, South Dakota) were missing data on number of psychiatrists for the majority of the study period and as such we did not impute these missing values. Louisiana and Wyoming were missing data on number of psychiatrists in 2012, which were also not imputed as there was no preceding year to use. These missing items led to deletion of 8 state-years from the sample for a total sample size of 242 states. We used 0.05 as the statistical significance level and data analysis was performed using R version 3.5.1.

Role of the Funding Source

Funding for this study was provided by the UCLA Fielding School of Public Health Gun Violence Prevention Pilot Grant. The funder had no role in the design, conduct, or reporting of this study.

RESULTS

On average during the study period, there were 7.9 suicides and 3.7 homicides per 100,000 population, per year. On average, states offered Medicaid benefits to adults for those whose income was up to 94% of the FPL (SD = 46%), with highs of 215% in Minnesota in 2012 and a low of 17% in Arkansas in 2012. States had a mean of 1.34 laws prohibiting firearm possession by individuals with mental illness or substance abuse concerns (SD = 1.41), and a mean of 1.26 laws prohibiting possession related to violence concerns (SD = 1.09) (Table 1). Figure 1 shows state differences in policy variables across states during the median study year, 2014.

Table 1 Summary of Study Variables

Variable	Mean	SD	Range
Primary care provider rate (1000 patients per provider)	2.94	1.95	0.86– 20.32
Psychiatrist rate (1000 patients per provider)	17.36	11.23	2.93– 77.11
Medicaid generosity (% of FPL)	0.94	0.53	0.16–2.15
Worker protections index (0–4)	1.80	1.27	0–4.00
Alcohol regulations (z-score)	0.18	1.37	–6.01– 1.95
Firearm policy count: mental illness/ substance abuse	1.37	1.31	0–3.00
Firearm policy count: violent offenders	1.25	1.08	0–4.00
Poverty rate (%)	17.88	4.39	9.20– 33.80
Hunting license rate (licenses per 1000 population)	0.20	0.21	0–1.27
Density (per 1000 county population)	1.11	2.37	0.01– 17.22

This table provides summary statistics for analytic variables over the entire study period (2012–2016) among US states (N = 242). FPL, Federal Poverty Line. The alcohol regulations and worker index variables were derived from the Cato Institute Freedom in the 50 States dataset. The alcohol regulation variable (conceptualized by the Cato Institute as “alcohol freedom”) gives the percent contribution of a state’s overall alcohol-related laws to degree of personal freedom. This includes laws related to alcohol distribution control, off-premises sales in grocery stores, blue law index, spirits taxes, wine taxes, beer taxes, direct wine shipment bans, keg regulations or bans, happy hour bans, and mandatory server training. We standardized the alcohol freedom values for our analysis and conceptualized the variable in reverse, such that higher values indicate higher levels of alcohol regulation. The worker index variable counts whether or not a state’s minimum wage exceeded the federal minimum wage, the presence of a short-term disability insurance program, the presence of a right-to-work law (conceptualized for this analysis as non-protective of workers), and a mean cutoff for the worker compensation mandated coverage index. Our worker protections index was the sum of these four items, with higher scores indicating more worker protections

In the first model, examining the effect of medical providers on firearm-related suicide rate and accounting for state socio-demographic factors (Table 2), there was no statistically significant relationship between either primary care providers or psychiatrists and firearm-related suicide rate. Hunting license rate was positively associated with suicide rate ($P < 0.001$), and higher average county population density was associated with fewer suicides ($P < 0.001$). When generosity of Medicaid benefits was added to the model (model 2), all of the above relationships remained significantly associated with the outcome and more generous Medicaid benefits were associated with significantly decreased suicide rate ($P < 0.001$).

The next model (model 3) added the worker protections index and alcohol regulations. In this model, generosity of Medicaid benefits was no longer a significant predictor of suicide rate, although hunting license rate and density remained significant predictors in a similar direction and magnitude as the earlier models. Higher poverty rates were associated with higher firearm-related suicide rates ($P = 0.03$). Each additional worker protection law in the index was associated with a 0.43% decrease in firearm-related suicide rate ($P = 0.01$) and higher levels of alcohol regulations were associated with a decreased firearm-related suicide rate ($P < 0.001$). When the mental health-related firearm

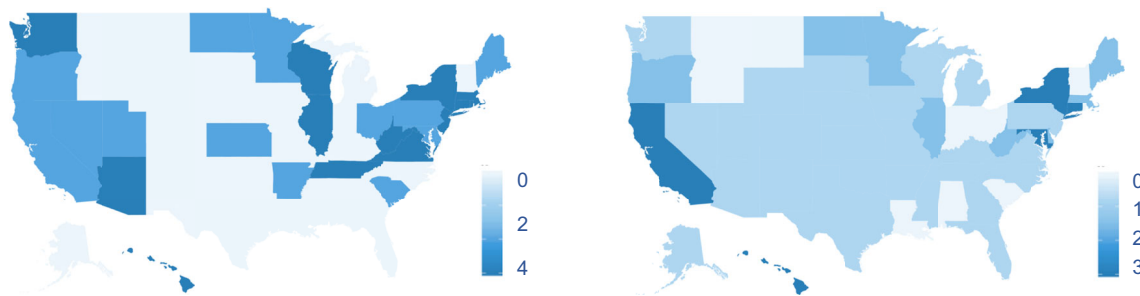


Figure 1 State variability in firearm policy variables, 2014. **a** Differences in number of mental illness- or substance abuse-related firearm prohibition policies across the US states in 2014, the median study year (range 0–6). **b** Differences in number of violence perpetration-related firearm prohibition policies across the US states in 2014 (range 0–4).

prohibition policy count was added in the final model (model 4), the relationships described in model 3 remained statistically significant. Each additional mental health-related firearm prohibition law was associated with a 0.5% decrease in firearm-related suicide rate ($P < 0.001$).

For the homicide models (Table 3), in model 1, there was a significant relationship between poverty rate and firearm-related homicide rate adjusting for sociodemographic covariates ($P < 0.001$), such that higher poverty rates were associated with higher homicide rates. Higher hunting license rate and higher density were associated with lower firearm-related homicide rate ($P = 0.04$ and $P = 0.03$, respectively). When Medicaid generosity was added in model 2, there were no statistically significant effects of Medicaid generosity on firearm-related homicide rate. In model 3, alcohol regulations and the worker protections index were added to the model. These additions resulted in hunting license rate no longer

being a significant predictor and Medicaid generosity becoming a significant predictor, such that more generous Medicaid benefits were associated with fewer firearm-related homicides ($P = 0.006$). More alcohol regulations were associated with higher firearm-related homicide rates ($P < 0.001$). In the final model (model 4) accounting for violence-related firearm prohibition policies, all of the findings from model 3 held true and the policy variable was non-significant.

We compared the fully saturated models for firearm-related suicide and homicide versus non-firearm-related suicide and homicide to verify our findings. In these models, we found that only density and alcohol regulations were predictors of non-firearm-related suicide, while poverty, hunting license rate, worker protections, and mental health-related firearm prohibition laws were additional predictors of firearm-related suicide. For non-firearm-related homicide, hunting license rate and worker protections had significant associations with the outcome, while these variables did not in the firearm-related homicide model.

Table 2 Models Predicting Firearm-Related Suicide Rate from 2012 to 2016 in the US

	Model 1 ($R^2 = 0.660$)	Model 2 ($R^2 = 0.678$)	Model 3 ($R^2 = 0.716$)	Model 4 ($R^2 = 0.742$)
	β (SE)	β (SE)	β (SE)	β (SE)
Primary care provider rate	< 0.01 (0.08)	0.01 (0.08)	-0.01 (0.07)	0.05 (0.07)
Psychiatrist rate	0.02 (0.01)	0.01 (0.01)	0.02 (0.01)	0.01 (0.01)
Poverty rate	0.05 (0.04)	0.03 (0.04)	0.08 (0.04)*	0.08 (0.04)*
Hunting license rate	0.01 (< 0.01)**	0.01 (< 0.01)**	0.01 (< 0.01)**	0.01 (< 0.01)**
Density	-0.27 (0.08)**	-0.25 (0.08)**	-0.15 (0.08)*	-0.14 (0.07)*
Medicaid generosity		-0.98 (0.28)**	-0.36 (0.30)	0.13 (0.30)
Worker index			-0.43 (0.17)*	-0.46 (0.16)**
Alcohol regulations			-0.44 (0.10)**	-0.43 (0.10)**
Mental illness prohibition laws				-0.50 (0.10)**

SE, standard error; $N = 242$. This table displays fixed effects models of state-level healthcare factors and policy factors predicting firearm-related suicide rate, excluding the District of Columbia and US territories. Models are adjusted for year and census division. *Value is significant at the 0.05 level. **Value is significant at the 0.01 level

CONCLUSIONS

This state-level analysis of healthcare and policy predictors of firearm-related suicide and homicide during the ACA implementation period found that social and firearm policy play an important role in firearm-related public health outcomes, with a less pronounced role for healthcare resources. These findings align with prior research on firearm policy and injury mortality. Even with substantial controls for covarying policy variables, laws restricting gun access for those with mental health problems were associated with significantly fewer suicides. Many policy variables in our analysis had no relationship to non-firearm-related suicide, suggesting that firearm availability plays a role in the pathway between protective social policy and suicide outcomes. Prior studies have found an association between higher public expenditures and lower suicide rates, as well as a protective effect of firearm policy on suicide rates^{5,27}. The current analysis lends additional support to these findings.

In contrast to policy variables, the physician variables were not associated with suicide or homicide rates at the state level in the fully adjusted models. These results

Table 3 Models Predicting Firearm-Related Homicide Rate from 2012 to 2016 in the US

	Model 1 ($R^2 = 0.609$)	Model 2 ($R^2 = 0.612$)	Model 3 ($R^2 = 0.642$)	Model 4 ($R^2 = 0.642$)
	β (SE)	β (SE)	β (SE)	β (SE)
Primary care provider rate	-0.06 (0.05)	-0.06 (0.05)	-0.05 (0.05)	-0.05 (0.05)
Psychiatrist rate	0.02 (0.01)	0.02 (0.01)	-0.01 (0.01)	0.01 (0.01)
Poverty rate	0.11 (0.03)**	0.10 (0.03)**	0.07 (0.03)**	0.07 (0.03)*
Hunting license rate	-<0.01 (<0.01)*	-<0.01 (<0.01)*	-<0.01 (<0.01)	-<0.01 (<0.01)
Density	-0.12 (0.06)*	-0.12 (0.06)*	-0.17 (0.06)**	-0.16 (0.06)**
Medicaid generosity		-0.28 (0.20)	-0.60 (0.22)**	-0.58 (0.23)*
Alcohol regulations			0.28 (0.08)**	0.28 (0.08)**
Worker index			0.18 (0.13)	0.18 (0.13)
Violent crime prohibition laws				-0.04 (0.18)

SE, standard error; N=242. This table displays fixed effects models of state-level healthcare factors and policy factors predicting firearm-related homicide rate, excluding the District of Columbia and US territories. Models are adjusted for year and census division. *Value is significant at the 0.05 level. **Value is significant at the 0.01 level

suggest that cross-sectional studies testing the relationship of healthcare provider variables may not be valid in the absence of strong controls for other, unrelated but covarying policies. Higher state average density was associated with fewer suicides and homicides in these models, a result that is consistent with public perceptions of dense, walkable neighborhoods being safer^{28,29}. The relationship of higher population density to fewer suicides may also reflect the contributions of social isolation and loneliness to poor mental health and suicidality^{30,31}.

Fewer policy variables were associated with homicide, with more alcohol regulations associated with higher firearm-related homicide rates (i.e., the opposite direction from what was expected) and more generous Medicaid benefits associated with lower firearm-related homicide rates. In the homicide models, Medicaid was statistically significant in fully saturated models while the opposite occurred in suicide models; Medicaid was initially significant, but became non-significant at full saturation. These divergent findings may be related to different mechanisms for how suicide and homicide occur at a population level and the role health services can play in preventing mortality. Health insurance coverage via Medicaid may play a role in help-seeking and receipt of appropriate treatment services—both emergency care and follow-up or long-term care—in cases of gunshot wounds, and uninsured individuals are more likely to die of gunshot wounds than their insured counterparts³². By comparison, suicides may be more likely to occur in isolation and result in mortality before help can be sought (i.e., higher lethality), which could explain the opposite findings in our final models and why there was no similar association of Medicaid generosity to firearm-related suicide rates³³. However, prior research has found that insurance coverage is protective against suicide and more research is needed to clarify these relationships, including the positive relationship found between alcohol regulations and homicide (which may be due to omitted variables bias)³⁴.

Higher poverty rate was a significant predictor of higher suicide and homicide rates in the final models, a finding that is well established in the literature^{35–37}. Economic deprivation

is associated with homicide at the individual level, and there is a matrix of other socioeconomic factors that also predict homicide among individuals (e.g., social inequality, unemployment, segregation)³⁶. Likewise, socioeconomic deprivation is associated with suicide³⁷. Poverty was a significant predictor of suicide only in models that accounted for the policy context, suggesting that policy variable omitted in the early models are important for understanding this relationship. Our analysis contributes to an ecological and macro-social understanding of the criminogenic and suicidogenic effects of poverty. It suggests that despite some indication that healthcare resources may play a role in population-level injury outcomes (i.e., Medicaid generosity), alone healthcare resources are not sufficient to disrupt the matrix of socioeconomic deprivation and policy factors associated with homicide or suicide.

Hunting license rate as a partial proxy for gun ownership was associated with more firearm-related suicides at the state level. These findings are consistent with recent studies finding an association between increased access and higher risk for suicide³⁸. Strong evidence suggests that firearm ownership, availability, accessibility, and familiarity increase risk for suicide—including among safe, legal, and responsible firearm owners^{38–40}. Suicidality is often an acute rather than chronic mental state, but suicide completion becomes more likely when lethal attempt methods, such as firearms, are freely available during a suicidal crisis. Our non-significant findings around hunting license rate and firearm-related homicide rate are inconsistent with prior studies finding a positive association between gun ownership and homicide at the state level^{41–44}. It is possible that our divergent findings are driven by our use of a partial proxy measure of gun ownership.

There are strengths and limitations to this study. Our analysis uses recent, longitudinal data and builds on prior work on firearm violence as a public health problem by accounting for healthcare resources and social policies in addition to firearm policy. The limitations are that our gun ownership variable was a proxy measure and may not have ideally captured actual gun ownership at the state level. Some of the variables used to operationalize concepts of healthcare resources and social

policy (e.g., Medicaid expansion, worker protections, alcohol index) have not been previously validated for use at the state level, although there is supporting evidence for our conceptualization at the individual level. We studied a relatively narrow range of firearm policies that are conceptually related to our outcome variables, but these policies may not fully capture the firearm policy context as other types of firearm laws may work synergistically.

While healthcare resources such as insurance coverage play a partial role in firearm-related outcomes at the state level, these associations are confounded by other social and firearm policies. We find continued evidence of a strong relationship of gun ownership to firearm-related suicide, and a beneficial association of laws reducing access to firearms for those with known mental health problems. These protective policy associations were not observed for homicide at the state level. Future research should further explore the role of medical providers and healthcare system factors in predicting firearm violence in communities, both at the individual and population level.

Disclaimer: The contents of this article do not represent the views of the US Department of Veterans Affairs or the US Government.

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