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Effects of Wisconsin's handgun waiting period repeal on suicide rates

Stephen N Oliphant

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/ip-2022-044719).

School of Criminal Justice, Michigan State University College of Social Science, East Lansing, Michigan, USA

Correspondence to
Stephen N Oliphant, School of Criminal Justice, Michigan State University College of Social Science, East Lansing, MI 48824, USA; olipha13@msu.edu

Received 28 July 2022
Accepted 5 August 2022
Published Online First 2 September 2022

To cite: Oliphant SN. *Inj Prev* 2022;**28**:580–584.

ABSTRACT

Objective To estimate the effect of a handgun purchase waiting period repeal on handgun and firearm suicides in Wisconsin.

Methods Data for outcome and predictor variables were obtained for the 1999–2020 study period. Synthetic controls were used to assess the impact of Wisconsin's waiting period repeal on mean-centred suicide rates. Placebo tests, difference-in-differences regression and augmented synthetic controls supplemented the synthetic control analyses.

Results Postrepeal suicides were more likely to involve handguns than those in the 5 years immediately preceding the repeal (χ^2 (1, N=8269) = 49.25, p<0.001). The waiting period repeal resulted in an estimated annual increase of 1.1 handgun suicides per 100 000, or roughly 65 handgun suicide deaths per year. Estimates from difference-in-differences regression and augmented synthetic control analyses indicated similar treatment effects. Relative to the synthetic control, firearm suicides increased 6.5% following the repeal.

Conclusion The waiting period repeal in Wisconsin was associated with increases in both handgun and firearm suicides. The findings suggest that waiting periods may be effective means restriction policies to reduce suicide. Additionally, the synthetic control's ability to closely approximate preintervention handgun suicide trends despite a limited donor pool has implications for future policy analyses.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Prior studies have found that waiting periods are associated with modest reductions in firearm suicides.

⇒ No study has examined the impact of a single-state waiting period policy change on handgun and firearm suicide rates.

WHAT THIS STUDY ADDS

⇒ The findings suggest that repealing a handgun-specific waiting period led to increased handgun and firearm suicide rates and resulted in a greater proportion of overall suicides attributable to handgun discharge injury.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Universal means restriction strategies, such as waiting periods, that do not rely on identifying high-risk individuals during acute suicidal crises may complement other suicide prevention efforts.

⇒ Future research examining the impact of state-level policy changes may benefit from using synthetic control estimation despite limited donor pools.

INTRODUCTION

Firearm suicide is a leading cause of injury death for nearly every age group in the USA.[1] Although preventable, suicide is a difficult public health problem to address due to the complexity of identifying high-risk individuals and accessing them when they are at greatest risk of attempting suicide.[2] Coupled with the elevated lethality of firearms relative to other suicide methods,[3] the availability of firearms poses an additional challenge to suicide prevention.[4]

In 2020, a firearm was used in over half of all suicides.[5] Although it is unclear what proportion of firearms used in suicides are newly acquired, the convenience with which firearms can be purchased may contribute to impulsive suicides. The National Instant Criminal Background Check System's immediate determination rate of nearly 90%[6] suggests that most firearm purchases from licensed dealers can be completed within minutes.

Given that suicide attempts can be preceded by hours or less of planning,[7] policies that delay firearm transfers may limit the capacity of prospective buyers experiencing transient suicidal ideation to commit suicide. States that implemented a 5-day handgun purchase waiting period alongside background check requirements experienced a significant decrease (−6%) in the firearm suicide rate among older individuals.[8] Edwards *et al*[9] noted a similar reduction (up to a 5% decrease in firearm suicides) for mandated purchase delays, while Luca *et al*[10] found that firearm purchase waiting periods were associated with a 7%–11% reduction in firearm suicides. A recent report by the RAND Corporation synthesising existing research concluded that there is 'moderate evidence that waiting periods may reduce firearm suicides.[11] Forty-four states had a firearm purchase waiting period at some point between 1970 and 2014 (19 of which were created in 1994 as part of the Brady Handgun Violence Prevention Act),[10] but only 9 states mandate such purchase delays in 2022.[11]

In 2015, Wisconsin repealed its 48-hour handgun purchase waiting period. As a result, handgun purchases from licensed firearm dealers could proceed without delay following a cleared background check. Dunton *et al*[12] found that the repeal was associated with increased firearm-related suicide among urban county residents and people of colour; however, the study did not control for

potential confounders and was limited to 3-year windows before and after the repeal.

To add to the limited research on waiting periods, this study uses a synthetic control approach to estimate the effect of Wisconsin's handgun waiting period repeal on handgun and firearm suicide rates.

METHODS

Measures

Mortality data for the 1999–2020 study period were obtained from the Centers for Disease Control and Prevention (CDC) WONDER database.[13] Two outcome variables were included in the analysis: handgun suicide (International Classification of Disease, Tenth Revision (ICD-10) code X72) and firearm suicide (X72–74). Following the approach used by Kagawa *et al*[14] when preintervention outcomes of the treated unit are larger than those of the donor units, suicide rates were centred around their preintervention means.

The following predictor variables were used in the study based on theoretical relevance[15] and/or utility in constructing counterfactual suicide trends in other studies[14 16 17]: state population, population density, the proportion of a state's population residing in metropolitan statistical areas, the proportions of each state's population that identify as Black and as white, unemployment rate, mean individual income, poverty rate, the ratio of firearm suicides to all suicides, per capita ethanol consumption, educational attainment and at least one lagged measure of the outcome in the preintervention period. Predictor variable data were obtained from CDC WONDER, the US Census Bureau (including the Current Population Survey and the American Community Survey), the Federal Bureau of Investigation's Uniform Crime Reporting Programme, the National Institute on Alcohol Abuse and Alcoholism, the Bureau of Economic Analysis and the Bureau of Labor Statistics (see online supplemental table 1 for an overview of variables and data sources).

Analysis

Synthetic controls were used to estimate the effect of the waiting period repeal on suicide rates. Rather than using a single state as a control, the synthetic control method (SCM) uses a weighted combination of untreated comparison states to model a counterfactual outcome. Seven states had waiting period laws that applied to handgun purchases for the entire study period. Given that Iowa's permit application process for first-time handgun purchasers mandated a 3-day delay prior to 2021, Iowa was also included as a purchase delay donor state. The firearm suicide donor pool includes eight states: California, Hawaii, Illinois, Iowa, Maryland, Minnesota, New Jersey and Rhode Island. Suppressed values of handgun suicide deaths for many or all study years limited the handgun suicide synthetic control donor pool to four states, namely—California, Illinois, Iowa and Minnesota. Wisconsin's waiting period was repealed in June 2015 and the postintervention treatment period was operationalised as 2015–2020.

There are two primary components in synthetic control construction: W, which captures the relative importance of each unit, and V, which measures the relative importance of each predictor.[18] The optimised vector W^* minimises the distance between preintervention characteristics of the treated and synthetic control units and is dependent on V—a matrix of weights representing each covariate's predictive ability. The optimal set of predictor variable weights is that which minimises the mean squared prediction error (MSPE) over the preintervention period (see online supplemental table 2). Having established similar preintervention characteristics and trends, the difference in outcomes between the treated and synthetic control units following the intervention is interpreted as the treatment effect.[19] The effect of Wisconsin's waiting period repeal was estimated using the following equation:

$$\hat{\alpha}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt}$$

where Y_{1t} is the outcome in Wisconsin, $J+1$ represents the donor pool, w_j^* is the optimised vector of weights and Y_{jt} represents the outcome of unit j at time t.[20]

Commonly used placebo tests (eg, 'in-place' placebos, 'in-time' placebos, 'leave-one-out' tests) were performed to assess the robustness of estimated effects. The Synth[21] and SCtools[22] packages were used to construct synthetic controls and conduct placebo tests. The augsynth[23] package was used to construct augmented synthetic controls as part of a secondary analysis. The augmented SCM (ASCM) is an extension of SCM that uses ridge regression and negative donor weights to reduce bias in SCM estimates.[23] All statistical analyses were conducted using R V.4.2.1.

RESULTS

Handgun suicide

Synthetic Wisconsin (MSPE=0.04), composed of Minnesota (weight=0.546), Iowa (0.243) and Illinois (0.21), closely approximates preintervention handgun suicide trends in Wisconsin (figure 1). Preintervention mean characteristics of Wisconsin and its synthetic control are appropriately similar across all predictor variables (table 1). The handgun purchase waiting period repeal resulted in an estimated increase of 1.14 deaths per 100 000, which translates to 66 additional handgun suicides per year or a 30.3% increase relative to Synthetic Wisconsin (see online supplemental table 3).

Synthetic controls were constructed for each donor pool state to model counterfactual handgun suicide trends and placebo effects. The postintervention deviation in demeaned handgun suicide rates is substantially larger in Wisconsin following the waiting period repeal than in any of the control states following a placebo intervention (figure 1). In place of traditional significance tests, the post-MPSE/pre-MSPE ratios of Wisconsin and donor states were compared. Wisconsin's postintervention/preintervention MSPE ratio of 33.9 is 12 times larger than that of any donor state. Therefore, the probability of obtaining an effect at least as large as that in Wisconsin on random assignment of the intervention to one of the five states is 1/5, or 0.2.

'Leave-one-out' robustness tests, in which a different donor state is excluded from each synthetic control, were used to assess the robustness of results to donor pool modifications.[24] Given that Iowa's purchase delay was a byproduct of its permit requirement (and not simply a waiting period), it was important to determine whether the estimated treatment effect was robust to its exclusion. Consistent with the original estimate of 1.14 deaths per 100 000, treatment effects using leave-one-out synthetic controls range from 1.15 to 1.19—demonstrating that the estimated effect is not driven by the weight of a single donor state (see online supplemental table 4). Similarly, an 'in-time' placebo test involving an artificially backdated repeal date did not lead to substantively different results (see online supplemental figure 1).

A supplementary difference-in-differences regression using Minnesota's parallel handgun suicide rate trend as a control (see online supplemental figure 2), several relevant covariates (obtained through 2019), and SEs clustered at the state level

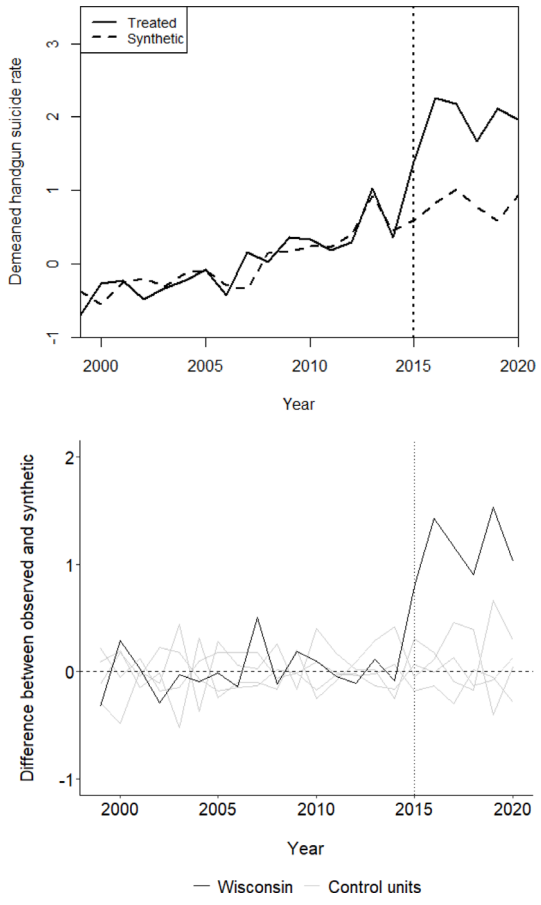

Figure 1 Demeaned handgun suicide rates in Wisconsin and Synthetic Wisconsin over the 1999–2020 study period (top); gaps in the observed and synthetic rates of Wisconsin and placebo states (bottom).

Table 1 Mean preintervention (1999–2014) characteristics of Wisconsin, its synthetic controls and the donor pool used to construct counterfactual handgun and firearm suicide rates

Variable	Wisconsin	Synthetic WI	Sample mean
Handgun suicide analysis			
Population	5 575 741	6 225 240	14 264 826
Population density	102.953	96.617	144.857
Proportion of population MSA	0.716	0.715	0.78
Proportion Black	0.066	0.068	0.078
Proportion white	0.9	0.886	0.851
Unemployment rate	5.624	5.202	5.951
Poverty rate	10.469	9.658	11.191
Mean individual income	36 406.56	38 778.17	38 989.44
Educational attainment	89.088	90.271	87.303
Ethanol consumption	2.375	1.943	1.879
Ratio of FS:S	0.479	0.462	0.444
2014 demeaned HS rate	0.364	0.449	0.226
Firearm suicide analysis			
Population	5 575 741	3 610 668	9 216 740
Population density	102.953	284.37	445.722
Proportion of population MSA	0.716	0.735	0.848
Proportion Black	0.066	0.051	0.108
Proportion white	0.9	0.907	0.75
Unemployment rate	5.624	5.254	5.864
Poverty rate	10.469	9.619	10.578
Mean individual income	36 406.56	38 376.52	40 724.31
Educational attainment	89.088	89.264	87.065
Ethanol consumption	2.375	1.966	1.899
Ratio of FS:S	0.479	0.431	0.375
2014 demeaned FS rate	0.136	0.249	0.194

Abbreviations: WI, Wisconsin; MSA, metropolitan statistical area; FS, firearm suicide; S, suicide; HS, handgun suicide.

estimated a similar treatment effect (0.95 deaths per 100,000, p=0.03). Notably, suicides in Wisconsin between 2015 and 2019 were more likely to involve handguns than those in 2010–2014 (χ^2 (1, N=8269) = 49.25, p<0.001). The share of overall suicide deaths identified as having been caused by handgun discharge rose from 26.0% in 2010–2014 to 32.4% after the repeal, whereas no donor state recorded an increase of more than 1.3 percentage points.

Firearm suicide

As shown in figure 2, Synthetic Wisconsin (MSPE=0.07) closely approximates firearm suicide trends in Wisconsin. The waiting period repeal resulted in an estimated treatment effect of 0.45 per 100,000, which translates to 26 additional firearm suicide deaths per year and a 6.5% increase in the firearm suicide rate. Using a restricted permutation distribution of states with preintervention MSPEs less than five times that of Wisconsin, the probability of obtaining an effect at least as large as that in Wisconsin on random assignment of the intervention to one of the eight states is 3/8 or 0.375. An artificially backdated repeal resulted in a poorer approximation by the synthetic counterfactual from 2010 to 2014 and a larger estimated increase in firearm suicides starting in 2015. Consistent with the original estimate of 0.45 per 100 000, estimates from leave-one-out robustness tests range from 0.36 to 0.65 (see online supplemental table 5).

Augmented synthetic control results

Augmented synthetic control models closely track handgun suicide (MSPE=0.046) and firearm suicide (MSPE=0.075) trends prior to the waiting period repeal (figure 3). Donor weights and comparisons of preintervention characteristics using ASCM are presented in online supplemental figure 3 and table 6. Estimates generated from ASCM models with jackknife standard errors are nearly identical to those discussed above. The estimated effect of the repeal on handgun suicide rates is 1.10 per 100 000 (95% CI 0.66 to 1.55), which corresponds to a 29.0% increase. The estimated effect of the repeal on firearm suicide rates is 0.49 per 100 000 (95% CI 0.19 to 0.79) or a 7.0% increase.

DISCUSSION

Waiting periods are hypothesised to reduce impulsive suicides by delaying the possession of purchased firearms. This is the first study to use synthetic controls to estimate the impact of a waiting period policy change on suicide rates. Allowing more immediate transfers of handguns from licensed firearm dealers led to a substantial increase in the handgun suicide rate in Wisconsin relative to its synthetic control. Moreover, suicides in 2015–2019 were significantly more likely to involve handguns than those that occurred in the 5 years preceding the repeal. Consistent with prior research examining waiting periods,[8–11] the estimated 7% increase in firearm suicides following the repeal of a handgun waiting period suggests that firearm purchase delays are an effective form of temporary lethal means restriction to reduce suicide.

Two explanations may account for the findings described above. First, the waiting period repeal eliminated a potentially important barrier to practical capacity[25]; individuals who

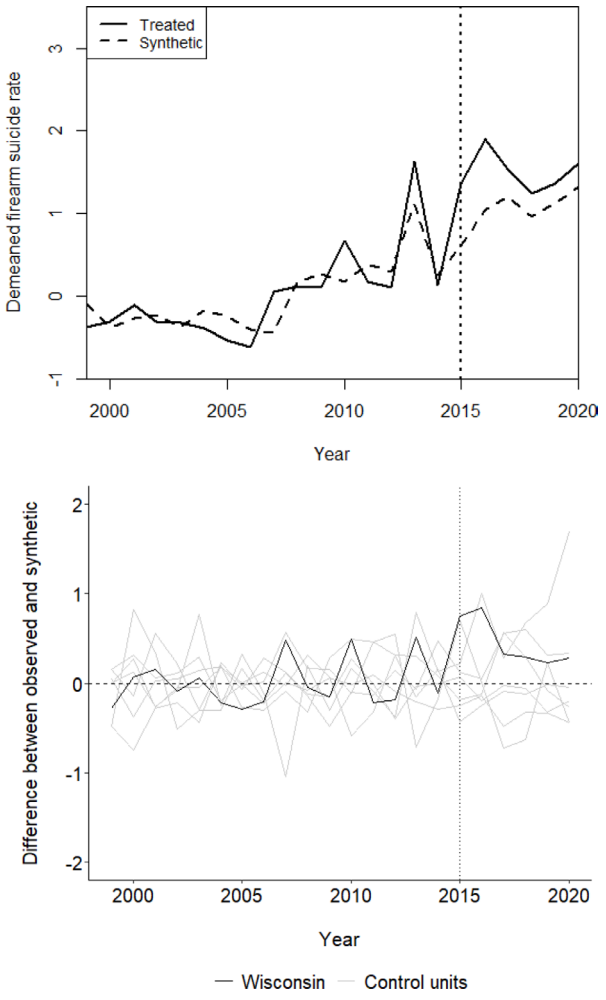

Figure 2 Demeaned firearm suicide rates in Wisconsin and Synthetic Wisconsin over the 1999–2020 study period (top); gaps in the observed and synthetic rates of Wisconsin and placebo states (bottom).

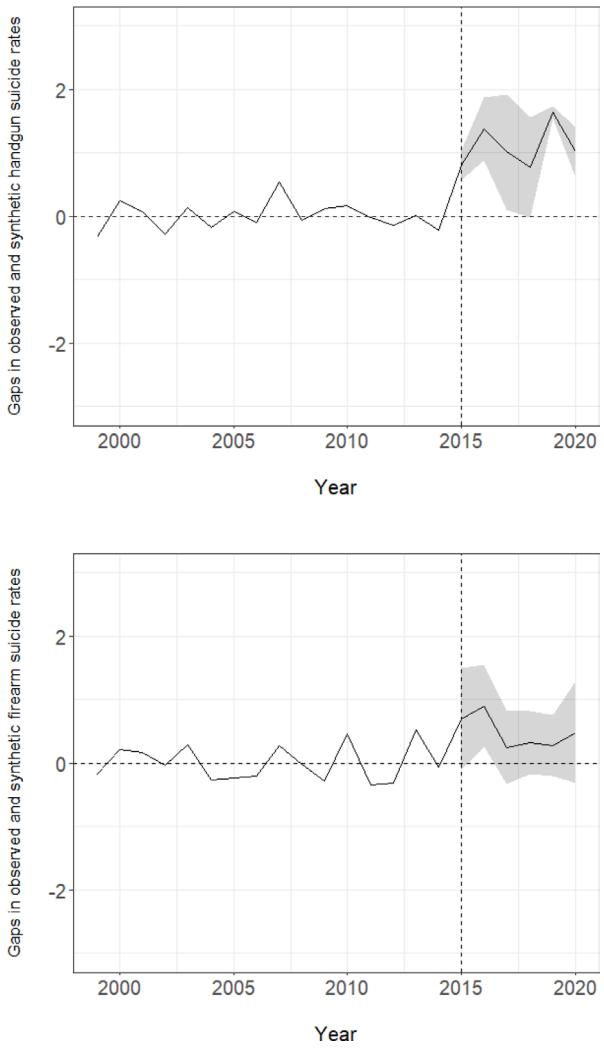

Figure 3 Estimated effects of Wisconsin's handgun purchase waiting period repeal on handgun suicide rates (top) and firearm suicide rates (bottom) using augmented synthetic controls.

were suicidal but would not have attempted another form of suicide were instead able to purchase a handgun during a crisis without delay. Second, suicidal individuals who may have otherwise resorted to less lethal methods were able to access more lethal means which previously required a 48-hour delay. Either scenario represents an outcome that means restriction is expressly intended to prevent.

As conceptualised in Barber and Miller,[26] restricting access to lethal means leads to (1) temporary or permanent delays in attempts or (2) substitution to less lethal methods. In either case, fewer fatal attempts occur due to the inaccessibility of lethal means during an acute suicidal crisis. Means restriction approaches such as waiting periods thus hinder the progression from strong suicidal ideation to attempt by limiting the practical capacity to commit suicide.[25] Regardless of the extent to which the handgun purchase waiting period prevented method-specific attempts or the use of more lethal means to attempt suicide, the findings suggest that the increases in handgun and firearm suicide deaths were preventable had the policy remained in effect.

The findings also add to the supportive evidence of universal prevention strategies. A substantial challenge to preventing suicide is identifying and accessing individuals when they are at greatest risk of attempting suicide.[2] The impulsive nature of some attempts leaves few opportunities for targeted intervention. Universal prevention strategies at the societal level that do not rely on identifying high-risk individuals during acute crises (eg, delaying firearm transfers) can complement selective or indicated interventions[27] at the individual level (eg, lethal means counselling).

A primary strength of this study, which has implications for future policy analyses, is the efficacy of the synthetic control approach despite a limited donor pool. Namely, the close approximation of preintervention handgun suicide trends by Synthetic Wisconsin suggests that synthetic controls can be constructed with substantially restricted donor pools under advantageous conditions (eg, similar sociodemographic measures and comparable outcome trends). All three states comprising the handgun suicide synthetic control border Wisconsin and exhibited similar preintervention suicide trends.

Limitations

Despite the methodological strengths of the study, the findings are not without important limitations. Most notably, the handgun suicide analysis involves only the subset of overall handgun suicides that were assigned ICD-10 code X72. Although 94% of firearm suicides in Wisconsin from 1999 to 2019 were classified specifically as handgun (X72) or long gun (X73) suicides, 54% and 76% of firearm suicides in Minnesota and Illinois, respectively, were coded as suicide 'by other and unspecified firearm discharge' (X74). To an extent, the threat posed by the lack of

specificity in firearm type in donor states was mitigated by the mean-centring transformation of handgun and non-handgun suicide rates. Differential classification of firearm suicides over space and time could introduce bias; however, handgun suicide rates were mean-centred and exhibited highly similar trends throughout the preintervention period.

Second, as with any analysis, the omission of important covariate measures or confounders could also bias estimates. Several relevant covariate measures, which have been used in other firearm suicide analyses,[14 16 17] were included in the study. Additionally, no other firearm policy changes occurred in Wisconsin around 2015.[28] Lastly, as outlined in a recent report by the RAND Corporation,[29] the generalisability and statistical significance of synthetic control analyses assessing single-state policy changes is uncertain. More research is needed to fully assess the effect of waiting period repeals on suicide rates.

CONCLUSION

Waiting periods may be an effective form of means restriction to reduce suicide. This study adds to the limited research on firearm purchase delays by using synthetic controls to estimate the causal effect of a waiting period repeal. Repealing the waiting period requirement in Wisconsin, thereby allowing more immediate possession of handguns, resulted in estimated increases in handgun suicide and overall firearm suicide. Future research should explore firearm purchasing behaviour and examine the impact of purchase delays at the individual level.

Acknowledgements I wish to thank the reviewers at the Society for Advancement of Violence and Injury Research conference for their helpful feedback on a previous version of the manuscript.

Contributors SNO confirms sole responsibility for the study conception and design, data collection, analysis and interpretation of results, and manuscript preparation. SNO is responsible for the overall content as guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data used in this study are publicly available from the sources listed in the supplemental file, mentioned in the text, and included here: CDC WONDER, the US Census Bureau (including the Current Population Survey and the American Community Survey), the Federal Bureau of Investigation's Uniform Crime Reporting Program, the National Institute on Alcohol Abuse and Alcoholism, the Bureau of Economic Analysis, and the Bureau of Labor Statistics.

ORCID iD

Stephen N Oliphant http://orcid.org/0000-0002-5235-173X

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