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Title: Examining the policy impact of Arizona's 2016 preemption law on firearm suicide rates in the greater Tucson area: An observational study

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ABSTRACT

Objectives: A suicide epidemic takes the lives of almost 50,000 Americans every year, with higher-than-average suicide rates occurring in the Mountain states. In 2016, the state of Arizona enacted SB 1487 to nullify Tucson's ordinance permitting the municipality to destroy confiscated and forfeited firearms, instead requiring the firearms to be resold to the public through a local auctioneer. Our objective was to examine whether firearm suicide rates increased in Pima County (greater Tucson area) relative to other Arizona counties following the enactment of Arizona's 2016 preemption law.

Design: Time-series cross-sectional analysis of a natural policy experiment. A difference-in-differences approach estimated the effect of Arizona enacting SB 1487 as a widening/narrowing of the gap in firearm suicide rates in Pima County compared to other counties from the pre-policy-enactment period to the post-policy-enactment period.

Setting: 9 Arizona counties from 2014-2019

Participants: A policy group was constructed using Pima County (Tucson-area) observations. A comparison group was constructed using data from 8 other Arizona counties. 54 county-year observations were analyzed.

Intervention: The 2016 enactment of SB 1487 which preempted Tucson law, allowing firearms that were seized/surrendered to law enforcement to be recirculated instead of destroyed.

Outcomes and Measures: Annual rates of firearm and non-firearm suicides per 100,000 persons extracted from the CDC WONDER system.

Results: A 1.126 increase in Pima County's firearm suicide rate per 100,000 persons was attributable to the enactment of Arizona's 2016 preemption law, relative to comparison group counties over the same period (P=0.003; 95% CI 0.522, 1.731). The preemption law did not affect non-firearm suicide rates in Pima County.

Conclusions: As fewer firearms were destroyed and more firearms would have reentered the greater Tucson area through 2019, SB 1487 led to higher firearm suicide rates in Pima County relative to other counties not targeted by the new law.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study examining the health-related implications of Arizona's 2016 local firearm preemption law.
- This study is the first to empirically show that state preemption of local firearm laws affects health-related outcomes, in this case firearm-related suicide, which is important because other states have passed preemptive laws designed to undermine local authority over firearm safety.
- This study compares both firearm and non-firearm suicide outcomes at the county level.
- In this and other studies of firearm suicide in the United States, data limitations preclude knowing the actual number of firearms in a community.

INTRODUCTION

The US is in the midst of a suicide epidemic taking the lives of almost 50,000 Americans every year, with high burden typically concentrated in the Mountain states.(1) Firearms are the most common method of suicide in the US,(1) and although suicide is a multifaceted public health problem with simultaneous biological, psychological, social, and environment contributors, access to firearms exacerbates suicide risk for suicidal persons.(2,3) Many people who attempt suicide will survive,(4) though survival is typically less likely for those who use firearms, given the 80-90% case-fatality rate of the firearm method. (5,6) Internationally, the US firearm suicide rate is 8 times higher than the average firearm suicide rate of 22 other high-income, developed countries, even though the total suicide rate for the United States is similar to that of other countries.(7) In the Mountain states (i.e. Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming) specifically, firearm suicide rates increased 30.4% from 2005-2019 and are consistently among the top ten in the US.(1)

Federal firearm safety and control reforms are controversial and difficult to enact and enforce, making state governments responsible for most firearm policymaking.(8) Frequently in the US, policies are enacted to curb homicide after incidents of highly-publicized mass shootings, even though most firearm mortality is attributable to suicide.(1,9) Even so, these policy changes often have implications for firearm suicide through the mechanism of supply or access restriction.(2,3,8) There is evidence demonstrating that stricter firearm safety laws enacted at the state level, such as child access prevention laws(10) and risk-based, time-limited civil protection orders for firearm removal(11) can reduce the rate of firearm suicide. However, these policies are enacted inconsistently from state to state, leaving many firearm-related issues unaddressed and motivating municipalities to enact firearm policies consistent with dangers or

concerns specific to their citizens. The issue has caused controversy between state and local governments, including in Richmond, Virginia, where a state preemption law prevented the banning of firearms at a white supremacist rally but allowed banning of less lethal weapons (e.g., knives).(12,13)

Tensions between Arizona's state government and local legislators in Tucson have been particularly problematic for firearm policymaking.(14) Absent action from state legislators, local policymakers in the city of Tucson passed an ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed, resulting in the elimination of over 4,800 firearms in Pima County during the years included in this study.(14) However, in 2016, the Arizona legislature enacted SB 1487 to preempt Tucson's ordinance. Upheld by the Arizona Supreme Court, SB 1487 forced Tucson to stop the destruction of confiscated firearms and resell the firearms to the public by auction, or else face an annual financial penalty of $115 million.(15)

For these reasons, SB 1487 disrupted the number of firearms in Tucson in two ways: First, by no longer allowing Tucson police to actively accept firearms through buyback programs or firearms voluntarily turned in by citizens for the purpose of destroying those firearms, and second, by requiring Tucson to resell all confiscated or forfeited firearms through a local auctioneer. Nearly 600 firearms were resold by the city of Tucson auctions in just one five-month period in 2017,(16) and many firearms likely reentered Tucson and surrounding communities through 2019. The legal implications of SB 1487 have been discussed elsewhere,(17) such as conceding to states over firearm-related policymaking, restricting local efforts to enact public safety interventions, and imposing one of the most punitive fiscal measures known to be applied to local government in the US. However, less is understood about the health-related implications of Arizona's 2016 preemption law, specifically how it may have

affected firearm suicide rates in the greater Tucson area. This exogenous instance of local policy preemption and deactivation affected the Tucson (Pima County) area relative to other counties in Arizona and motivated ideal conditions for a natural experiment.(18)

The objective of our study was therefore to examine whether firearm suicide rates increased in Pima County relative to other Arizona counties following the enactment of Arizona's 2016 preemption law. Given the systematic link between firearm availability and suicide, and considering the availability of same-day firearm purchasing in Arizona,(19) we hypothesized that firearm suicide rates (but not *non*-firearm suicide rates) would increase in Pima County following the enactment of SB 1487, including the restriction on local firearm destruction and likely introduction of a new supply of firearms in Tucson-area communities.

METHODS

Data & Study Design

Our primary data source was the Centers for Disease Control and Prevention (CDC) WONDER system, an interactive database that compiles information on the underlying causes of death in the US. Data from the Bureau of Labor Statistics (BLS) Local Area Unemployment statistics program and Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Federal Firearms Licensees database were also used. CDC data restrictions prevent the analysis of county-level suicide rates involving less than 10 decedents. For this reason, counties with restricted data were excluded from the analysis. This included the 6 least-populated counties (with also the lowest firearm suicide counts) in Arizona. The remaining counties represented 93.4% of the state population in 2019 (data not shown).

We conducted a time-series cross-sectional analysis taking advantage of a natural policy experiment. The final analytic sample included 54 county-year observations including 6 observations for each of 9 counties from 2014 to 2019, permitting multiple years of data both before and after the preemption law was enacted.

Dependent variables

We examined two dependent variables extracted from the CDC WONDER system. Our primary dependent variable was a measure of the annual rate of firearm suicides (ICD-10 codes X72–X74) per 100,000 persons (all ages). Because the 2016 preemption law should not have affected non-firearm suicide rates in Pima County, we also examined a second dependent variable measuring the annual rate of non-firearm suicides per 100,000 persons (all ages) as a robustness test.

Independent variables

There were two independent policy variables. The first variable was an indicator of being affected by Arizona's preemption law – SB 1487 – enacted in 2016. Arizona enacted the 2016 preemption law to nullify Tucson's ordinance allowing the Tucson Police Department to destroy unclaimed and forfeited firearms, instead making the firearms available in the community through resale. The variable equaled 1 for Pima County (Tucson-area) observations (policy group) and 0 for all other county observations (comparison group).

The second variable was a measure of policy enactment timing equal to 1 for observations after the 2016 law was enacted, and equal to 0 for observations prior to 2016.

Covariates

Our fully-adjusted multivariate statistical models included a vector of covariates to absorb residual variance in the outcomes and adjust for potential confounding factors. Population demographic covariates included county-level measures of age (% of population <25yo), gender (% of population male), and race (% of population white) in each county-year. BLS data were used to adjust for differences in county-level unemployment rates, a proxy for socioeconomic status differences shown to be correlated with suicide risk.(20) ATF data were used to construct a county-level proxy measure of firearm ownership, as firearm availability is associated with suicide.(2) The variable adjusted for the per capita rate of Category 1 and Category 2 federal firearm licenses in each county-year, which may be the most suitable proxy for county-level analyses.(21)

Analysis

We used a standard difference-in-differences (DID) estimation approach to examine the effect of Arizona enacting SB 1487 as a widening or narrowing of the gap in suicide rates in Pima County compared to 8 other Arizona counties from the pre-policy-enactment period to the post-policy-enactment period. The pre-policy-enactment reference period was the average of outcomes from 2014 until 2016. We estimated four models using the following general regression approach:

$$Y_{ct} = \beta_0 + \beta_1 Policy\ Group + \beta_2 Post\text{-}Law\ Enactment\ Period + \beta_3 (Policy\ Group \times Post\text{-}Law\ Enactment\ Period) + \mathbf{B}Z_{ct} + \varepsilon_{ct} \quad (1)$$

where Y_{ct} is the annual firearm (or non-firearm) suicide rate for county c at time t, including the vector of covariates (Z_{ct}) in Models 2 and 4.

Models 1 and 3 estimated the policy parameters (independent variables) without covariate adjustment for the two dependent variables. Models 2 and 4 estimated the policy

parameters with covariate adjustment. In all four models, the coefficient of interest was the DID policy estimate (β_3) for the interaction of the two independent variables, attributable to Arizona's decision to enact the 2016 law preempting Tucson's firearm destruction ordinance. This empirical approach assumed that, absent the 2016 policy, the average changes in the firearm suicide rates would have been the same in both Pima County (Tucson area) and the comparison group counties, known as the common trends assumption.(22,23) In Model 2, β_3 is thus an estimate of the change in Pima County's average firearm suicide rate from the pre-policy-enactment to the post-policy-enactment period minus the change in the comparison group counties' average firearm suicide rate over the time period. A corollary of this common trends assumption was examined in the Supplemental Material and described below.(18,24)

To correct for serial correlation and heteroskedasticity in the error terms, robust standard errors were clustered at the county level, and the statistical models were weighted by county-year population. We established an a priori two-sided significance level of 0.05. All analyses were conducted using Stata version 17.1 (College Station, TX).

RESULTS

Across the study period, the comparison group counties had an average of 14.87 firearm suicides per 100,000 persons per year, compared to 11.56 firearm suicides per 100,000 persons per year in Pima County (Table 1). Supplemental Figure A1 depicts similar pre-expansion firearm suicide trends from 2014 through 2015 between Pima County and the comparison group counties,(18) and the Supplemental Material provides additional statistical evidence suggesting the corollary of the common trends assumption was satisfactory for our outcome (i.e., the difference in differences were not significantly different between the two groups in the pre-treatment period).

Table 2 describes our multivariate analysis findings. The Model 1 results show Arizona's enactment of the 2016 preemption law was associated with an increase in Pima County's firearm suicide rate by an additional 1.201 suicides per 100,000 persons from the pre-policy period to the post-policy period, relative to the change over the same time period in the comparison group counties (P<0.01). Model 2 produced similar estimates of the impact of the 2016 preemption law following covariate adjustment, though with greater variability explained by the model overall (R^2=0.88). In this adjusted model, a 1.126 increase in Pima County's firearm suicide rate per 100,000 persons was attributable to the enactment of the 2016 law, relative to the comparison group counties over the same time period (P<0.01). Consistent with previous studies, the unemployment rate(20) was also positively associated with higher suicide rates, as was our proxy for firearm availability.(21)

As a robustness test, Models 3 and 4 estimated the impact of the 2016 preemption law on non-firearm suicide rates in Pima County. In both models, the new law was not statistically associated with changes in the non-firearm suicide rate. In the adjusted model (Model 4), and in contrast to the main firearm suicide model results, the proxy for firearm availability was also not associated with the non-firearm suicide rate. The unemployment rate was associated with lower firearm suicide rates (P=0.025) in the adjusted model.

DISCUSSION

Our findings suggest there was a statistically significant increase in the firearm suicide rate in Pima County (greater Tucson area) associated with the enactment of Arizona's 2016 preemption law. Although the mean annual firearm suicide rate was higher in the comparison group counties over the full study period (Table 1), by 2019, the firearm suicide rate in Pima

County increased and was nearly equivalent to the firearm suicide rate in the comparison counties (14.1 and 14.6 per 100,000 persons, respectively).

Despite having a firearm suicide rate that is 52.4% higher than the national average,(1) the state of Arizona responded to firearm safety and control policies adopted by local Tucson government with a preemption measure including significant punitive financial consequences.(17) Other authors – and this paper – have demonstrated and discussed the link between firearm availability and suicide rates.(2,3,25,26) Following Arizona's 2016 preemption law, Tucson was not only no longer able to destroy confiscated and forfeited firearms, it was also required to redistribute those firearms by way of auction. As additional firearms may have reentered the greater Tucson area through 2019 (and were no longer removed and destroyed), our findings suggest SB 1487 had the consequence of independently increasing the firearm suicide rate in Pima County relative to other counties not targeted by the new law, even after adjusting for other important explanatory factors. Further supporting our main findings, we also found that the 2016 preemption law did not impact *non*-firearm suicide rates in Pima County relative to other counties over the same time period, further suggesting that SB 1487 affected the supply of firearms and firearm suicide specifically in Prima County.

State preemption of local law has several adverse consequences for localism, resting on the idea that state power supersedes local government which is relegated to primarily execute state policy.(27) The state-local government dynamic is one of state agency over local municipalities, often supported by aggressive and threatening preemption measures(28) that are a detriment to public health. Such preemption to interfere with local policy for firearm safety has been supported and encouraged by the firearm industry.(28,29) State preemption of local government rule on other public health issues such as nutrition policy(30,31) and tobacco

control(32) have also been documented and demonstrate their broad use as a policy tool by various interests to wield power over local public health. To date, following a strategic push by several influential lobbies, over 40 states have passed some version of preemptive laws designed to undermine local authority over firearm safety.(30,33) Our study is the first to empirically show that state preemption of local firearm laws affects health-related outcomes – in this case increasing firearm suicide by supplying the local community in Tucson with additional firearms, which would have been previously destroyed.

Limitations

This study had several key limitations. First, because we conducted a county-level analysis and estimated average effects of the 2016 preemption law on county-level firearm suicide rates, readers should refrain from making inferences about individual behavior. For example, we could not directly examine at the person level whether Arizona's 2016 preemption law resulted in suicidal persons acquiring firearms that would have previously been confiscated and destroyed by Tucson police or newly resold firearms for the purpose of making suicide attempts.

Second, Tucson was the municipality with the firearm destruction policy, yet city-level data were unavailable and data were aggregated at the county level. Tucson is the only city in Pima County, and the Tucson metropolitan statistical area is defined as Pima County. The majority of Pima County resides in the city of Tucson, which is demographically like the county as a whole. However, smaller rural areas in Pima County may have been less sensitive to the potential increase in firearms available through auction after SB 1487 as it may be more likely they already possessed firearms, though not necessarily handguns,(34) which is the type of firearm used in most urban and rural suicides.(35)

Third, SB 1487 disrupted the number of firearms in Tucson in two ways: First, by no longer allowing Tucson police to actively accept firearms through buyback programs or firearms voluntarily turned in by citizens for the purpose of destroying those firearms, and second, by requiring Tucson to resell all confiscated or forfeited firearms through a local auctioneer. However, in this and other studies, data limitations preclude knowing the actual number of firearms in a community. Because we cannot directly measure the number of firearms before and after the policy change, we make the logical assumption that more firearms entered Pima County after the new policy was enacted. Notably, the Tucson firearm auctions were administered in-person and online to persons with federal firearms licenses (e.g., dealers and pawnbrokers) by a third-party auctioneer based in Tucson.

Fourth, and related, it is possible persons outside the city of Tucson could have won the confiscated and forfeited firearms; however, it is likely many bidders were from the greater Tucson area because the auctioneer was located in Tucson and the auctions were advertised locally. Notably, some firearms sold for as little $15.(36) It is feasible local pawnbrokers and dealers could have won the firearms cheaply and then resold them at a discount. Persons seeking firearms may be more likely to purchase them from pawnbrokers or dealers than a government auction. Beyond the general link between greater firearm availability and suicide risk, studies have suggested some persons purposely buy firearms with the intent of suicide.(37)

Fifth, as described earlier, CDC data restrictions prevented us from constructing our dependent variables for all Arizona counties. The generalizability of our results is limited to the comparison counties included in our analytic sample; however, the included counties represented about 93.4% of the state population in 2019.

Finally, as with other studies, we could not directly control for firearm availability. To address this concern, we used the proxy measure of firearm availability most recommended for county-level analysis.(21)

CONCLUSIONS

In Arizona, state-level policy efforts to preempt or limit local government from enacting firearm safety and control policies – especially policies that decrease the availability of firearms in local communities – appear to have had the consequence of increasing firearm suicide risk in Pima County. Just as the medical community and policymakers can advocate for state-level firearm reforms shown to prevent suicide,(8,11) policy actors and advocates must also be aware of other state-level policy issues that can either intentionally or unintentionally affect suicide risk in their states. The research community must evaluate other preemption measures in terms of their relationship to broad measures of public health. With this evidence we can encourage the revision or revocation of existing preemption laws, which seem to benefit special interests at the expense of public health.

CONTRIBUTORS

EG planned the concept and study design, performed the data analysis, and drafted and revised the manuscript. LP contributed to the study design, data interpretation, and manuscript revision. Both authors revised and approved the final manuscript.

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COMPETING INTERESTS

None declared.

PATIENT AND PUBLIC INVOLVEMENT

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

PATIENT CONSENT FOR PUBLICATION

Not applicable.

ETHICS APPROVAL

This study conducted secondary data analysis of public use data and was deemed exempt from Institutional Review Board review.

DATA AVAILABILITY STATEMENT

Data are available in a public, open access government repositories at https://wonder.cdc.gov/ and https://www.atf.gov/resource-center/data-statistics.

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Tables

Table 1. Characteristics of the pooled analytic sample, by policy group: 2014-2019

	Policy Group		Comparison Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Firearm suicides per 100,000 persons	11.56	1.52	14.87	6.28
Non-firearm suicides per 100,000 persons				
Unemployment rate, %	4.95	0.67	7.77	4.64
Population white, %	86.59	0.25	82.49	14.44
Population <25yo, %	33.19	0.72	31.86	5.77
Population male, %	49.19	0.03	50.34	1.05
Per capita rate of federal firearm licenses	0.00019	0.00001	0.00034	0.00016

Notes: Authors' analysis of the CDC WONDER, BLS, and ATF data. For each variable shown in the table, unadjusted mean annual percentages or rates are shown from across the study period. The policy group contained 6 observations and the comparison group contained 48 observations.

Table 2: Estimating the effect of Arizona's 2016 preemption law on suicide outcomes in Pima County: 2014-2019

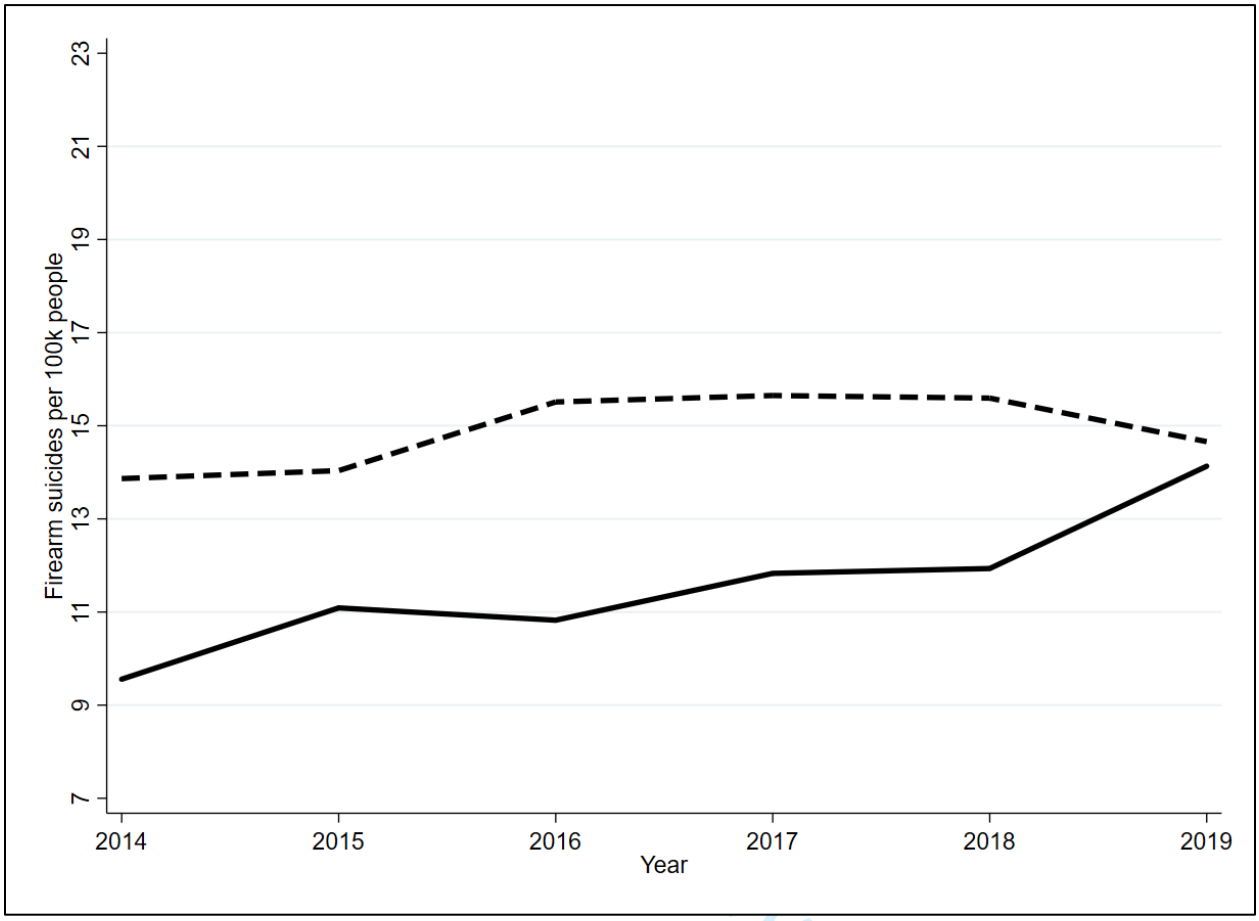
	Outcome: Firearm suicide rate		**Outcome:** Non-firearm suicide rate	
	1 *Unadjusted Model*	**2** *Adjusted Model*	**3** *Unadjusted Model*	**4** *Adjusted Model*
Policy variables				
SB 1487 exposure				
Comparison group	Ref	Ref	Ref	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	0.133	0.516*	0.803	1.167**
	(1.369)	(0.169)	(0.715)	(0.224)
Policy enactment timing				
Pre-law enactment	Ref	Ref	Ref	Ref
Post-law enactment	0.667**	0.198	-0.342	-0.572
	(0.179)	(0.233)	(0.323)	(0.577)
Policy group x Post-law enactment (**difference-in-differences estimate**)	1.201**	1.126**	0.208	0.189
	(0.179)	(0.262)	(0.323)	(0.446)
Covariates				
Unemployment rate (%)		0.231**		0.347*
		(0.065)		(0.126)
Population white (%)		0.102*		-0.349**
		(0.03)		(0.064)
Population <25yo (%)		-0.731**		-0.521+
		(0.138)		(0.253)
Population male (%)		-0.520*		-0.981**
		(0.165)		(0.268)
Per capita rate of federal firearm licenses		20,336.073**		7392.025
		(3,087.126)		(5567.404)
Constant	10.192**	63.851**	8.033**	100.513**
	(1.369)	(13.898)	(0.715)	(25.207)
Observations	54	54	54	54
R-squared	0.02	0.88	0.02	0.67

Notes: * P < 0.05, ** P < 0.0.1. Authors' analyses of CDC WONDER, BLS, and ATF data. Standard deviations shown in parentheses. Observations reflect county-year data. The "Policy Group x Post-Law Enactment" coefficient is the difference-in-differences (DID) policy estimate attributable to the state's decision to enact the law preempting Tucson's ordinance allowing destruction of unclaimed and forfeited firearms. The DID estimate tested the difference

in the changes in the average suicide outcomes from the pre-law-enactment period to the post-law-enactment period between Pima County and the comparison group counties.

Supplemental Material

Figure A1: Unadjusted trends in the firearm suicide rate, by policy group, 2014-2019



Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in the outcomes between Pima County (solid black line) and comparison group counties (dashed black line) over the study period, allowing for a visual examination of the pre-expansion common trends assumption in the outcomes. The post-policy-enactment period was 2016-2019.

If the trends in the outcomes between the two groups were similar in the pre-expansion period, then one can be more confident about similar potential outcomes between the two policy groups. The preemption law variable was interacted with year indicators and the firearm suicide rate variable was regressed on the interactions of the time variables and the law variable indicator, excluding the first pre-expansion year indicator (e.g., 2015). The coefficient for year = 2014 was statistically equivalent to zero (B=-1.53, P=0.87), further suggesting the corollary of the common trends assumption was satisfactory (i.e., the difference in differences was not significantly different between the two groups in the pre-treatment period).

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2

Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	#3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	#4	Present key elements of study design early in the paper	6-9
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	6-7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-8

Bias	#9	Describe any efforts to address potential sources of bias	8-9
Study size	#10	Explain how the study size was arrived at	6-7
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	7-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	8-9
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	N/A. No interactions or subgroups.
Statistical methods	#12c	Explain how missing data were addressed	N/A. No missing data.
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	N/A
Statistical methods	#12e	Describe any sensitivity analyses	7-9. Models 3 and 4, robustness outcome.
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the	8-9, 21

		study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	N/A
Participants	#13c	Consider use of a flow diagram	N/A
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9, 21, Supplementary File
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	N/A - no missing data.
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	21
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10, 22
Main results	#16b	Report category boundaries when continuous variables were categorized	N/A

Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	10, 22
Discussion			
Key results	#18	Summarise key results with reference to study objectives	10-11
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	12-14
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11
Generalisability	#21	Discuss the generalisability (external validity) of the study results	11, 13
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

Notes:

- 12b: N/A. No interactions or subgroups.
- 12c: N/A. No missing data.
- 12e: 7-9. Models 3 and 4, robustness outcome.
- 14a: 9, 21, Supplementary File
- 14b: N/A - no missing data. The STROBE checklist is distributed under the terms of the Creative Commons Attribution License CC-BY. This checklist was completed on 08. October 2021 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

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Examining the policy effects of Arizona's 2016 preemption law on firearm suicide rates in the greater Tucson area: An observational study

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Title: Examining the policy effects of Arizona's 2016 preemption law on firearm suicide rates in the greater Tucson area: An observational study

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ABSTRACT

Objectives: In 2016, Arizona enacted SB 1487 to nullify Tucson's ordinance permitting the municipality to destroy confiscated and forfeited firearms and instead require the firearms to be resold to the public through an auctioneer. Our objective was to examine whether firearm suicide rates increased in Pima County (greater Tucson area) relative to other Arizona counties following the enactment of Arizona's 2016 preemption law.

Design: An observational study of a natural policy experiment. We used a difference-in-differences approach to estimate the effects of Arizona enacting SB 1487 on firearm suicide rates in Pima County. Our statistical analyses adjusted for county-level differences in population demographics (age, gender, and race) and unemployment rates, as well as a proxy for firearm availability and mental health professional shortage area status.

Setting: 9 Arizona counties from 2014-2019

Participants: A policy group was constructed using Pima County (Tucson-area) observations. A comparison group was created using data from 8 other Arizona counties. 54 county-year observations were analyzed.

Intervention: SB 1487, which preempted Tucson law and allowed firearms that were seized/surrendered to law enforcement to be recirculated instead of destroyed.

Outcomes and Measures: Annual rates of firearm and non-firearm suicides per 100,000 persons extracted from the CDC WONDER system.

Results: Over the study period, comparison group counties had an average of 14.87 firearm suicides per 100,000 persons per year, compared to 11.56 firearm suicides per 100,000 persons per year in Pima County. A 1.13 increase in Pima County's firearm suicides per 100,000 persons coincided with the enactment of Arizona's 2016 preemption law, relative to comparison group counties over the same period.

Conclusions: As fewer firearms were destroyed and more firearms would have reentered the greater Tucson area through 2019, SB 1487 was associated with firearm suicide rates in Pima County relative to other areas not targeted by the law.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study uses a quasi-experimental design to examine a natural policy experiment in Arizona, USA, accounting for other explanatory factors.
- This study compares both firearm and non-firearm suicide rates at the county level, conducting empirical robustness and placebo tests.
- In this and other studies of firearm suicide in the US, data limitations preclude adjusting for the actual number of firearms in a community, a strong risk factor for suicide.
- City-level data were unavailable, and data were aggregated at the county level.
- As with other non-experimental studies, our findings should be interpreted as correlative, not causal.

INTRODUCTION

The US is in the midst of a suicide epidemic taking the lives of almost 50,000 Americans every year, with high burden typically concentrated in the Mountain states.(1) Firearms are the most common method of suicide in the US,(1). Although suicide is a multifaceted public health problem with simultaneous biological, psychological, social, and environmental contributors, access to firearms exacerbates suicide risk for suicidal persons.(2,3) Many people who attempt suicide will survive,(4) though survival is typically less likely for those who use firearms, given the 80-90% case-fatality rate . (5,6) Internationally, the US firearm suicide rate has been estimated to be 8 times higher than the average firearm suicide rate of 22 other high-income countries, even though the total suicide rate for the US is similar to that of other countries.(7) In the Mountain states (i.e., Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) specifically, firearm suicide rates increased 30.4% from 2005-2019 and are consistently among the top ten in the US.(1)

Federal firearm safety and control reforms are controversial and difficult to enact and enforce, making state governments responsible for most firearm policymaking.(8) Frequently, in the US, policies are enacted to curb homicide after incidents of highly-publicized mass shootings, even though most firearm mortality is attributable to suicide.(1,9) Even so, these policy changes often have implications for firearm suicide through the mechanism of supply or access restriction.(2,3,8) There is evidence demonstrating that stricter firearm safety laws enacted at the state level, such as child access prevention laws(10) and risk-based, time-limited civil protection orders for firearm removal(11) can reduce the rate of firearm suicide. However, these policies are enacted inconsistently from state to state, leaving many firearm-related issues unaddressed and motivating municipalities to enact firearm policies consistent with dangers or

concerns specific to their citizens. This issue has caused controversy between state and local governments, including in Richmond, Virginia, where a state preemption law prevented banning firearms at a white supremacist rally but allowed banning of less-lethal weapons (e.g., knives).(12,13)

Tensions between Arizona's government and local legislators in Tucson have been particularly problematic for firearm policymaking.(14) Absent action from state legislators, local policymakers in the city of Tucson passed an ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed, resulting in the elimination of over 4,800 firearms in Pima County during the years included in this study.(14) However, in 2016, the Arizona legislature enacted SB 1487 to preempt Tucson's ordinance. Upheld by the Arizona Supreme Court, SB 1487 forced Tucson to stop the destruction of confiscated firearms and resell the firearms to the public by auction or face an annual financial penalty of $115 million.(15)

For these reasons, SB 1487 disrupted the number of firearms in Tucson in two ways. First, SB 1487 no longer allowed Tucson police to actively accept firearms voluntarily turned in by citizens or through buyback programs for the purpose of destroying those firearms. Second, SB 1487 required Tucson to resell all confiscated or forfeited firearms through a local auctioneer. The city of Tucson auctions resold nearly 600 firearms in just one five-month period in 2017,(16) and many firearms likely reentered Tucson and surrounding communities through 2019. The legal implications of SB 1487 have been discussed elsewhere,(17) such as conceding to states over firearm-related policymaking, restricting local efforts to enact public safety interventions, and imposing one of the most punitive fiscal measures known to be applied to local government in the US. However, less is understood about the health-related implications of Arizona's 2016 preemption law, specifically how it may have affected firearm suicide rates in

the greater Tucson area. This example of an exogenous local policy affecting the Tucson (Pima County) area relative to other counties in Arizona provided ideal conditions for a natural policy experiment.(18)

Our objective was to examine whether firearm suicide rates increased in Pima County relative to other Arizona counties following Arizona's 2016 preemption law. Given the systematic link between firearm availability and suicide, and considering the availability of same-day firearm purchasing in Arizona,(19) we hypothesized that firearm suicide rates (but not non-firearm suicide rates) would increase in Pima County following the enactment of SB 1487, which restricted local firearm destruction and likely introduced of a new supply of firearms in Tucson-area communities.

METHODS

Data & Study Design

Our primary data source was the Centers for Disease Control and Prevention (CDC) WONDER system, an interactive database compiling information on the underlying causes of death in the US. Data from the Bureau of Labor Statistics (BLS) Local Area Unemployment statistics program; Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Federal Firearms Licensees database; and the Area Health Resource Files (AHRF) were also used. CDC data restrictions prevent the analysis of county-level suicide rates involving less than 10 decedents. For this reason, counties with restricted data were excluded from the analysis. This included the 6 least-populated counties (with also the lowest firearm suicide counts) in Arizona. The remaining counties represented 93.4% of the state population in 2019 (data not shown).

We used a quasi-experimental study design taking advantage of a natural policy experiment. Our final analytic sample included 54 county-year observations, including 6 observations for each of 9 counties from 2014 through 2019, permitting multiple years of data both before and after the preemption law was enacted.(20)

Dependent variables

Our primary dependent variable was a measure of the annual rate of firearm suicides (ICD-10 codes X72–X74) per 100,000 persons (all ages). Because the 2016 preemption law should not have affected non-firearm suicide rates in Pima County, we also examined a second dependent variable measuring the annual rate of non-firearm suicides per 100,000 persons (all ages) as a robustness test. Both variables were created using data extracted from the CDC WONDER system.

Independent variables

There were two independent policy variables. The first variable was an indicator of being affected by Arizona's preemption law, SB 1487. Arizona enacted the preemption law in 2016 to nullify Tucson's ordinance allowing the Tucson Police Department to destroy unclaimed and forfeited firearms and instead required the firearms to be made available through resale. The variable equaled 1 for Pima County (Tucson-area) observations (policy group) and 0 for all other county observations (comparison group).

The second variable was a measure of policy enactment timing equal to 1 for observations after the 2016 law was enacted and 0 for observations before 2016.

Covariates

Our empirical approach assumes that confounders varying across the policy and comparison groups are time-invariant and time-varying confounders are group invariant. Our fully-adjusted multivariate statistical models included a vector of covariates to absorb residual variance in the outcomes and adjust for potential confounding factors varying between the two groups. Population demographic covariates included county-level measures of age (% of population <25yo), gender (% of population male), and race (% of population white) in each county-year. BLS data were used to adjust for differences in county-level unemployment rates, a proxy for socioeconomic status differences shown to be correlated with suicide risk.(21) ATF data were used to construct a county-level proxy measure of firearm ownership, as firearm availability is associated with suicide.(2) The variable adjusted for the per capita rate of Category 1 and Category 2 federal firearm licenses in each county-year, which may be the most suitable proxy for county-level analyses.(22) Recent studies have shown mental health professional shortage areas are associated with higher suicide rates at the county level.(23) For this reason, we also included a measure of mental health professional shortage area status (partial or full shortage area county-year) using data from the AHRF, as defined by the US federal government.(24)

Analysis

We used a linear two-group, two-period difference-in-differences (DID) estimation approach to examine the effect of SB 1487 as a widening or narrowing of the gap in suicide rates in Pima County compared to 8 other Arizona counties from the pre-policy-enactment period to the post-policy-enactment period.(18) The pre-policy-enactment reference period was the average of outcomes from 2014 and 2015. We estimated four models using the following general regression approach:

$$Y_{ct} = \beta_0 + \beta_1 Policy\ Group + \beta_2 Post\text{-}Policy\ Enactment\ Period + \beta_3 (Policy\ Group \times Post\text{-}Policy\ Enactment\ Period) + \mathbf{B}Z_{ct} + \varepsilon_{ct} \quad (1)$$

where Y_{ct} is the annual firearm (or non-firearm) suicide rate for county c at time t, including the vector of covariates (Z_{ct}) in the adjusted models.

Model 1 estimated the policy parameters (independent variables) without covariate adjustment for our primary dependent variable. Model 2 estimated the policy parameters with covariate adjustment. As a robustness test, we also estimated Models 3 and 4 examining the effects of the 2016 preemption law on measure of non-firearm suicide rates in the policy and comparison group counties.

The coefficient of interest was the DID policy estimate (β_3) for the interaction of the two independent variables, coinciding with Arizona's decision to enact the 2016 law preempting Tucson's firearm destruction ordinance. This empirical approach assumed that absent the 2016 policy, the average changes in the firearm suicide rates would have been the same in both Pima County (Tucson area) and the comparison group counties, known as the common trends assumption (25,26) β_3 is thus an estimate of the change in Pima County's average firearm suicide rate from the pre-policy-enactment to the post-policy-enactment period minus the change in the comparison group counties' average firearm suicide rate over the time period. This approach also assumed that there were no other unmeasured policy changes or factors coinciding with the timing of Arizona's 2016 preemption law that could have affected firearm suicide rates in Pima County relative to the comparison group counties.

A corollary of this common trends assumption was examined graphically below.(18,27) We also conducted a placebo test of the expected policy effects and pre-policy common trends assumption.(20) For this test, we performed an additional DID estimation using a "fake" policy

group for our primary dependent variable. Specifically, we replicated our estimation of Model 2 using Maricopa County observations for our policy group and all other non-Pima counties for the comparison group. Because the 2016 preemption law should not have affected firearm suicide rates in Maricopa County relative to the other comparison counties, the DID estimate (β_3) from the placebo test model should not statistically differ from 0.

To correct for serial correlation and heteroskedasticity in the error terms, robust standard errors were clustered at the county level, and the statistical models were weighted by county-year population. We established an a priori two-sided significance level of 0.05. All analyses were conducted using Stata version 17.1 (College Station, TX).

RESULTS

Across the study period, the comparison group counties had an average of 14.87 firearm suicides per 100,000 persons per year, compared to 11.56 firearm suicides per 100,000 persons per year in Pima County (Table 1). Figure 1 illustrates the geographic variation in firearm suicide rates for each Arizona county in 2019, as well as the relative land size of each county. By 2019, Pima County's firearm suicide rate increased to 14.13 deaths per 100,000 persons. Figure 2 describes the unadjusted firearm suicide rates in Pima County and the comparison group counties from 2005 through 2015, depicting similar pre-policy trends between Pima County and the comparison group counties.(18) This suggests the corollary of the common trends assumption was satisfactory for our dependent variable of interest. Supplemental Figure A1 describes the unadjusted non-firearm suicide rates over the study period.

Table 2 presents our multivariate analysis findings. The Model 1 results show Arizona's enactment of the 2016 preemption law was associated with an increase in Pima County's firearm suicide rate by an additional 1.20 suicides per 100,000 persons from the pre-policy period to the

post-policy period, relative to the change over the same period in the comparison group counties (95% CI 0.79, 1.61; P<0.01). Model 2 produced similar estimates of the effect of the 2016 preemption law following covariate adjustment. In the adjusted model, a 1.13 increase in Pima County's firearm suicides per 100,000 persons coincided with the enactment of the 2016 law, relative to the comparison group counties over the same period (95% CI 0.51, 1.74; P<0.01). Consistent with previous studies, our proxy for firearm availability was also positively associated with higher suicide rates.(22)

The results of our placebo test are shown in supplemental Table A1. The DID estimate from the placebo test model did not statistically differ from zero at the 0.05 level (β_3 = -0.86; 95% CI -2.36, 0.64; P = 0.216). In other words, the 2016 preemption law did not significantly affect firearm suicide rates in the "fake" policy group (Maricopa County), compared to the remaining comparison group counties. These supplemental results further suggest the common trends assumption was satisfactory for our main outcome. If the DID estimate from the placebo test significantly differed from zero, the impact would have likely come from some underlying difference in the trends between the two groups. In turn, this would cast doubt on the assumption of similar pre-policy trends between our main policy and comparison groups.

Supplemental Table A2 shows the results of our robustness test, describing the estimated effects of the 2016 preemption law on non-firearm suicide rates in Pima County. In Models 3 and 4, the new law was not statistically associated with changes in the non-firearm suicide rate. In the adjusted model (Model 4), and in contrast to the main firearm suicide model results, the proxy for firearm availability was also not associated with the non-firearm suicide rate. The unemployment rate was associated with lower non-firearm suicide rates in the adjusted model (β = 0.33; 95% CI 0.02, 0.64; P=0.03; Model 4).

DISCUSSION

Our findings suggest a modest but statistically significant increase in the firearm suicide rate in Pima County (greater Tucson area) during the years following the enactment of Arizona's 2016 preemption law. Relative to the comparison counties, the 2016 law coincided with a 10.9% relative increase in the firearm suicide rate in Pima County from the pre-policy period to the post-policy period. Although the mean annual firearm suicide rate was higher in the comparison group counties over the full study period (Table 1), by 2019, the firearm suicide rate in Pima County increased and was nearly equivalent to the firearm suicide rate in the comparison counties (14.1 and 14.6 per 100,000 persons, respectively).

Despite having a firearm suicide rate 52.4% higher than the national average,(1) the state of Arizona responded to firearm safety and control policies adopted by the local Tucson government with a preemption measure including significant punitive financial consequences.(17) Other authors – and this paper – have demonstrated and discussed the link between firearm availability and suicide rates.(2,3,28,29) Following Arizona's 2016 preemption law, Tucson was not only no longer able to destroy confiscated and forfeited firearms, but it was also required to redistribute those firearms by way of auction. As additional firearms may have reentered the greater Tucson area through 2019 (and were no longer removed and destroyed), our findings suggest SB 1487 contributed to higher firearm suicide rates in Pima County relative to other counties not targeted by the new law. Not surprisingly, we also found the 2016 preemption law did not impact non-firearm suicide rates in Pima County relative to other counties over the same period, further suggesting that SB 1487 affected firearm suicide specifically in Prima County.

State preemption of municipal policies has several adverse consequences for localism, resting on the idea that state power supersedes local government and that municipalities are relegated to primarily executing state policy.(30) This notion can be detrimental to public health. Preemption efforts interfering with local firearm safety policies have been supported and encouraged by the firearm industry.(31,32) State preemption of local government authority on other public health issues such as nutrition policy(33,34) and tobacco control(35) have also been documented, seemingly used by organized interests to wield power over local public health initiatives. Following a strategic push by several influential lobbying entities, over 40 states have passed some version of preemptive law designed to undermine local authority over firearm safety.(33,36) Our study is the first to empirically show that state preemption of local firearm laws appears to have specifically affected suicide-related outcomes.

Limitations

This study had several key limitations, and readers should carefully interpret the findings. First, because we conducted a county-level analysis and estimated the effects of the 2016 preemption law on county-level firearm suicide rates, readers should refrain from making inferences about individual behavior. For example, we could not directly examine at the person level whether Arizona's 2016 preemption law resulted in suicidal persons acquiring firearms that would have previously been confiscated and destroyed by Tucson police or newly resold firearms to make suicide attempts.

Second, Tucson was the municipality with the firearm destruction policy, yet city-level data were unavailable, and data were aggregated at the county level. Tucson is the only city in Pima County, and the Tucson metropolitan statistical area is defined as Pima County. The majority of Pima County resides in Tucson, which demographically resembles the county as a

whole. However, smaller rural areas in Pima County may have been less sensitive to the potential increase in firearms available through auction after SB 1487. It may be more likely they already possessed firearms, though not necessarily handguns,(37) which is the type of firearm used in most urban and rural suicides.(38)

Third, SB 1487 disrupted the number of firearms in Tucson in two ways. First, SB 1487 no longer allowed Tucson police to actively accept firearms voluntarily turned in by citizens or through buyback programs for the purpose of destroying those firearms. Second, SB 1487 required Tucson to resell all confiscated or forfeited firearms through a local auctioneer. However, in this and other studies, data limitations preclude knowing the actual number of firearms in a community. Because we cannot directly measure the number of firearms before and after the policy change, we make a logical assumption that more firearms entered Pima County after the new policy was enacted. Notably, the Tucson firearm auctions were administered in-person and online to persons with federal firearms licenses (e.g., dealers and pawnbrokers) by a third-party auctioneer based in Tucson.

Fourth, and related, it is possible persons outside the city of Tucson could have won the confiscated and forfeited firearms; however, it is likely many bidders were from the greater Tucson area because the auctioneer was located in Tucson and the auctions were advertised locally. Notably, some firearms sold for as little as $15.(39) It is feasible local pawnbrokers and dealers could have won the firearms cheaply and then resold them at a discount. Persons seeking firearms may be more likely to purchase them from pawnbrokers or dealers than at a government auction. Beyond the general link between greater firearm availability and suicide risk, studies have suggested some persons purposely buy firearms with the intent of suicide.(40)

Fifth, as described earlier, CDC data restrictions prevented us from constructing our dependent variables for all Arizona counties. The generalizability of our results is limited to the comparison counties included in our analytic sample; however, the included counties represented about 93.4% of the state population in 2019.

Finally, unobserved characteristics not accounted for in Models 2 and 4 may have biased our estimates, imposing limits to causal interpretations of our findings. Specifically, we did not adjust for county-level measures of veteran population size or the unmet mental health care needs. Veteran status and different mental illnesses are often suicide risk factors, although mental illness is less likely to be diagnosed among those who use firearms for suicide.(41) We also could not directly adjust for firearm availability, though we used the proxy measure of firearm availability most recommended for county-level analysis in an attempt to address this concern.(22) We also assumed that there were no other unmeasured policy changes coinciding with the timing of Arizona's 2016 preemption law that could have affected firearm suicide rates in Pima County relative to the comparison group counties. As with other non-experimental studies, our findings should be interpreted as correlative, not causal.

CONCLUSIONS

In Arizona, state-level policy efforts to preempt or limit local government from enacting firearm safety and control policies – especially policies that decrease the availability of firearms in local communities – appear to coincide with higher firearm suicide rates in Pima County. Just as the medical community and policymakers can advocate for state-level firearm reforms shown to prevent suicide,(8,11) policy actors and advocates must also be aware of other state-level policy issues that can intentionally or unintentionally affect suicide risk in their states. Further examination of existing preemption laws is needed to determine whether these policies are

counterproductive to suicide prevention efforts, including additional analyses of the effects of Arizona's 2016 preemption law over time. The research community must also continue to evaluate relationships between preemption law and broader public health measures.

CONTRIBUTORS

EG planned the concept and study design, performed the data analysis, and drafted and revised the manuscript. LP contributed to the study design, data interpretation, and manuscript revision. Both authors revised and approved the final manuscript.

FUNDING

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COMPETING INTERESTS

None declared.

PATIENT AND PUBLIC INVOLVEMENT

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

PATIENT CONSENT FOR PUBLICATION

Not applicable.

ETHICS APPROVAL

This study conducted secondary data analysis of public use data and did not rise to the level of “human subjects research" per the University of Utah IRB policy on Secondary Data Analysis of Public Use Datasets (B2819).

DATA AVAILABILITY STATEMENT

Data are available in a public, open access government repositories at https://wonder.cdc.gov/ and https://www.atf.gov/resource-center/data-statistics.

FIGURE CAPTIONS

Figure 1. Firearm suicides per 100,000 persons in Arizona, by county: 2019. Notes: Authors' analysis of the CDC WONDER data. This map describes the firearm suicide rate per 100,000 persons in 2019 for each county included in our analyses. This map also illustrates the relative land size of each Arizona county. Pima County had 14.13 firearm suicide per 100,000 persons in 2019. Counties excluded from our analyses are shown in white.

Figure 2. Unadjusted trends in the firearm suicide rate, by policy group, 2005-2019. Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in firearm suicide rates between Pima County (**solid black line**) and comparison group counties (**dashed black line**) from 2005-2019, allowing for a visual examination of the pre-policy common trends assumption in the primary dependent variable. The post-policy enactment period was 2016-2019. Tucson's ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed was adopted in 2005 and would have been implemented in subsequent years.

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Tables

Table 1. Characteristics of the pooled analytic sample, by policy group: 2014-2019

	Policy Group		Comparison Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Firearm suicides per 100,000 persons	11.56	1.52	14.87	6.28
Non-firearm suicides per 100,000 persons	8.74	0.83	10.66	5.24
Unemployment rate, %	4.95	0.67	7.77	4.64
Population white, %	86.59	0.25	82.49	14.44
Population <25yo, %	33.19	0.72	31.86	5.77
Population male, %	49.19	0.03	50.34	1.05
Per capita rate of federal firearm licenses	0.00019	0.00001	0.00034	0.00016
Mental Health Professional Shortage Area Status				
Partial shortage area county-years, %	33.33	0.52	34.04	0.48
Full shortage area county-years, %	66.67	0.52	65.96	0.48

Notes: Authors' analysis of the CDC WONDER, BLS, ATF, and AHRF data. For each variable shown in the table, unadjusted mean annual percentages or rates are shown from across the study period. The policy group contained 6 observations and the comparison group contained 48 observations.

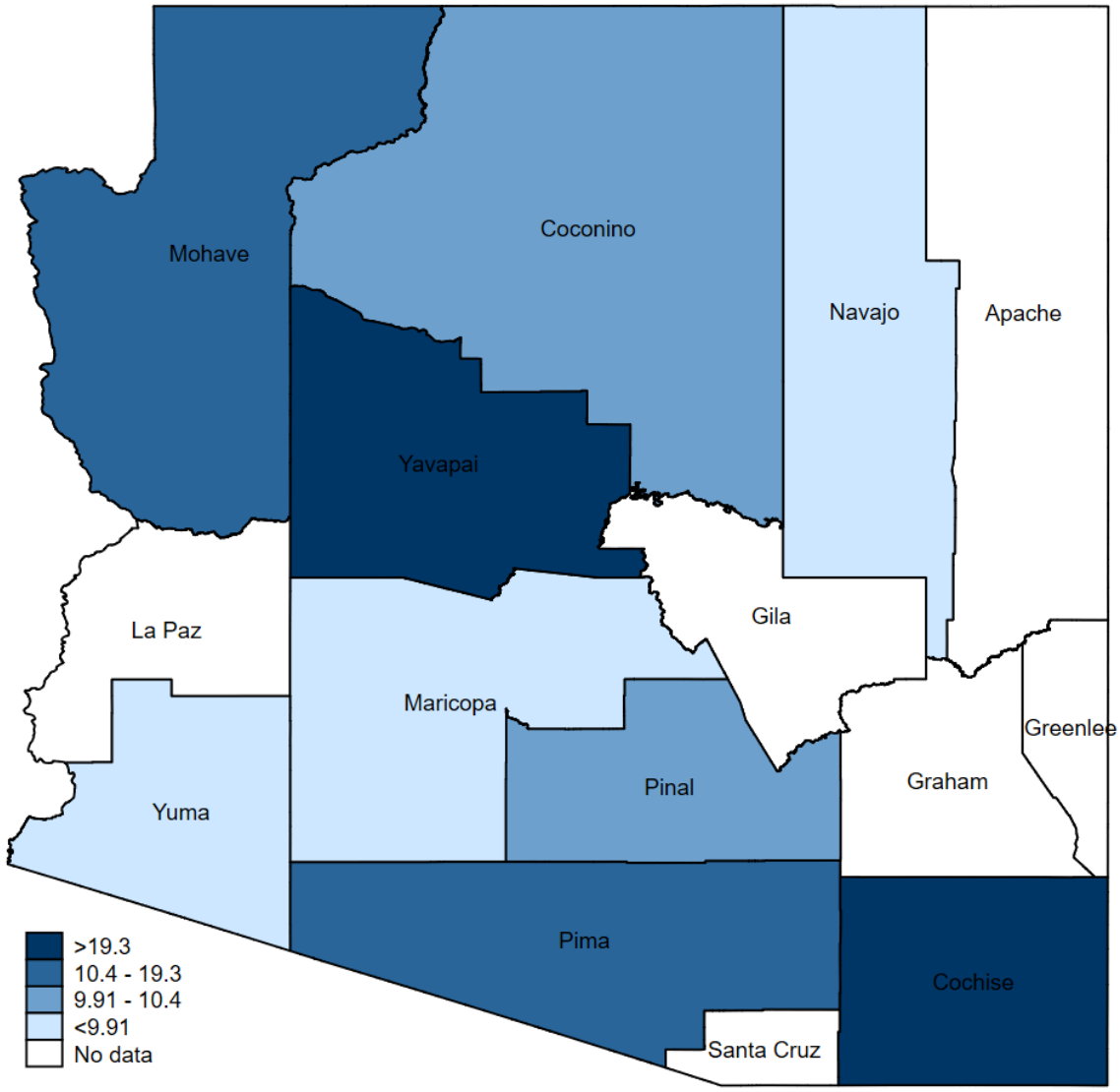
Table 2: Estimating the effect of Arizona's 2016 preemption law on firearm suicide rates in Pima County: 2014-2019

	1 *Unadjusted Model*	2 *Adjusted Model*
Policy variables		
SB 1487 exposure		
Comparison group	Ref	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	0.13 (-3.03, 3.29)	0.52* (0.13, 0.90)
Policy enactment timing		
Pre-policy enactment	Ref	Ref
Post-policy enactment	0.67** (0.26, 1.08)	0.30 (-0.34, 0.90)
Policy group x Post-policy enactment (difference-in-differences estimate)	1.20** (0.79, 1.61)	1.13** (0.51, 1.74)
Covariates		
Unemployment rate (%)		0.24** (0.02, 0.39)
Population white (%)		-0.10** (-0.17, -0.03)
Population <25yo (%)		-0.75** (-1.06, -0.42)
Population male (%)		-0.53* (-0.92, -0.14)
Per capita rate of federal firearm licenses		20,066.99** (12,901.60, 27,232.37)
Mental Health Professional Shortage Area Status		
Partial shortage area		Ref
Full shortage area		0.22 (-1.05, 1.50)
Constant	10.192** (7.03, 13.34)	64.97** (32.80, 97.14)
Observations	54	54
R-squared	0.02	0.90

Notes: + P < 0.10, * P < 0.05, ** P < 0.01. Authors' analyses of CDC WONDER, BLS, ATF, and AHRF data. 95% confidence intervals (CIs) shown in parentheses. Observations reflect county-year data. The "Policy Group x Post-Policy Enactment" coefficient is the difference-in-differences (DID) policy estimate attributable to the state's decision to enact the law preempting Tucson's ordinance allowing destruction of unclaimed and forfeited firearms.

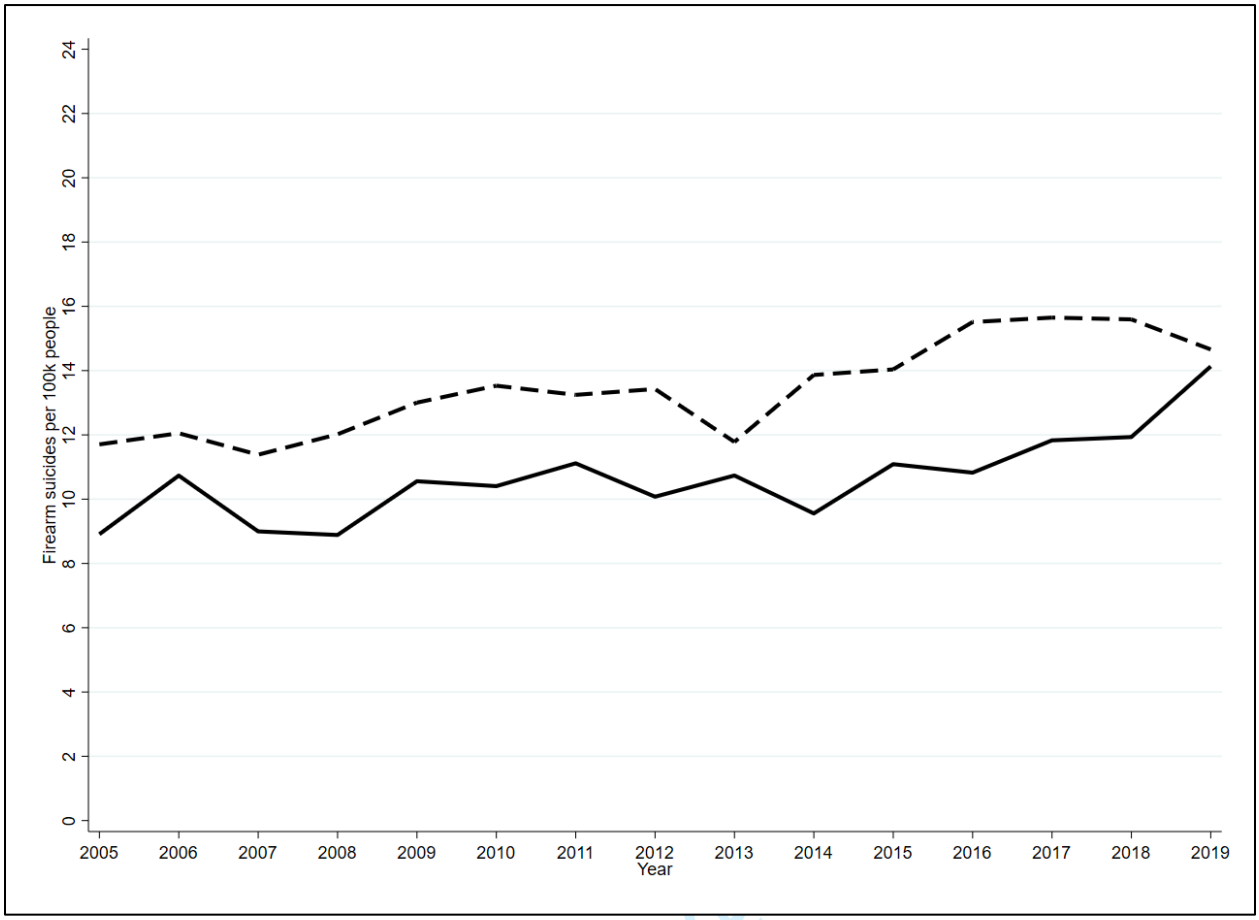
The DID estimate tested the difference in the changes in the average suicide outcomes from the pre-policy-enactment period to the post-policy-enactment period between Pima County and the comparison group counties.

Figure 1. Firearm suicides per 100,000 persons in Arizona, by county: 2019



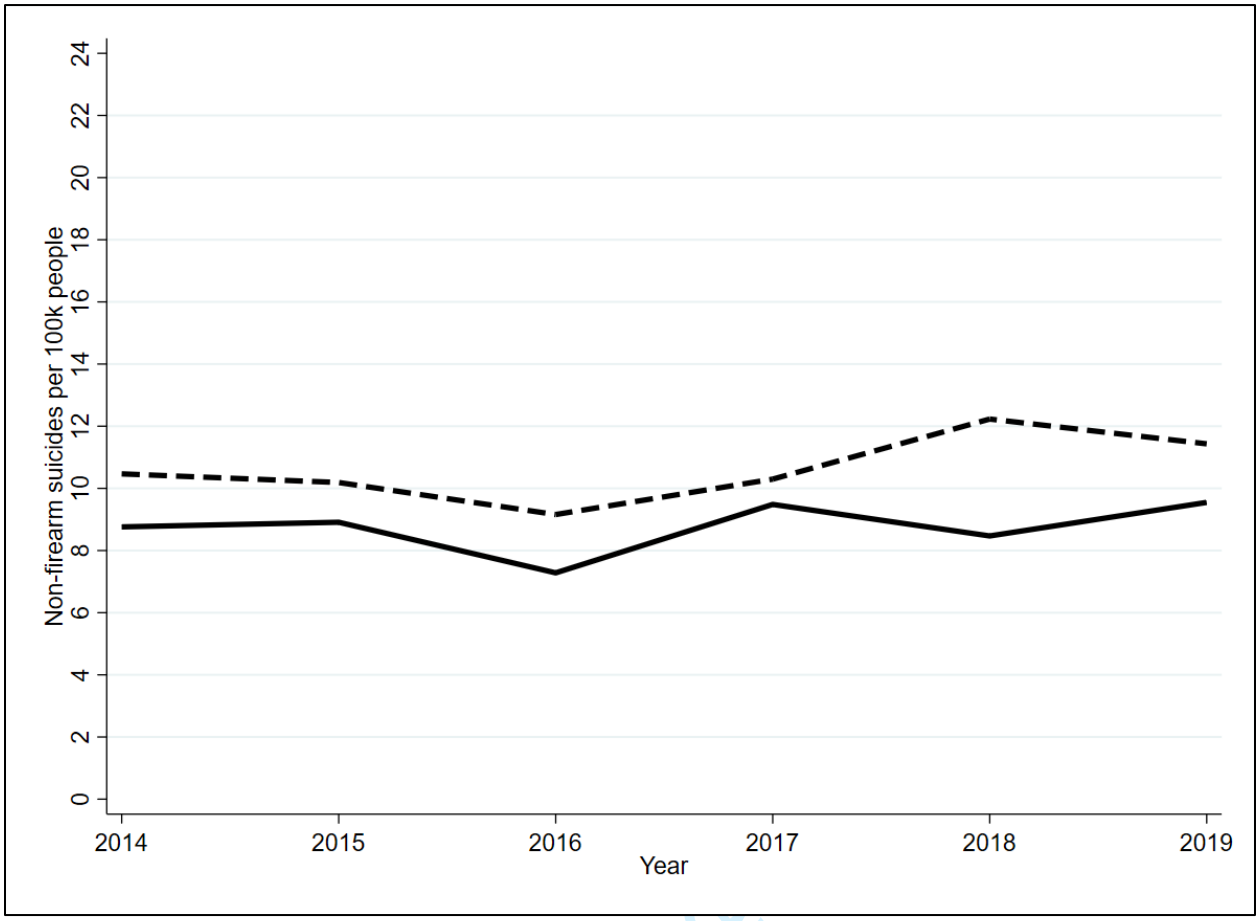
Notes: Authors' analysis of the CDC WONDER data. This map describes the firearm suicide rate per 100,000 persons in 2019 for each county included in our analyses. This map also illustrates the relative land size of each Arizona county. Pima County had 14.13 firearm suicide per 100,000 persons in 2019. Counties excluded from our analyses are shown in white.

Figure 2. Unadjusted trends in the firearm suicide rate, by policy group, 2005-2019



Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in firearm suicide rates between Pima County (**solid black line**) and comparison group counties (**dashed black line**) from 2005-2019, allowing for a visual examination of the pre-policy common trends assumption in the primary dependent variable. The post-policy enactment period was 2016-2019. Tucson's ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed was adopted in 2005 and would have been implemented in subsequent years.

Figure A1. Unadjusted trends in the non-firearm suicide rate, by policy group, 2014-2019



Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in non-firearm suicide rates between Pima County (solid black line) and comparison group counties (dashed black line) over the study period.

Table A1. Placebo test estimating the effect of Arizona's 2016 preemption law on suicide outcomes in Maricopa County: 2014-2019

	1 *Adjusted Model*
Policy variables	
SB 1487 exposure	
Comparison group	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	-1.297
	(1.473)
Policy enactment timing	
Pre-law enactment	Ref
Post-law enactment	1.087
	(0.73)
Policy group x Post-law enactment (difference-in-differences estimate)	-0.864
	(0.635)
Covariates	
Unemployment rate (%)	0.173+
	(0.083)
Population white (%)	-0.078*
	(0.03)
Population <25yo (%)	-0.699**
	(0.12)
Population male (%)	-1.088+
	(0.48)
Per capita rate of federal firearm licenses	16,116.934**
	(2,784.19)
Mental Health Professional Shortage Area Status	
Partial shortage area	Ref
Full shortage area	0.533
	(0.422)
Constant	90.650**
	(22.247)
Observations	48
R-squared	0.91

Notes: * P < 0.05, ** P < 0.0.1. Authors' analyses of CDC WONDER, BLS, ATF, and AHRF data. Standard deviations are shown in parentheses. Observations reflect county-year data. For this placebo test, the "Policy Group x Post-Law Enactment" coefficient is the difference-in-differences (DID) policy estimate of interest. The DID estimate tested the difference in the changes in average firearm suicide rates from the pre-policy-enactment period to the post-policy-enactment period between Maricopa County and the comparison group counties excluding Pima County.

Table A2: Estimating the effect of Arizona's 2016 preemption law on non-firearm suicide rates in Pima County: 2014-2019

	Model 3 *Unadjusted Model*	**Model 4** *Adjusted Model*
Policy variables		
SB 1487 exposure		
Comparison group	Ref	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	0.80	1.16**
	(-0.846, 2.452)	(0.623, 1.693)
Policy enactment timing		
Pre-policy enactment	Ref	Ref
Post-policy enactment	-0.34	-0.94+
	(-1.09, 0.40)	(-1.92, 0.03)
Policy group x Post-policy enactment (difference-in-differences estimate)	0.21	0.18
	(-0.53, 0.95)	(-0.84, 1.21)
Covariates		
Unemployment rate (%)		0.33*
		(0.02, 0.64)
Population white (%)		-0.33**
		(-0.48, -0.18)
Population <25yo (%)		-0.46+
		(-1.08, 0.15)
Population male (%)		-0.94*
		(-1.66, -0.23)
Per capita rate of federal firearm licenses		8,389.44
		(-5,511.819, 22,290.7)
Mental Health Professional Shortage Area Status		
Partial shortage area		Ref
Full shortage area		-0.83
		(-1.87, 0.21)
Constant	8.033**	96.34**
	(6.38, 9.68)	(31.75, 160.93)
Observations	54	54

R-squared	0.02	0.69

Notes: + P < 0.10, * P < 0.05, ** P < 0.01. Authors' analyses of CDC WONDER, BLS, ATF, and AHRF data. 95% confidence intervals (CIs) shown in parentheses. Observations reflect county-year data. The "Policy Group x Post-Policy Enactment" coefficient is the difference-in-differences (DID) policy estimate attributable to the state's decision to enact the law preempting Tucson's ordinance allowing destruction of unclaimed and forfeited firearms. The DID estimate tested the difference in the changes in the average suicide outcomes from the pre-policy-enactment period to the post-policy-enactment period between Pima County and the comparison group counties.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cross sectionalreporting guidelines, and cite them as:

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		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2

Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	#3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	#4	Present key elements of study design early in the paper	6-9
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	6-7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-8

Bias	#9	Describe any efforts to address potential sources of bias	8-9
Study size	#10	Explain how the study size was arrived at	6-7
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	7-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	8-9
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	N/A. No interactions or subgroups.
Statistical methods	#12c	Explain how missing data were addressed	N/A. No missing data.
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	N/A
Statistical methods	#12e	Describe any sensitivity analyses	7-9. Models 3 and 4, robustness outcome.
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the	8-9, 21

		study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	N/A
Participants	#13c	Consider use of a flow diagram	N/A
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9, 21, Supplementary File
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	N/A - no missing data.
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	21
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10, 22
Main results	#16b	Report category boundaries when continuous variables were categorized	N/A

Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	10, 22
Discussion			
Key results	#18	Summarise key results with reference to study objectives	10-11
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	12-14
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11
Generalisability	#21	Discuss the generalisability (external validity) of the study results	11, 13
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

Notes:

- 12b: N/A. No interactions or subgroups.
- 12c: N/A. No missing data.
- 12e: 7-9. Models 3 and 4, robustness outcome.
- 14a: 9, 21, Supplementary File
- 14b: N/A - no missing data. The STROBE checklist is distributed under the terms of the Creative Commons Attribution License CC-BY. This checklist was completed on 08. October 2021 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

Examining the policy effects of Arizona's 2016 preemption law on firearm suicide rates in the greater Tucson area: An observational study

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Keywords:	PUBLIC HEALTH, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Health & safety < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Suicide & self-harm < PSYCHIATRY

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Title: Examining the policy effects of Arizona's 2016 preemption law on firearm suicide rates in the greater Tucson area: An observational study

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ABSTRACT

Objectives: In 2016, Arizona enacted SB 1487 to nullify Tucson's ordinance permitting the municipality to destroy confiscated and forfeited firearms and instead require the firearms to be resold to the public through an auctioneer. Our objective was to examine whether firearm suicide rates increased in Pima County (greater Tucson area) relative to other Arizona counties following the enactment of Arizona's 2016 preemption law.

Design: An observational study of a natural policy experiment. We used a difference-in-differences approach to estimate the effects of Arizona enacting SB 1487 on firearm suicide rates in Pima County. Our statistical analyses adjusted for county-level differences in population demographics (age, gender, and race) and unemployment rates, as well as a proxy for firearm availability and mental health professional shortage area status.

Setting: 9 Arizona counties from 2014-2019

Participants: A policy group was constructed using Pima County (Tucson-area) observations. A comparison group was created using data from 8 other Arizona counties. 54 county-year observations were analyzed.

Intervention: SB 1487, which preempted Tucson law and allowed firearms that were seized/surrendered to law enforcement to be recirculated instead of destroyed.

Outcomes and Measures: Annual rates of firearm and non-firearm suicides per 100,000 persons extracted from the CDC WONDER system.

Results: Over the study period, comparison group counties had an average of 14.87 firearm suicides per 100,000 persons per year, compared to 11.56 firearm suicides per 100,000 persons per year in Pima County. A 1.13 increase in Pima County's firearm suicides per 100,000 persons coincided with the enactment of Arizona's 2016 preemption law, relative to comparison group counties over the same period.

Conclusions: SB 1487 was associated with higher firearm suicide rates in Pima County relative to other areas not targeted by the law, assuming fewer firearms were destroyed and more firearms reentered the greater Tucson area through 2019.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This study uses a quasi-experimental design to examine a natural policy experiment in Arizona, USA, accounting for other explanatory factors.
- This study compares both firearm and non-firearm suicide rates at the county level, conducting empirical robustness and placebo tests.
- In this and other studies of firearm suicide in the US, data limitations preclude adjusting for the actual number of firearms in a community, a strong risk factor for suicide.
- City-level data were unavailable, and data were aggregated at the county level.
- As with other non-experimental studies, our findings should be interpreted as correlative, not causal.

INTRODUCTION

The US is in the midst of a suicide epidemic taking the lives of over 40,000 Americans every year, with a high burden typically concentrated in the Mountain states.(1) Firearms are the most common suicide method in the US(1). Although suicide is a multifaceted public health problem with simultaneous biological, psychological, social, and environmental contributors, access to firearms exacerbates suicide risk for suicidal persons.(2,3) Many people who attempt suicide will survive,(4) though survival is typically less likely for those who use firearms, given the 80-90% case-fatality rate. (5,6) Internationally, the US firearm suicide rate has been estimated to be 8 times higher than the average firearm suicide rate of 22 other high-income countries, even though the total suicide rate for the US is similar to that of other countries.(7) In the Mountain states (i.e., Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) specifically, firearm suicide rates increased 30.4% from 2005-2019 and are consistently among the top ten in the US.(1)

Federal firearm safety and control reforms are controversial and difficult to enact and enforce, making state governments responsible for most firearm policymaking.(8) Frequently, in the US, policies are enacted to curb homicide after incidents of highly-publicized mass shootings, even though most firearm mortality is attributable to suicide.(1,9) Even so, these policy changes often have implications for firearm suicide through the mechanism of supply or access restriction.(2,3,8) There is evidence demonstrating that stricter firearm safety laws enacted at the state level, such as child access prevention laws(10) and risk-based, time-limited civil protection orders for firearm removal(11) can reduce the rate of firearm suicide. However, these policies are enacted inconsistently from state to state, leaving many firearm-related issues unaddressed and motivating municipalities to enact firearm policies consistent with dangers or

concerns specific to their citizens. This issue has caused controversy between state and local governments, including in Richmond, Virginia, where a state preemption law prevented banning firearms at a white supremacist rally but allowed banning of less-lethal weapons (e.g., knives).(12,13)

Tensions between Arizona's government and local legislators in Tucson have been particularly problematic for firearm policymaking.(14) Absent action from state legislators, local policymakers in the city of Tucson passed an ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed, resulting in the elimination of over 4,800 firearms in Pima County from 2013-2016.(14) However, in 2016, the Arizona legislature enacted SB 1487 to preempt Tucson's ordinance. Upheld by the Arizona Supreme Court, SB 1487 forced Tucson to stop the destruction of confiscated firearms and resell the firearms to the public by auction or face an annual financial penalty of $115 million.(15)

For these reasons, SB 1487 likely disrupted the number of firearms in Tucson in two ways. First, SB 1487 no longer allowed Tucson police to actively accept firearms voluntarily turned in by citizens or through buyback programs for the purpose of destroying those firearms. Second, SB 1487 required Tucson to resell all confiscated or forfeited firearms through a local auctioneer. The city of Tucson auctions resold nearly 600 firearms in just one five-month period in 2017,(16) and many firearms likely reentered Tucson and surrounding communities through 2019. The legal implications of SB 1487 have been discussed elsewhere,(17) such as conceding to states over firearm-related policymaking, restricting local efforts to enact public safety interventions, and imposing one of the most punitive fiscal measures known to be applied to local government in the US. However, less is understood about the health-related implications of Arizona's 2016 preemption law, specifically how it may have affected firearm suicide rates in

the greater Tucson area. This example of an exogenous local policy affecting the Tucson (Pima County) area relative to other counties in Arizona provided ideal conditions for a natural policy experiment.(18)

Our objective was to examine whether firearm suicide rates increased in Pima County relative to other Arizona counties following Arizona's 2016 preemption law. Given the systematic link between firearm availability and suicide, and considering the availability of same-day firearm purchasing in Arizona,(19) we hypothesized that firearm suicide rates (but not non-firearm suicide rates) would increase in Pima County following the enactment of SB 1487, which restricted local firearm destruction and likely introduced of a new supply of firearms in Tucson-area communities.

METHODS

Data & Study Design

Our primary data source was the Centers for Disease Control and Prevention (CDC) WONDER system,(20) an interactive database compiling information on the underlying causes of death in the US. Data from the Bureau of Labor Statistics (BLS) Local Area Unemployment statistics program;(21) Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Federal Firearms Licensees database;(22) and the Area Health Resource Files (AHRF) were also used. CDC data restrictions prevent the analysis of county-level suicide rates involving less than 10 decedents. For this reason, counties with restricted data were excluded from the analysis. This included the 6 least-populated counties (with also the lowest firearm suicide counts) in Arizona. The remaining counties represented 93.4% of the state population in 2019 (data not shown).

We used a quasi-experimental study design taking advantage of a natural policy experiment. Our final analytic sample included 54 county-year observations, including 6 observations for each of 9 counties from 2014 through 2019, permitting multiple years of data both before and after the preemption law was enacted.(23)

Dependent variables

Our primary dependent variable was a measure of the annual rate of firearm suicides (ICD-10 codes X72–X74) per 100,000 persons (all ages). Because the 2016 preemption law should not have affected non-firearm suicide rates in Pima County, we also examined a second dependent variable measuring the annual rate of non-firearm suicides per 100,000 persons (all ages) as a robustness test. Both variables were created using data extracted from the CDC WONDER system.

Independent variables

There were two independent policy variables. The first variable was an indicator of being affected by Arizona's preemption law, SB 1487. Arizona enacted the preemption law in 2016 to nullify Tucson's ordinance allowing the Tucson Police Department to destroy unclaimed and forfeited firearms and instead required the firearms to be made available through resale. The variable equaled 1 for Pima County (Tucson-area) observations (policy group) and 0 for all other county observations (comparison group).

The second variable was a measure of policy enactment timing equal to 1 for observations after the 2016 law was enacted and 0 for observations before 2016.

Covariates

Our empirical approach assumes that confounders varying across the policy and comparison groups are time-invariant and time-varying confounders are group invariant. Our fully-adjusted multivariate statistical models included a vector of covariates to absorb residual variance in the outcomes and adjust for potential confounding factors varying between the two groups. Population demographic covariates included county-level measures of age (% of population <25yo), gender (% of population male), and race (% of population white) in each county-year. BLS data were used to adjust for differences in county-level unemployment rates, a proxy for socioeconomic status differences shown to be correlated with suicide risk.(24) ATF data were used to construct a county-level proxy measure of firearm ownership, as firearm availability is associated with suicide.(2) The variable adjusted for the per capita rate of Category 1 and Category 2 federal firearm licenses in each county-year, which may be the most suitable proxy for county-level analyses.(25) Recent studies have shown mental health professional shortage areas are associated with higher suicide rates at the county level.(26) For this reason, we also included a measure of mental health professional shortage area status (partial or full shortage area county-year) using data from the AHRF, as defined by the US federal government.(27)

Analysis

We used a linear two-group, two-period difference-in-differences (DID) estimation approach to examine the effect of SB 1487 as a widening or narrowing of the gap in suicide rates in Pima County compared to 8 other Arizona counties from the pre-policy-enactment period to the post-policy-enactment period.(18) The pre-policy-enactment reference period was the average of outcomes from 2014 and 2015. We estimated four models using the following general regression approach:

$$Y_{ct} = \beta_0 + \beta_1 Policy\ Group + \beta_2 Post\text{-}Policy\ Enactment\ Period + \beta_3 (Policy\ Group \times Post\text{-}Policy\ Enactment\ Period) + \mathbf{B}Z_{ct} + \varepsilon_{ct} \quad (1)$$

where Y_{ct} was the annual firearm (or non-firearm) suicide rate for county c at time t, including the vector of covariates (Z_{ct}) in the adjusted models.

Model 1 estimated the policy parameters (independent variables) without covariate adjustment for our primary dependent variable. Model 2 estimated the policy parameters with covariate adjustment. As a robustness test, we also estimated Models 3 and 4 examining the effects of the 2016 preemption law on measure of non-firearm suicide rates in the policy and comparison group counties.

The coefficient of interest was the DID policy estimate (β_3) for the interaction of the two independent variables, coinciding with Arizona's decision to enact the 2016 law preempting Tucson's firearm destruction ordinance. This empirical approach assumed that absent the 2016 policy, the average changes in the firearm suicide rates would have been the same in both Pima County (Tucson area) and the comparison group counties, known as the common trends assumption.(28,29) β_3 is thus an estimate of the change in Pima County's average firearm suicide rate from the pre-policy-enactment to the post-policy-enactment period minus the change in the comparison group counties' average firearm suicide rate over the time period. This approach also assumed that there were no other unmeasured policy changes or factors coinciding with the timing of Arizona's 2016 preemption law that could have affected firearm suicide rates in Pima County relative to the comparison group counties.

A corollary of this common trends assumption was examined graphically below.(18,30) We also conducted a placebo test of the expected policy effects and pre-policy common trends assumption.(23) For this test, we performed an additional DID estimation using a "fake" policy

group for our primary dependent variable. Specifically, we replicated our estimation of Model 2 using Maricopa County observations for our policy group and all other non-Pima counties for the comparison group. Because the 2016 preemption law should not have affected firearm suicide rates in Maricopa County relative to the other comparison counties, the DID estimate (β_3) from the placebo test model should not statistically differ from 0.

To correct for serial correlation and heteroskedasticity in the error terms, robust standard errors were clustered at the county level, and the statistical models were weighted by county-year population. We established an a priori two-sided significance level of 0.05. All analyses were conducted using Stata version 17.0 (College Station, TX).

RESULTS

Across the study period, the comparison group counties had an average of 14.87 firearm suicides per 100,000 persons per year, compared to 11.56 firearm suicides per 100,000 persons per year in Pima County (Table 1). Figure 1 illustrates the geographic variation in firearm suicide rates for each Arizona county in 2019, as well as the relative land size of each county. By 2019, Pima County's firearm suicide rate increased to 14.13 deaths per 100,000 persons. Figure 2 describes the unadjusted firearm suicide rates in Pima County and the comparison group counties from 2005 through 2015, depicting similar pre-policy trends between Pima County and the comparison group counties.(18) This suggests the corollary of the common trends assumption was satisfactory for our dependent variable of interest. Supplemental Figure A1 describes the unadjusted non-firearm suicide rates over the study period.

Table 2 presents our multivariate analysis findings. The Model 1 results show Arizona's enactment of the 2016 preemption law was associated with an increase in Pima County's firearm suicide rate by an additional 1.20 suicides per 100,000 persons from the pre-policy period to the

post-policy period, relative to the change over the same period in the comparison group counties (95% CI 0.79, 1.61; P<0.01). Model 2 produced similar estimates of the effect of the 2016 preemption law following covariate adjustment. In the adjusted model, a 1.13 increase in Pima County's firearm suicides per 100,000 persons coincided with the enactment of the 2016 law, relative to the comparison group counties over the same period (95% CI 0.51, 1.74; P<0.01). Consistent with previous studies, our proxy for firearm availability was also positively associated with higher suicide rates.(25)

The results of our placebo test are shown in supplemental Table A1. The DID estimate from the placebo test model did not statistically differ from zero at the 0.05 level (β_3 = -0.86; 95% CI -2.36, 0.64; P = 0.216). In other words, the 2016 preemption law did not significantly affect firearm suicide rates in the "fake" policy group (Maricopa County), compared to the remaining comparison group counties. These supplemental results further suggest the common trends assumption was satisfactory for our main outcome. If the DID estimate from the placebo test significantly differed from zero, the impact would have likely come from some underlying difference in the trends between the two groups. In turn, this would cast doubt on the assumption of similar pre-policy trends between our main policy and comparison groups.

Supplemental Table A2 shows the results of our robustness test, describing the estimated effects of the 2016 preemption law on non-firearm suicide rates in Pima County. In Models 3 and 4, the new law was not statistically associated with changes in the non-firearm suicide rate. In the adjusted model (Model 4), and in contrast to the main firearm suicide model results, the proxy for firearm availability was also not associated with the non-firearm suicide rate. The unemployment rate was associated with lower non-firearm suicide rates in the adjusted model (β = 0.33; 95% CI 0.02, 0.64; P=0.03; Model 4).

DISCUSSION

Our findings suggest a modest but statistically significant increase in the firearm suicide rate in Pima County (greater Tucson area) during the years following the enactment of Arizona's 2016 preemption law. Relative to the comparison counties, the 2016 law coincided with a 10.9% relative increase in the firearm suicide rate in Pima County from the pre-policy period to the post-policy period. Although the mean annual firearm suicide rate was higher in the comparison group counties over the full study period (Table 1), by 2019, the firearm suicide rate in Pima County increased and was nearly equivalent to the firearm suicide rate in the comparison counties (14.1 and 14.6 per 100,000 persons, respectively).

Despite having a firearm suicide rate 52.4% higher than the national average,(1) the state of Arizona responded to firearm safety and control policies adopted by the local Tucson government with a preemption measure including significant punitive financial consequences.(17) Other authors – and this paper – have demonstrated and discussed the link between firearm availability and suicide rates.(2,3,31,32) Following Arizona's 2016 preemption law, Tucson was not only no longer able to destroy confiscated and forfeited firearms, but it was also required to redistribute those firearms by way of auction. As additional firearms may have reentered the greater Tucson area through 2019 (and were no longer removed and destroyed), our findings suggest SB 1487 may have contributed to higher firearm suicide rates in Pima County relative to other counties not targeted by the new law. Not surprisingly, we also found the 2016 preemption law did not impact non-firearm suicide rates in Pima County relative to other counties over the same period, further suggesting that SB 1487 affected firearm suicide specifically in Pima County.

State preemption of municipal policies has several adverse consequences for localism, resting on the idea that state power supersedes local government and that municipalities are relegated to primarily executing state policy.(33) This notion can be detrimental to public health. Preemption efforts interfering with local firearm safety policies have been supported and encouraged by the firearm industry.(34,35) State preemption of local government authority on other public health issues such as nutrition policy(36,37) and tobacco control(38) have also been documented, seemingly used by organized interests to wield power over local public health initiatives. Following a strategic push by several influential lobbying entities, over 40 states have passed some version of preemptive law designed to undermine local authority over firearm safety.(36,39) Our study is the first to empirically show that state preemption of local firearm laws appears to have specifically affected suicide-related outcomes.

Limitations

This study had several limitations, and readers should carefully interpret the findings. First, unobserved characteristics not accounted for in Models 2 and 4 may have biased our estimates, imposing limits to causal interpretations of our findings. Specifically, we did not adjust for county-level measures of veteran population size or the unmet mental health care needs. Veteran status and different mental illnesses are often suicide risk factors, although mental illness is less likely to be diagnosed among those who use firearms for suicide.(40) We also could not directly adjust for firearm availability, though we used the proxy measure of firearm availability most recommended for county-level analysis in an attempt to address this concern.(25) We also assumed that there were no other unmeasured policy changes coinciding with the timing of Arizona's 2016 preemption law that could have affected firearm suicide rates

in Pima County relative to the comparison group counties. As with other non-experimental studies, our findings should be interpreted as correlative, not causal.

Second, because we conducted a county-level analysis and estimated the effects of the 2016 preemption law on county-level firearm suicide rates, readers should refrain from making inferences about individual behavior. For example, we could not directly examine at the person level whether Arizona's 2016 preemption law resulted in suicidal persons acquiring firearms that would have previously been confiscated and destroyed by Tucson police or newly resold firearms to make suicide attempts.

Third, Tucson was the municipality with the firearm destruction policy, yet city-level data were unavailable, and data were aggregated at the county level. Tucson is the only city in Pima County, and the Tucson metropolitan statistical area is defined as Pima County. The majority of Pima County resides in Tucson, which demographically resembles the county as a whole. However, smaller rural areas in Pima County may have been less sensitive to the potential increase in firearms available through auction after SB 1487. It may be more likely they already possessed firearms, though not necessarily handguns,(41) which is the type of firearm used in most urban and rural suicides.(42)

Fourth, SB 1487 likely disrupted the number of firearms in Tucson in two ways. First, SB 1487 no longer allowed Tucson police to actively accept firearms voluntarily turned in by citizens or through buyback programs for the purpose of destroying those firearms. Second, SB 1487 required Tucson to resell all confiscated or forfeited firearms through a local auctioneer. Tucson's 2005 ordinance contributed the elimination of over 4,800 firearms from 2013-2016.(14) However, in this and other studies, data limitations preclude knowing the actual number of firearms in a community. Because we cannot directly measure the number of firearms

before and after the policy change, we make a logical assumption that more firearms entered Pima County after the new policy was enacted. Notably, the Tucson firearm auctions were administered in-person and online to persons with federal firearms licenses (e.g., dealers and pawnbrokers) by a third-party auctioneer based in Tucson.

Fifth, and related, it is possible persons outside the city of Tucson could have won the confiscated and forfeited firearms; however, it is likely many bidders were from the greater Tucson area because the auctioneer was located in Tucson and the auctions were advertised locally. Notably, some firearms sold for as little as $15.(43) It is feasible local pawnbrokers and dealers could have won the firearms cheaply and then resold them at a discount. Persons seeking firearms may be more likely to purchase them from pawnbrokers or dealers than at a government auction. Beyond the general link between greater firearm availability and suicide risk, studies have suggested some persons purposely buy firearms with the intent of suicide.(44)

Finally, as described earlier, CDC data restrictions prevented us from constructing our dependent variables for all Arizona counties. The generalizability of our results is limited to the comparison counties included in our analytic sample; however, the included counties represented about 93.4% of the state population in 2019.

CONCLUSIONS

Access to firearms exacerbates suicide risk,(2,3) yet the risk of substitution towards other methods when highly-lethal methods are absent is likely small,(45) especially during a suicidal crisis. Although the extent to which Tucson's 2005 ordinance contributed to lower firearm suicide rates remains elusive, the ordinance resulted in the elimination of over 4,800 firearms from 2013-2016 alone. In turn, Arizona's 2016 preemption law preempting Tucson from

enacting or enforcing policies to decrease local firearm availability coincided with higher firearm suicide rates in Pima County.

Just as the medical community and policymakers can advocate for state-level firearm reforms shown to prevent suicide,(8,11) policy actors and advocates must also be aware of other state-level policy issues that can intentionally or unintentionally affect suicide risk in their states. Further examination of existing preemption laws is needed to determine whether these policies are counterproductive to suicide prevention efforts, including additional analyses of the effects of Arizona's 2016 preemption law over time. The research community must also continue to evaluate relationships between preemption law and broader public health measures.

CONTRIBUTORS

EG planned the concept and study design, performed the data analysis, and drafted and revised the manuscript. LP contributed to the study design, data interpretation, and manuscript revision. Both authors revised and approved the final manuscript.

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COMPETING INTERESTS

None declared.

PATIENT AND PUBLIC INVOLVEMENT

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

PATIENT CONSENT FOR PUBLICATION

Not applicable.

ETHICS APPROVAL

This study conducted secondary data analysis of public use data and did not rise to the level of “human subjects research" per the University of Utah IRB policy on Secondary Data Analysis of Public Use Datasets (B2819).

DATA AVAILABILITY STATEMENT

Data are available in a public, open access government locations at https://wonder.cdc.gov/ and https://www.atf.gov/resource-center/data-statistics and https://www.bls.gov/lau/.

FIGURE CAPTIONS

Figure 1. Firearm suicides per 100,000 persons in Arizona, by county: 2019. Notes: Authors' analysis of the CDC WONDER data. This map describes the firearm suicide rate per 100,000 persons in 2019 for each county included in our analyses. This map also illustrates the relative land size of each Arizona county. Pima County had 14.13 firearm suicide per 100,000 persons in 2019. Counties excluded from our analyses are shown in white.

Figure 2. Unadjusted trends in the firearm suicide rate, by policy group, 2005-2019. Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in firearm suicide rates between Pima County (**solid black line**) and comparison group counties (**dashed black line**) from 2005-2019, allowing for a visual examination of the pre-policy common trends assumption in the primary dependent variable. The post-policy enactment period was 2016-2019. Tucson's ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed was adopted in 2005 and would have been implemented in subsequent years.

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Tables

Table 1. Characteristics of the pooled analytic sample, by policy group: 2014-2019

	Policy Group		Comparison Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Firearm suicides per 100,000 persons	11.56	1.52	14.87	6.28
Non-firearm suicides per 100,000 persons	8.74	0.83	10.66	5.24
Unemployment rate, %	4.95	0.67	7.77	4.64
Population white, %	86.59	0.25	82.49	14.44
Population <25yo, %	33.19	0.72	31.86	5.77
Population male, %	49.19	0.03	50.34	1.05
Per capita rate of federal firearm licenses	0.00019	0.00001	0.00034	0.00016
Mental Health Professional Shortage Area Status				
Partial shortage area county-years, %	33.33	0.52	34.04	0.48
Full shortage area county-years, %	66.67	0.52	65.96	0.48

Notes: Authors' analysis of the CDC WONDER, BLS, ATF, and AHRF data. For each variable shown in the table, unadjusted mean annual percentages or rates are shown from across the study period. The policy group contained 6 observations and the comparison group contained 48 observations.

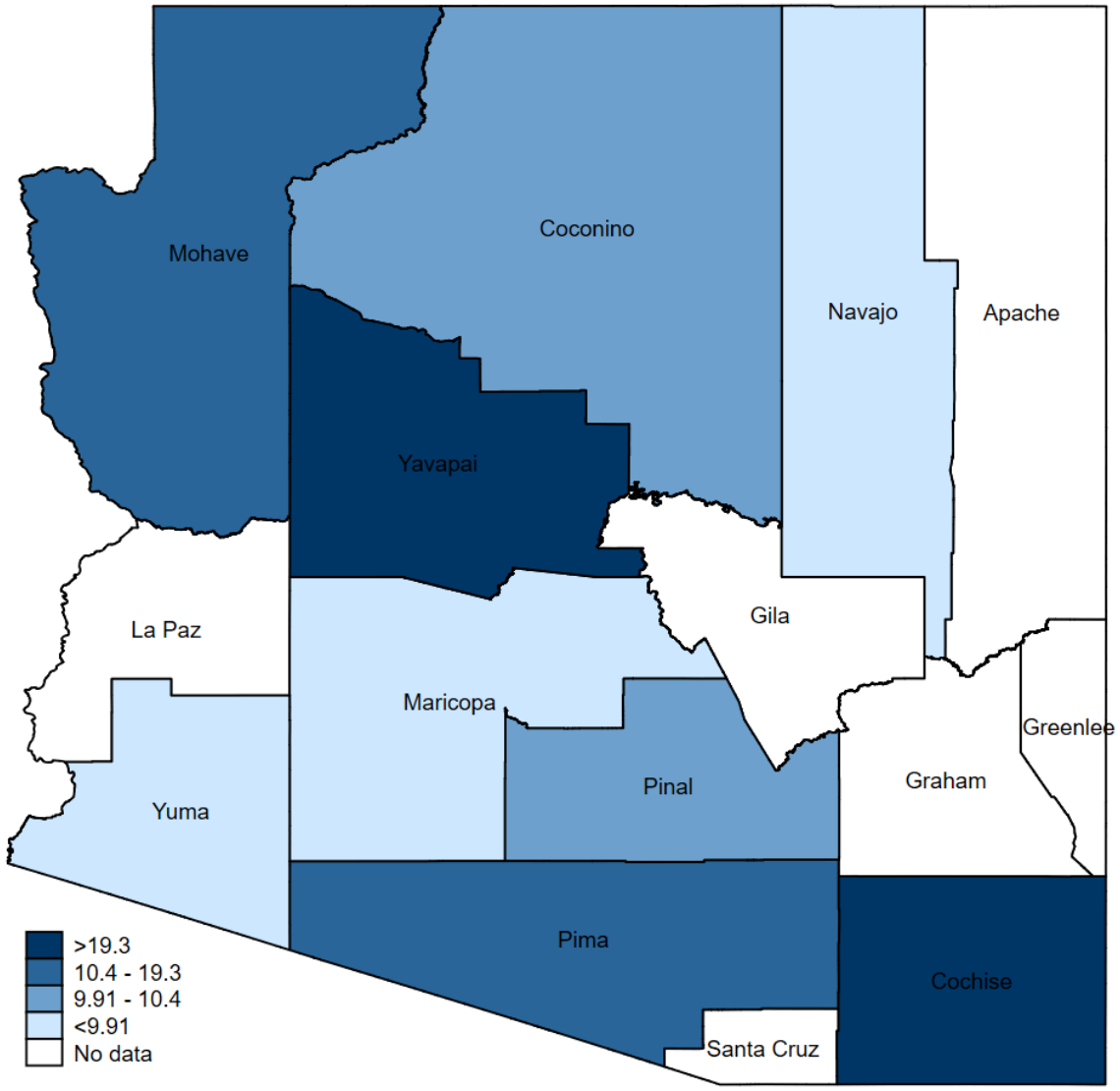
Table 2: Estimating the effect of Arizona's 2016 preemption law on firearm suicide rates in Pima County: 2014-2019

	1 *Unadjusted Model*	2 *Adjusted Model*
Policy variables		
SB 1487 exposure		
Comparison group	Ref	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	0.13 (-3.03, 3.29)	0.52* (0.13, 0.90)
Policy enactment timing		
Pre-policy enactment	Ref	Ref
Post-policy enactment	0.67** (0.26, 1.08)	0.30 (-0.34, 0.90)
Policy group x Post-policy enactment (difference-in-differences estimate)	1.20** (0.79, 1.61)	1.13** (0.51, 1.74)
Covariates		
Unemployment rate (%)		0.24** (0.02, 0.39)
Population white (%)		-0.10** (-0.17, -0.03)
Population <25yo (%)		-0.75** (-1.06, -0.42)
Population male (%)		-0.53* (-0.92, -0.14)
Per capita rate of federal firearm licenses		20,066.99** (12,901.60, 27,232.37)
Mental Health Professional Shortage Area Status		
Partial shortage area		Ref
Full shortage area		0.22 (-1.05, 1.50)
Constant	10.192** (7.03, 13.34)	64.97** (32.80, 97.14)
Observations	54	54
R-squared	0.02	0.90

Notes: + P < 0.10, * P < 0.05, ** P < 0.01. Authors' analyses of CDC WONDER, BLS, ATF, and AHRF data. 95% confidence intervals (CIs) shown in parentheses. Observations reflect county-year data. The "Policy Group x Post-Policy Enactment" coefficient is the difference-in-differences (DID) policy estimate attributable to the state's decision to enact the law preempting Tucson's ordinance allowing destruction of unclaimed and forfeited firearms.

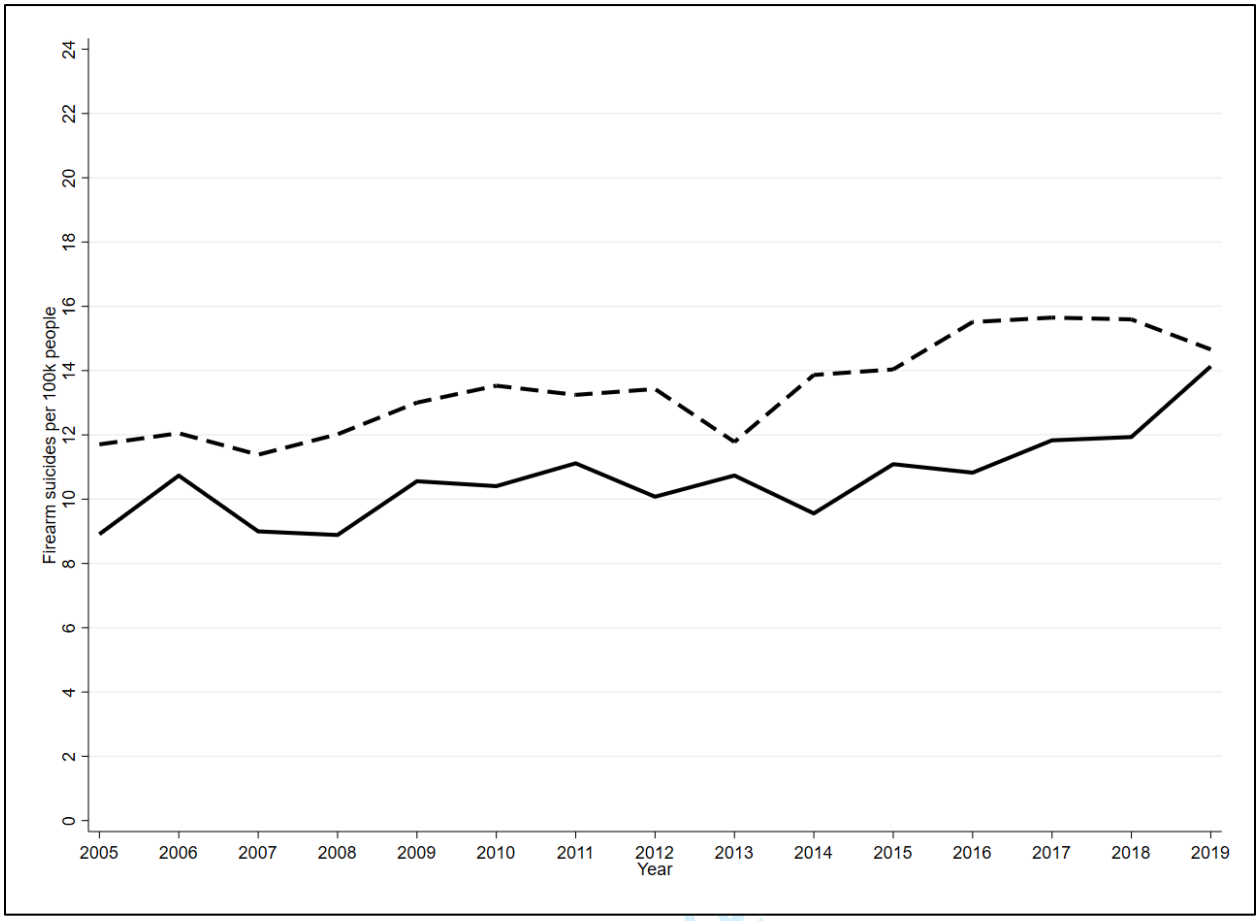
The DID estimate tested the difference in the changes in the average suicide outcomes from the pre-policy-enactment period to the post-policy-enactment period between Pima County and the comparison group counties.

Figure 1. Firearm suicides per 100,000 persons in Arizona, by county: 2019



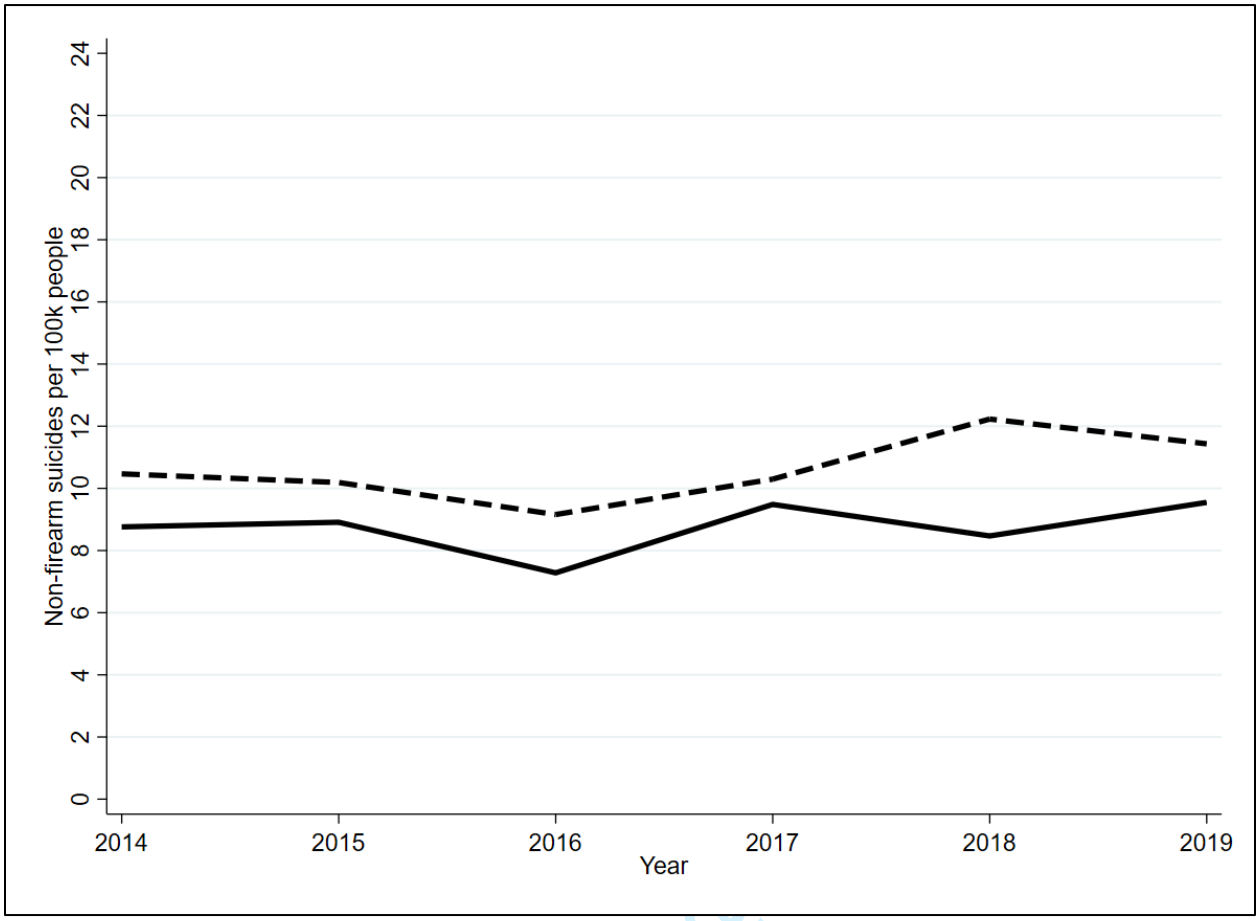
Notes: Authors' analysis of the CDC WONDER data. This map describes the firearm suicide rate per 100,000 persons in 2019 for each county included in our analyses. This map also illustrates the relative land size of each Arizona county. Pima County had 14.13 firearm suicide per 100,000 persons in 2019. Counties excluded from our analyses are shown in white.

Figure 2. Unadjusted trends in the firearm suicide rate, by policy group, 2005-2019



Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in firearm suicide rates between Pima County (**solid black line**) and comparison group counties (**dashed black line**) from 2005-2019, allowing for a visual examination of the pre-policy common trends assumption in the primary dependent variable. The post-policy enactment period was 2016-2019. Tucson's ordinance requiring firearms confiscated by (or voluntarily surrendered to) Tucson police to be destroyed was adopted in 2005 and would have been implemented in subsequent years.

Figure A1. Unadjusted trends in the non-firearm suicide rate, by policy group, 2014-2019



Notes: Authors' analysis of CDC WONDER data. This figure shows the unadjusted trends in non-firearm suicide rates between Pima County (solid black line) and comparison group counties (dashed black line) over the study period.

Table A1. Placebo test estimating the effect of Arizona's 2016 preemption law on suicide outcomes in Maricopa County: 2014-2019

	1 *Adjusted Model*
Policy variables	
SB 1487 exposure	
Comparison group	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	-1.297
	(1.473)
Policy enactment timing	
Pre-law enactment	Ref
Post-law enactment	1.087
	(0.73)
Policy group x Post-law enactment (difference-in-differences estimate)	-0.864
	(0.635)
Covariates	
Unemployment rate (%)	0.173+
	(0.083)
Population white (%)	-0.078*
	(0.03)
Population <25yo (%)	-0.699**
	(0.12)
Population male (%)	-1.088+
	(0.48)
Per capita rate of federal firearm licenses	16,116.934**
	(2,784.19)
Mental Health Professional Shortage Area Status	
Partial shortage area	Ref
Full shortage area	0.533
	(0.422)
Constant	90.650**
	(22.247)
Observations	48
R-squared	0.91

Notes: * P < 0.05, ** P < 0.0.1. Authors' analyses of CDC WONDER, BLS, ATF, and AHRF data. Standard deviations are shown in parentheses. Observations reflect county-year data. For this placebo test, the "Policy Group x Post-Law Enactment" coefficient is the difference-in-differences (DID) policy estimate of interest. The DID estimate tested the difference in the changes in average firearm suicide rates from the pre-policy-enactment period to the post-policy-enactment period between Maricopa County and the comparison group counties excluding Pima County.

Table A2: Estimating the effect of Arizona's 2016 preemption law on non-firearm suicide rates in Pima County: 2014-2019

	Model 3 *Unadjusted Model*	**Model 4** *Adjusted Model*
Policy variables		
SB 1487 exposure		
Comparison group	Ref	Ref
Policy group (Enactment of state law, SB 1487, preempting gun disposal ordinance in Tucson, Pima County)	0.80	1.16**
	(-0.846, 2.452)	(0.623, 1.693)
Policy enactment timing		
Pre-policy enactment	Ref	Ref
Post-policy enactment	-0.34	-0.94+
	(-1.09, 0.40)	(-1.92, 0.03)
Policy group x Post-policy enactment (difference-in-differences estimate)	0.21	0.18
	(-0.53, 0.95)	(-0.84, 1.21)
Covariates		
Unemployment rate (%)		0.33*
		(0.02, 0.64)
Population white (%)		-0.33**
		(-0.48, -0.18)
Population <25yo (%)		-0.46+
		(-1.08, 0.15)
Population male (%)		-0.94*
		(-1.66, -0.23)
Per capita rate of federal firearm licenses		8,389.44
		(-5,511.819, 22,290.7)
Mental Health Professional Shortage Area Status		
Partial shortage area		Ref
Full shortage area		-0.83
		(-1.87, 0.21)
Constant	8.033**	96.34**
	(6.38, 9.68)	(31.75, 160.93)
Observations	54	54

R-squared	0.02	0.69

Notes: + P < 0.10, * P < 0.05, ** P < 0.01. Authors' analyses of CDC WONDER, BLS, ATF, and AHRF data. 95% confidence intervals (CIs) shown in parentheses. Observations reflect county-year data. The "Policy Group x Post-Policy Enactment" coefficient is the difference-in-differences (DID) policy estimate attributable to the state's decision to enact the law preempting Tucson's ordinance allowing destruction of unclaimed and forfeited firearms. The DID estimate tested the difference in the changes in the average suicide outcomes from the pre-policy-enactment period to the post-policy-enactment period between Pima County and the comparison group counties.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cross sectionalreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2

Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	#3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	#4	Present key elements of study design early in the paper	6-9
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	6-7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-8

Bias	#9	Describe any efforts to address potential sources of bias	8-9
Study size	#10	Explain how the study size was arrived at	6-7
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	7-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	8-9
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	N/A. No interactions or subgroups.
Statistical methods	#12c	Explain how missing data were addressed	N/A. No missing data.
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	N/A
Statistical methods	#12e	Describe any sensitivity analyses	7-9. Models 3 and 4, robustness outcome.
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the	8-9, 21

		study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	N/A
Participants	#13c	Consider use of a flow diagram	N/A
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9, 21, Supplementary File
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	N/A - no missing data.
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	21
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10, 22
Main results	#16b	Report category boundaries when continuous variables were categorized	N/A

Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	10, 22
Discussion			
Key results	#18	Summarise key results with reference to study objectives	10-11
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	12-14
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11
Generalisability	#21	Discuss the generalisability (external validity) of the study results	11, 13
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

Notes:

- 12b: N/A. No interactions or subgroups.
- 12c: N/A. No missing data.
- 12e: 7-9. Models 3 and 4, robustness outcome.
- 14a: 9, 21, Supplementary File
- 14b: N/A - no missing data. The STROBE checklist is distributed under the terms of the Creative Commons Attribution License CC-BY. This checklist was completed on 08. October 2021 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai