Gun-free zones and active shootings in the United States: a matched case-control study

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Summary

Background Most Americans believe that gun-free zones make locations more vulnerable to violent crimes, particularly active shootings. However, there is no empirical evidence regarding the impact of gun-free zones on protecting locations from violence. The objective of this study was to estimate the association between gun-free zones and active shootings.

Methods We used a pair-matched case-control study where cases were all US establishments where active shootings occurred between 2014 and 2020, and controls were randomly selected US establishments where active shootings could have but did not occur, pair-matched by establishment type, year, and county. Gun-free status of included establishments was determined via local laws, company policy, news reporting, Google Maps and posted signage, and calling establishments.

Findings Of 150 active shooting cases, 72 (48.0%) were determined to have occurred in a gun-free zone. Of 150 controls where no active shooting occurred, 92 (61.3%) were determined to be gun-free. After accounting for matched pairs, the conditional odds of an active shooting in gun-free establishments were 0.38 times those in non-gun-free establishments, with a 95% confidence interval of 0.19–0.73 (p-value = 0.0038). Several robustness analyses affirmed these findings.

Interpretation It is unlikely that gun-free zones attract active shooters; gun-free zones may be protective against active shootings. This study challenges the proposition of repealing gun-free zones based on safety concerns.

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Introduction

Active shootings are defined as incidents where an individual (or pair of individuals) intentionally and indiscriminately shoots at bystanders in a public place.[1] In the United States, mass shootings, a subset of active shootings where four or more people are killed, have occurred at a higher rate than in any other developed country; an estimated 73% of all mass shootings and 62% of resulting fatalities have happened in the US.[2] Active (and mass) shootings occur frequently enough that one-third of US adults report avoiding certain public places for fear of being a victim of one of these tragedies.[3]

One hypothesis about why the United States bears the burden of the majority of active shootings among developed countries is the nation's high gun ownership rate. Studies have found that countries[4] and US states[5,6] with higher rates of gun ownership also have significantly higher rates of mass shootings. This is disputed by some gun-rights activists, who contend that the occurrence of active shootings is due to the presence of "gun-free zones," although this position is not

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Research in context

Evidence before this study

Prior to undertaking this study, we conducted an extensive literature review on the topic of gun-free zones and their relationship to active or mass shootings. We utilized two primary databases: PubMed and Scopus. The search was comprehensive, covering publications from their inception until the end date of our search in May 2022. We included studies without restriction to publication language. The search terms employed included "gun-free zones," and "gun free zones." Our inclusion criteria required that studies provide quantitative data on the impact of gun-free zones, while our exclusion criteria eliminated studies lacking empirical data or focusing solely on theoretical frameworks without quantitative analysis. Despite this thorough search, we found no quantitative studies addressing the impact of gun-free zones on any form of violent crime, including active or mass shootings. Furthermore, the RAND Corporation conducted an independent literature review, corroborating our findings. Their review similarly found no evidence indicating that gun-free zones have either increased or decreased any firearm-related outcome. This lack of empirical evidence underscores the necessity for our study to fill this critical gap in the literature.

Added value of this study

This study is the first ever to estimate to association between gun-free zones and the occurrence of active shootings. The findings from this study can be used to inform the public, politicians, and policy makers about the impact of gun-free zones on active shootings.

Implications of all the available evidence

Since this is the first study conducted on the topic, more studies are needed to create consensus. However, the results of this study suggest that gun-free zones do not attract active shooters, and instead may prevent active shootings. This is an important finding given recent calls to repeal gun-free zones in the United States. This is also in line with other research that suggests that places with more firearms have higher rates of firearm violence.

supported by the peer-reviewed literature.[7,8] Gun-free zones are locations, areas, or establishments where the carrying of firearms is prohibited by members of the public. Gun-free zones are maintained through federal, state, and local laws, as well as policies implemented by private and/or non-governmental entities, such as certain companies and universities.[9] Gun-free zones are intended to prevent shootings, although some believe that they instead invite active shootings due to a presumed lower probability of defensive gun use occurring within their borders.[8] This latter idea has likely influenced public perceptions of gun-free zone effectiveness: one random sample survey representing the US showed that 62% of residents were opposed to gun-free zones, and 65% believed they made locations less safe.[10]

This negative perception of gun-free zones may be due to the inherent confounding that exists in the relationship between gun-free zones and active shootings. Active shootings, by definition, occur in public spaces. Gun-free zones are also much more likely to occur in public spaces, creating a spurious association between gun-free zones and active shootings that may not be causal. Therefore, simple estimates of the percent of active shootings that occur in gun-free zones reveal little about the causal relationship between these two variables. These estimates also vary widely (from 11% to 98%) depending on the source and how an active shooting is defined.[11,12]

Given the intended creation of gun-free zones to prevent shootings and the objections to gun-free zones by gun-rights activists, public uncertainty over their effectiveness is understandable as there have been no controlled, quantitative studies of gun-free zones and active shootings.[13] Moreover, in a systematic literature search, no studies showing that gun-free zones have either increased or decreased any firearm-related outcome were found.[9] This backdrop of uncertainty is further complicated by the Supreme Court's 2022 decision in New York State Rifle & Pistol Association Inc. v. Bruen, which made it more difficult to limit *who* can carry firearms, resulting in some states passing laws based on *where* firearms may be carried. As a result, the aftermath of Bruen has seen a notable rise in both the frequency and success of legal challenges to sensitive place-based restrictions.[14] This shift emphasises the need for empirical research to assess the actual impact of gun-free zones on the incidence of gun violence, with the goal of grounding both policy and public discourse in solid evidence. Therefore, the aim of this study was to fill this gap by examining the associations between establishments' status as gun-free vs. gun-allowing and their risks for experiencing an active shooter incident. We hypothesised that establishments that were gun-free were less likely to have experienced an active shooting.

Methods

Design

The design of this investigation was a matched case-control study in the United States. Cases were all US establishments where active shootings occurred between 2014 and 2020, and controls were randomly selected US establishments where active shootings could have but did not occur, pair-matched by establishment type/function, year, and county. Given the subjects of the study were establishments, IRB approval

was not required. This determination aligns with regulatory guidelines stipulating that IRB oversight is mandated only for studies involving living individuals or animals to ensure their protection and ethical treatment.

Data sources

The cases—active shootings—were obtained from the FBI's active shooting database,[15] the New York Police Department (NYPD) database of active shootings,[16] the Mother Jones database of mass shootings,[17] the Secret Service's database of attacks in public places,[18] and the Violence Project's mass shooting database.[19] Cases were only included if they matched the definition of an active shooting: incidents where an individual (or pair of individuals) intentionally and indiscriminately shoots at bystanders in a public place. This definition is based off of intent. A case would still be included if it fit the definition, but no one was injured or killed. Repeats were excluded. More detail on the inclusion criteria of each database is included in Appendix Table 1. Schools were excluded from the analysis due to all schools being "gun-free zones" as a result of the Gun-Free Zones School Act of 1990.[20]

The controls—business establishments that have not experienced an active shooting— were obtained from the U.S. Business Database,[21] which includes information on over 70 million active businesses in the United States. Controls were pair-matched using the Standard Industrial Classification code (SIC) and county. Additionally, the business must have been open at the same time as the case. The U.S. Business Database numbers the results, and to facilitate random selection, a random number generator was used to select the controls. If a location was not represented in the U.S. Business Database (e.g. a public park), a list containing all the locations in the county was created and a control was randomly chosen from that list. Open spaces (on the street, in an empty field, etc.) were not reflected in this database, and they were chosen by a random pin drop in the same county as the case via Google Maps. Specifically, a program was used that would move the cursor to a random point within a defined, confined area on the screen.[22] If the pin did not fall on an open space (or outside the county due to irregular borders of counties), then a new random pin drop was performed until the pin fell on an open space within the county. Appendix Figure 1 broadly shows the frequency of the different establishment types represented in this study.

Exposure ascertainment

The exposure in this study was the gun-free status of cases and controls. If the active shooting occurred in multiple locations, the first public location was used as the establishment in the analysis, on the assumption that if an active shooter were targeting a gun-free zone they would go there first, and the latter locations may be less likely to be purposely targeted. Furthermore, some of the shootings occurred immediately outside the establishment. In these cases, the case was determined to be gun-free if the establishment itself was gun-free, even if the outside area might not be (i.e. parking lot). This reasonably assumes that if active shooters were targeting gun-free zones, they would expect that the area immediately surrounding a gun-free zone would also be less likely to have armed civilians.

The process and method for obtaining the exposure status was kept the same for both the cases and the controls and based on a process with presumed increasing levels of misclassification. At first, local policies were considered to determine if an establishment was gun-free by law the year of the incident. If gun-free status was undetermined, the posted public policies of businesses or establishments were considered, which were often made public via corporate websites or media releases. If still undetermined, news reports were used, that included both reports of the incident but also of other incidents regarding gun-free policies (e.g. implementation by a specific establishment or controversy related to someone carrying in an establishment where it is not allowed). If the gun-free status was still unknown, then Google Maps, Street View was utilised to see if gun-free signs were posted the year of the incident (for open spaces, Google Maps was also used to determine if the incident happened in a gun-free zone). Finally, if all these methods did not result in knowing the gun-free status of the case or control, the establishment was called on the telephone. A standard script was used for these telephone calls for both cases and controls that asked about the gun-free status of the establishment in the year of the incident. If an establishment did not answer, they were called nine times before choosing a new random control or dropping them as a case. If the caller was hung up on, the case or control was called at a different point in time. Cases were dropped and controls were replaced if determining gun-free status was not possible.

Analysis

The proportion of cases and controls that were gun-free was calculated and compared. A conditional logistic regression (command: *clogit*), via the *survival* package in R 4.1.3 was used to determine the conditional odds of an active shooting occurring in an establishment that was gun-free. The conditional logistic regression equation for this model and explanation is included in Appendix A. The pair-matching accounted for the major known confounders in the analysis: 1) establishment/business type, which accounts for the fact that some places might be more likely to be gun-free and may be more likely to be targeted (i.e. bars), and 2) county, which accounts for the gun laws and norms that may cause an establishment to be gun-free and can increase or decrease the risk of active shooting occurring.[5] In a sensitivity analysis, we added distance to the closest police station to

	Conditional odds	95% Confidence interval	p-value
Main analysis	0.38	(0.19, 0.73)	0.0038
Sensitivity analysis 1[a]	0.37	(0.19, 0.72)	0.0033
Sensitivity analysis 2[b]	0.30	(0.30, 0.68)	0.0039

[a]Adjusted for the nearest police station. [b]Adjusted for exposure ascertainment type.

Table 1: **The association between gun-free zones and conditional odds of an active shooting.**

the case and control as a possible confounder. We also adjusted for exposure ascertainment type in case the ascertainment of the exposure may have biased the results. Finally, to obtain the minimum strength of association that an unmeasured confounder would need to have with both the exposure and the outcome to bring the point estimate to null,[23] we calculated an E-value via the E-value package in R 4.1.3.

Robustness analyses

To explore the potential bias in point estimates, hypothetical scenarios were created by manipulating the data to create possible patterns of misclassification by exposure status. We estimated the impact of these misclassifications of exposure on the association between the conditional odds of an active shooting occurring in an establishment that was gun-free. More information regarding this process is included in Appendix B. To further elucidate the extent of potential measurement error of the exposure ascertainment, the percentage of times each ascertainment method for the exposure was used and the percentage of each exposure ascertainment that resulted in a gun-free designation was compared between the cases and controls. Given phone-calls may be less likely to be accurate than other forms of exposure ascertainment, ten cases and ten controls were also randomly selected that were determined to be gun-free or gun-allowing due to posted company policies, a presumed gold standard. Each establishment was called to determine the extent to which there would be disagreement between the posted company policy and the reported gun-free status on the phone call. Large disagreement would imply that the phone calls were unlikely to be accurate. Little disagreement would imply that phone calls are relatively accurate ways of determining the gun-free status of the cases and controls in this study.

Role of the funding source

The funders had no role in study design, data collection and analyses, decision to publish, or preparation of the manuscript.

Results

Based on the systematic process for obtaining case and control exposure status, we could not determine gun-free status for 1.3% (2/152) of cases who were dropped and 24.6% (37/150) of controls who were replaced in our analyses. Of the 150 active shooting cases, 72 or 48% were determined to have occurred in a gun-free zone. Of the 150 controls where no active shooting occurred, 92, or 61.3% were determined to be gun-free. After accounting for matched pairs, the conditional odds of an active shooting occurring in an establishment that was a gun-free zone were 0.38 times that of an active shooting occurring in an establishment that was not a gun-free zone, with a 95% confidence interval ranging from 0.19 to 0.73 (p-value = 0.0038) (Table 1). In the first sensitivity analysis where distance from case or control to the nearest police station was added as a confounder, the results did not meaningfully change. Specifically, the conditional odds of an active shooting occurring in an establishment that was gun-free were 0.37 times that of an active shooting occurring in an establishment that was gun-allowing, with a 95% confidence interval ranging from 0.19 to 0.72 (p-value = 0.0033) (Table 1). Additionally, adjusting for exposure ascertainment type did not meaningfully change the results (conditional odds: 0.30, with a confidence interval ranging from 0.13 to 0.68, p-value = 0.0039) (Table 1). Finally, the E-value, or the risk ratio that was associated with both the exposure and outcome that would explain away the observed conditional odds ratio of 0.38, was calculated to be 4.78.[23]

Robustness analyses

Between six to nine cases or controls may be misclassified in a manner that biases the estimate away from the null without affecting result significance. Details of this analysis are reported in Appendix B. The numbers of cases and controls, categorised by ascertainment type and gun-free determination, are detailed in Appendix Table 2. Case and control differences in terms of exposure ascertainment type and gun-free determination are displayed in Fig. 1. Reporting was more common among the cases than the controls, while phone calls were more common among the controls. As reported, overall, the controls were more likely to be gun-free (61.3%) compared to the cases (48.0%), a 13.3% difference. Across the ascertainment types, the percentage of times the controls were more likely to be gun-free than the cases ranged from +15.3% among phone calls to +27.5% among reporting (laws and gun-free signs could only be used to determine a place was gun-free).

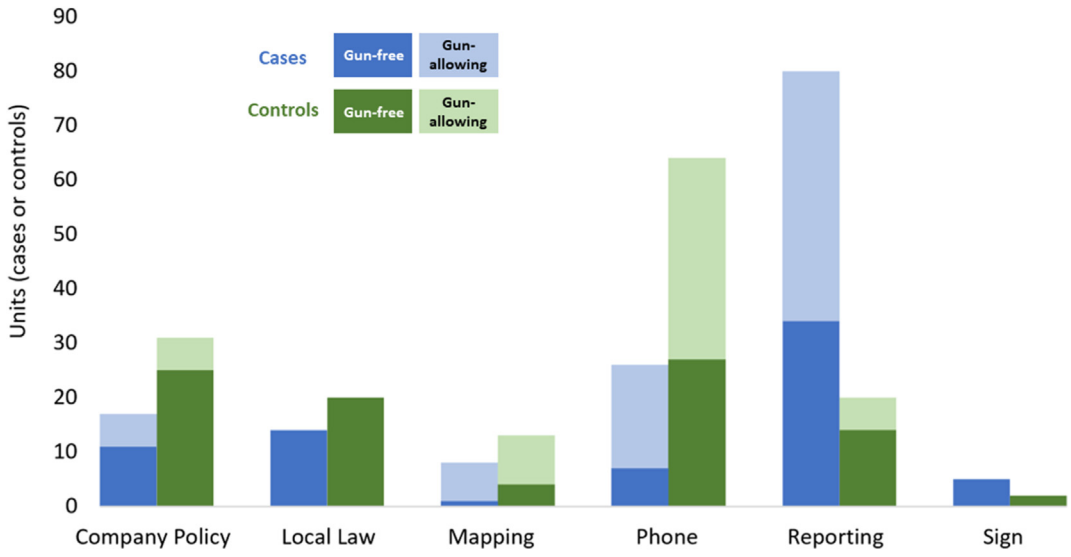

Fig. 1: **Case and control differences in terms of exposure ascertainment type and gun-free determination**.

The disagreement between exposure ascertainment between online company policy (a presumed gold standard) and phone calls among ten cases and ten controls is shown in Appendix Table 3. There was one case of disagreement, or a 5% disagreement rate.

Discussion

The aim of this study was to quantify, for the first time, the impact of gun-free and gun-allowing zones on active shootings. We accomplished this by conducting a national case-control study in the United States where cases were the locations of establishments where active shootings occurred between 2014 and 2020, and controls were randomly selected locations of establishments where active shootings could have but did not occur over the same time period, pair-matched by establishment type/function and county. Adjusted analyses showed that active shootings were 62.5% less likely to occur in gun-free establishments than in gun-allowing establishments, and these results were robust to sensitivity analyses. We therefore conclude that it is unlikely that active shooters are targeting gun-free zones to commit crimes; conversely, places that are gun-free zones may be inversely associated with active shootings. Although this is the first study to evaluate the association between gun-free zones and active shootings, the results are in line with other studies that have found that a higher prevalence of firearms is associated with higher levels of mass shootings, a subset of active shootings. For example, two studies have found that states with higher rates of gun ownership had higher rates of public mass shootings.[5,6] Additionally, multiple studies have consistently shown that higher firearm ownership is associated with higher levels of firearm-related injuries and fatalities at both individual[24,25] and ecological levels.[5,26–28]

The dozens of types of establishment types and the tight connection between establishment type and gun-free zone status necessitated a pair-matched case-control design to ensure that all of the different establishment types represented in the cases were also represented in the controls.[29] There are few case-control studies that use physical locations as their units of analysis and no such studies that do so focusing on gun-free zones. However, location-based case-control studies are not without precedent. For example, schools have been used as the units of analysis in at least three different case-control studies, to evaluate risk factors for child pedestrian motor vehicle accidents[30] and infectious disease.[31] One of these studies[31] also pair-matched its cases and controls on county, to account for the difficult to measure underlying causes of H1N1 that vary by locality. This is akin to the matching in this study to account for the many county level variables that were not possible to measure but that may have distorted our findings.

Despite a relatively large point estimate and significant results, our study has limitations. Importantly, these findings are limited in their generalizability regarding gun-free school zones, despite being the main target of criticism by gun-rights activists.[32] This is because, with few exceptions, all schools are gun-free by federal law,[20] and the addition of schools to the analysis does not have an effect on the results due to a lack of proper comparator. However, other research has found that gun-free school zones do not appear to be targeted for crimes committed with a firearm.[33] Furthermore, the variability in enforcing gun-free zones presents a

challenge, as data on enforcement levels were not accessible for our study. Consequently, our inclusion of gun-free zones, regardless of their enforcement status, likely leads to a more conservative estimate—potentially biasing results towards the null—compared to an analysis restricted to zones with confirmed active enforcement.

We also conducted several robustness analyses to address other limitations. We first determined the number of times case or control exposure status could be misclassified specifically in a way that could have artificially inflated the study's primary point estimate. We determined that the exposure would have to be misclassified up to nine times, specifically in a pattern that would bias the estimate away from the null, for our reported results to be truly null. More details of this process are included in Appendix B. We believe that this systematic exposure misclassification was highly unlikely. We also called a subset of cases and controls whose exposure status was measured by company policy, which we presumed was most accurate, to determine if this was different from what was ascertained over the telephone, which we presumed produced the least accurate exposure ascertainment. Based on this, only 5% of the phone calls could have resulted in a misclassified exposure, a percentage that was not high enough to alter the study's conclusion. Another study limitation was the possibility of unknown and unmeasured confounders creating an omitted variable bias of the relationship between active shootings and gun-free zones. However, a robustness analysis that considered distance from case and control establishments to the nearest police station as a potential confounder produced nearly identical results and the calculation of an E-value indicated that any unmeasured confounder would need to be excessively large in order to significantly change our reported results.

Conclusion

This nationwide, case-control study was the first study to evaluate the association between gun-free zones and active shootings in the United States. We found that gun-free places were less likely to have experienced an active shooting than places that were not gun-free. After several robustness analyses, we conclude that it is unlikely that gun-free zones attract active shooters; rather, gun-free zones may be protective against active shootings. This study suggests that gun-free zone policies should not be repealed. Given that this is the first study on this topic, more research is needed to confirm these findings.

Contributors

Paul Reeping: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, validation, visualization, writing-original draft, writing-review and editing. *Christopher Morrison:* conceptualization, methodology, supervision, writing-review and editing. *Ariana Gobaud*: methodology, data validation and access to raw data, writing-review and editing. *Sonali Rajan*: methodology, super vision, writing-review and editing. *Douglas Wiebe*: methodology, super vision, writing-review and editing. *Charles Branas*: conceptualization, methodology, supervision, validation, writing-review and editing.

All contributors had the final responsibility for the decision to submit the manuscript for publication.

Data sharing statement

The datasets generated and analysed during the current study are not publicly available due to privacy restrictions. However, data are available from the corresponding author upon reasonable request.

Declaration of interests

The authors, PR, CM, AG, SR DW and CB, declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lana.2024.100837.

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