Association of State Firearm Legislation With Female Intimate Partner Homicide

Josie J. Sivaraman, MSPH, BSN,[1,2] Shabbar I. Ranapurwala, PhD, MPH,[1,2] Kathryn E. Moracco, PhD, MPH,[2,3] Stephen W. Marshall, PhD[1,2]

Introduction: The aim of this study was to assess the association between state firearm legislation and female intimate partner homicide.

Methods: In 2017, the authors conducted a secondary data analysis of 16 states from 2010 to 2014, using data from the National Violent Death Reporting System, the State Firearm Law Database, and additional public sources. Poisson regression analyses quantified the association between the number of state restrictive firearm legislative provisions and the female population-based intimate partner homicide rate. For etiologic reasons, intimate partner homicide was disaggregated into homicide−suicide (intimate partner homicide followed by perpetrator suicide) and homicide-only intimate partner homicide (intimate partner homicide in the absence of perpetrator suicide).

Results: There were 1,693 female intimate partner homicide deaths in the 16 states during 2010−2014; 67% were homicide-only intimate partner homicide. The number of state-level legislative provisions related to firearm restrictions ranged from four (Alaska) to 95 (Massachusetts). The intimate partner homicide rate in states with zero to 39 provisions was 1.16 per 100,000 person years (95% CI=1.10, 1.22) and in states with >40 provisions was 0.68 per 100,000 person years (95% CI=0.61, 0.72). The incidence of female intimate partner homicide was 56% lower in states with ≥40 legislative provisions (adjusted incidence rate ratio=0.44, 95% CI=0.28, 0.68), relative to states with zero to 39 provisions. This protective association was stronger for homicide-only intimate partner homicide than homicide−suicide intimate partner homicide.

Conclusions: More state-level restrictive firearm legislation is associated with a lower rate of female intimate partner homicides.

Am J Prev Med 2019;56(1):125−133.

INTRODUCTION

Intimate partner violence (IPV) is a widespread and serious public health problem in the U.S., with a lifetime prevalence of approximately 37% among women.[1] This problem arises from multiple factors, including the desire for control over another person.[2] IPV accounts for more than half of all homicides in women[3] and the majority of these intimate partner homicides (IPH) are committed using a firearm,[4] suggesting that restrictive firearm legislation has the potential to prevent IPH. Federal laws have pursued this strategy by making it illegal to possess or receive a firearm while under a qualifying restraining order that protects a current or former intimate partner or their child. Federal law also makes it illegal to possess or receive a firearm if convicted of a qualifying misdemeanor crime of domestic violence.[5−8] State-level legislation has also sought to further protect IPV-affected women by strengthening

From the [1]Department of Epidemiology, University of North Carolina, Chapel Hill, North Carolina; [2]Injury Prevention Research Center, University of North Carolina, Chapel Hill, North Carolina; and [3]Department of Health Behavior, University of North Carolina, Chapel Hill, North Carolina

Address correspondence to: Josie J. Sivaraman, MSPH, BSN, Department of Epidemiology, Injury Prevention Research Center, University of North Carolina, 137 East Franklin Street, Campus Box 7505, Chapel Hill NC 27599. E-mail: josie_caves@med.unc.edu.

0749-3797/$36.00
https://doi.org/10.1016/j.amepre.2018.09.007

background checks and firearm permit laws, extending restraining orders protections to a broader range of intimate partners, or allowing firearms to also be restricted under temporary or emergency restraining orders.[9] The impact of this subset of firearm legislation on rates of IPH has been the focus of past studies.[9–13] Such laws were found to be associated with 7% to 40% lower rates of IPH.[9–13]

It is plausible that firearm legislation may influence IPH rates by limiting the overall number of firearms in a geographic area, and the ability of potential IPH perpetrators to access them.[9–13] The perpetrators sometimes have no prior domestic violence convictions, but they may have other red flags that can be addressed by firearm legislation not meant to prevent IPH specifically. The question of how much firearm regulation is appropriate is a topic of active debate.[14] Legislators and women's health advocates may be interested in the effectiveness of laws specific to the prevention of IPH in relation to a more general strategy of seeking broad firearm restrictions. Past research has used the number of state firearm laws to represent stringency of firearm restrictions, and to evaluate how unintended populations may have been impacted.[15–17] However, no prior study has evaluated how the number of firearm laws impact IPH, because the bulk of this research has focused on IPH-specific legislation.

One prior study moderately expanded this approach by including both specific provisions of IPV-related firearm laws as well as several non-IPV firearm laws thought to impact IPH (such as violent misdemeanor firearm restrictions).[12] Zeoli et al.[12] found that broader restrictions were more impactful; for example, violent misdemeanor restrictions had a greater estimated effect on rates of IPH (incidence rate ratio [IRR]=0.77, 95% CI=0.65, 0.92) than laws targeting these incidents. However, as with most previous IPV research,[9–11,13] that study relied upon the Federal Bureau of Investigation's Supplementary Homicide Reports data to quantify IPH,[12] which have several limitations, including lapses in state reporting and about 30% missing data on decedent–suspect relationship.[18] More importantly, Supplementary Homicide Reports do not include ex-boyfriend and ex-girlfriend relationships,[19] thereby excluding such IPH deaths. Supplementary Homicide Reports also do not offer a way to differentiate between incidents where a perpetrator does or does not commit suicide, which may be important because associations with restrictive firearm legislation may vary for homicide-only and homicide–suicide IPH. These limitations lead to outcome misclassification but can be addressed by using the National Violent Death Reporting System (NVDRS) data. NVDRS provides more complete information on decedent–suspect relationships, including ex-boyfriend and ex-girlfriend,[14] and accounts for perpetrator suicide.[20]

Although previous studies of restrictive firearm legislation effects often relied upon the Brady Center to Prevent Gun Violence[21] data for exposure assessment, a recent collaborative effort by Seigel and colleagues[22] cataloged all state-level firearm laws and provisions that have been enacted since 1991. This new resource offers data on up to 133 specific state-level regulations, compared with 42 available previously. The authors leverage these data to examine the association between the number of state-level restrictive firearm provisions and the rate of female IPH.

METHODS

Study Population

In 2017, the authors conducted a state-level study to assess the association between the number of state-level restrictive firearm provisions (hereafter referred to as legislative provisions) on female IPH in 16 states between 2010 and 2014. NVDRS is managed by the Centers for Disease Control and Prevention, which receives surveillance data on violent death decedents and suspects obtained from participating states' death certificates, law enforcement, and coroner or medical examiner reports.[14] At the time of this study, 16 states (Alaska, Colorado, Georgia, Kentucky, Maryland, Massachusetts, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Rhode Island, South Carolina, Utah, Virginia, and Wisconsin) had complete data through 2014. These data were used to generate quarterly counts of female homicides by intimate partners, by age category, race (white/non-white), and ethnicity (Hispanic/non-Hispanic) of the decedent. National Vital Statistics' bridged race postcensal state population estimates contributed the denominator (person time) of the rates for each population age, race, and ethnicity subset.[23] The University of North Carolina IRB granted an exemption for this study because of the secondary and de-identified nature of the data.

Measures

The exposure of interest was the number of state-level legislative provisions. Data on legislative provisions were downloaded from the publicly available State Firearm Law Database (SFLD).[22] This database is the result of a collaborative effort to catalog all state-level firearm provisions that have been enacted since 1991 (n=133), organized into 14 categories.[22] This includes 11 categories of laws primarily intended to promote firearm restrictions (Table 1). These data, which have been described in detail elsewhere,[22] offer more granular detail than was previously available to researchers interested in measuring strength of legislative efforts, and provide the year of enactment for each specific provision. Only legislative provisions intended to restrict firearms (as designated by the SFLD) were included in the exposure.[22] Notably, the SFLD records three categories of what are considered "gun industry and gun ownership protections" (one example is "stand your ground" legislation, which reverses the common "duty to retreat" standard, giving individuals immunity for using deadly force to defend themselves in any place where they are

Table 1. State-Level Restrictive Firearm Legislative Provisions in 16 States, 2010–2014

Variables	States with legislation (number of legislative provisions)				
	2010[a]	2011	2012	2013	2014
IPV-specific					
Domestic violence	Colorado (1), Maryland (6), Massachusetts (17), New Jersey (7), North Carolina (10), Oklahoma (1), Utah (1), Wisconsin (6)	—	—	Colorado (+6)	
Not IPV-specific					
Ammunition regulations	Maryland (2), Massachusetts (6), New Jersey (2), Rhode Island (2)	—	—	Maryland (+2)	
Assault weapons and large capacity magazines	Maryland (1), Massachusetts (4), New Jersey (5)	—	—	Colorado (+1), Maryland (+4)	
Background checks	Colorado (4), Maryland (6), Massachusetts (7), New Jersey (5), North Carolina (4), Oregon (6), Rhode Island (9)	—	—	Colorado (+5)	
Buyer regulations	Alaska (1), Maryland (8), Massachusetts (10), New Jersey (10), North Carolina (2), Oklahoma (1), Oregon (2), Rhode Island (9), Virginia (1), Wisconsin (2)	—	Virginia (−1)	Maryland (+1)	
Child access prevention	Maryland (7), Massachusetts (11), New Jersey (6), North Carolina (4), Rhode Island (4), Wisconsin (2)	—	—	—	
Conceal carry permitting	Alaska (1), Colorado (5), Georgia (4), Kentucky (5), Maryland (5), Massachusetts (5), New Jersey (7), New Mexico (4), North Carolina (4), Oklahoma (4), Oregon (4), Rhode Island (3), South Carolina (4), Utah (3), Virginia (4), Wisconsin (7)	Wisconsin (−1)		North Carolina (+1)	
Dealer regulations	Colorado (1), Georgia (2), Maryland (7), Massachusetts (14), New Jersey (8), North Carolina (1), Oregon (5), Rhodes Island (8), South Carolina (2)	—	South Carolina (−2)	Colorado (+1)	Georgia (−2)
Gun trafficking	Colorado (2), Maryland (3), Massachusetts (5), New Jersey (1), Utah (2), Virginia (2)		—	—	—
Possession regulations	Alaska (1), Colorado (2), Georgia (4), Kentucky (1), Maryland (3), Massachusetts (9), New Jersey (7), New Mexico (3), North Carolina (3), Oklahoma (2), Oregon (1), Rhode Island (3), South Carolina (5), Utah (2), Virginia (1), Wisconsin (2)	—	—	—	Georgia (−3)
Prohibitions on high-risk gun possession	Alaska (1), Colorado (1), Georgia (1), Kentucky (1), Maryland (6), Massachusetts (7), New Jersey (4), New Mexico (1), North Carolina (1), Oregon (4), Rhode Island (5), South Carolina (1), Utah (3), Virginia (4), Wisconsin (5)	Maryland (+1)	—	South Carolina (+2)	Rhode Island (−2)

[a]Legislation present in, or acquired during, 2010.
IPV, intimate partner violence.

legally allowed to be[22]). Such laws were not included in the exposure counts. The total number of legislative provisions by year and state were included in the study data set.

This study evaluated three female IPH measures: total IPH, homicide-only IPH, and homicide–suicide IPH. IPH was defined as a violent death of a female aged ≥18 years listed as a homicide, in which the suspect was listed as a spouse, ex-spouse, girlfriend, boyfriend, ex-girlfriend, or ex-boyfriend. The sample was restricted to adults aged ≥18 years because risk factors of IPH among adolescents likely differ from adults.[24] The results were restricted to females because IPH is much more common in this group, and risk factors likely differ between males and females.[25] NVDRS distinguishes homicides that were followed by an attempted or completed suicide by the assumed perpetrator within 24 hours; IPHs that received this designation defined the homicide–suicide IPH outcome. Any IPH that did not receive this designation defined the homicide-only IPH outcome. These two outcomes combined represent the total IPH outcome. Some subanalyses disaggregated results by firearm IPHs and all-cause IPH.

Adjustment variables were selected by using a directed acyclic graph (DAG),[26] which was developed based on a review of the relevant literature evaluating policy associations with IPH (Appendix Figure 1, available online). The DAG helps identify which covariates to control so that all observed non-causal pathways (observed confounding) can be controlled, while keeping the causal pathways open (i.e., not controlling for causal intermediates). The DAG led the authors to choose a minimally sufficient set of control variables, including state-level demographics (age, race, ethnicity), anxiety,[27] violent crime rates, per-capita income, and firearm ownership.

State-level anxiety can be defined as the level of statewide apprehension or concern over the degree of local government restrictions on individual rights, including Second Amendment firearm rights.[27] Adjustment for state-level anxiety has not been considered in previous studies, but as can be seen in this study's DAG (Appendix Figure 1, available online), it is a potential confounder because such anxiety may impact legislative strictness and the rate of IPH (e.g., if anxiety is associated with more patriarchal culture). Harrington and Gelfand[27] developed a tightness −looseness score for all 50 states that reflects an index of how individual states value strength of punishment, latitude/permissiveness, and institutionalized moral order and constraint. The authors found a significant association between tight societies and states with greater political and legal gender inequality. This one-time score was included as a proxy for anxiety. In addition, a potentially strong predictor of state-level anxiety, statewide annual per capita income, accounted for any potential residual confounding. This was extracted from the Bureau of Economic Analysis personal income summary.[28] State-level violent crime rates per 100,000 population for 2010 were accessed from the Uniform Crime Reporting Statistics data tool.[29] State-level proportions of citizens owning firearms came from a national survey conducted in 2013.[30] Potential confounding by state educational attainment levels and unemployment were examined in sensitivity analyses. For education, statewide proportions of individuals aged ≥25 years with a bachelors' degree were obtained from the 2011−2015 American Community Survey 5-year estimates.[31] Annual state-level unemployment rates were obtained from the U.S. Bureau of Labor Statistics' employment status of the civilian and non-institutional population data.[32]

Statistical Analysis

The authors conducted descriptive analyses to calculate overall rates of IPH by age, race, and ethnicity and the median number of state laws. Next, Poisson regression with a population offset was used with generalized estimating equations to account for state-level autoregressive clustering, generating IRRs and 95% CIs using quarterly rates. The association between number of laws and IPH using continuous (increases of ten provisions), categorical (0−19, 20−39, and ≥40 provisions), and binary (0−39 vs ≥40 provisions) representations of the law counts were examined. Over the course of the study period, some states gained or lost legislative provisions, causing them to switch categories. An indicator variable for the calendar year was initially included in the model to adjust for any changing number of state legislative provisions over time but this variable did not affect the estimates.

The authors conducted sensitivity analyses to examine a quartile-based exposure variable and its association with IPH. Also, sensitivity analyses were done to examine the effect of any residual confounding using state-level education obtainment and unemployment rates in the place of violent crime rates, in accordance with the DAG (Appendix Figure 1, available online). Traditional regression approaches may be subject to bias if a time-varying confounder is causally affected by the previous exposure, such as the effect of the number of firearm provisions on subsequent violent crime rates.[33] To correct for this possible bias, the analysis was replicated using inverse probability of treatment weights with annual state-level violent crime rates per 100,000 population for 2010−2014. To account for the possibility of a temporality violation (e.g., a homicide that took place before the enactment of a piece of firearm legislation from the same year), the authors also replicated the analysis with a 1-year lag.

The authors also conducted stratified analyses to assess modification of the exposure−outcome relationship by the (binary) presence of state-level stand your ground laws. This exploratory analysis was based on evidence that stand your ground legislation is associated with increased firearm violent deaths,[34] suggesting that it may modify effects associated with restrictive firearm legislation. In these data, every state that had stand your ground had the other two categories of permissive gun laws also.

RESULTS

Over the 5-year period, NVDRS identified 1,693 IPHs in the 16 states, including 1,128 homicides where the perpetrator did not attempt suicide (67%) and 565 homicides where the perpetrator attempted or completed suicide (33%). These included 1,025 firearm-specific homicides; 48% (n=547) of homicide-only IPH were committed using a firearm vs 84% (n=478) of homicide−suicides. The gender of the perpetrator was known in 99.5% of cases, 99.2% of those were males. The median number of legislative provisions per state was 15 (Alaska, Georgia, Kentucky, New Mexico, Oklahoma, South Carolina, Utah, and Virginia had <15 provisions; Table 1) and the range was 4 to 95. The total female IPH rate was 0.90 (95% CI=0.86, 0.95) per 100,000 person years (PY); 1.23 (95% CI=1.15, 1.31) per 100,000 PY in states with ≤15 legislative provisions and 0.87 (95% CI=0.82, 0.94) per 100,000 PY in states with >15 legislative provisions. In both of these groups, the unadjusted rates were highest among non-whites for total IPH and homicide-only IPH (Appendix Table 1, available online). The unadjusted 5-year homicide rates for each outcome suggest that rates were lower in states with more provisions (Pearson's correlation coefficient for total IPV mortality= −0.63; Figure 1).

Unadjusted results show that states with greater numbers of legislative provisions had lower rates of total (n=1,693) and homicide-only IPH (n=1,128; Table 2). In the adjusted model, continuous increments of ten legislative provisions were associated with 8% lower total

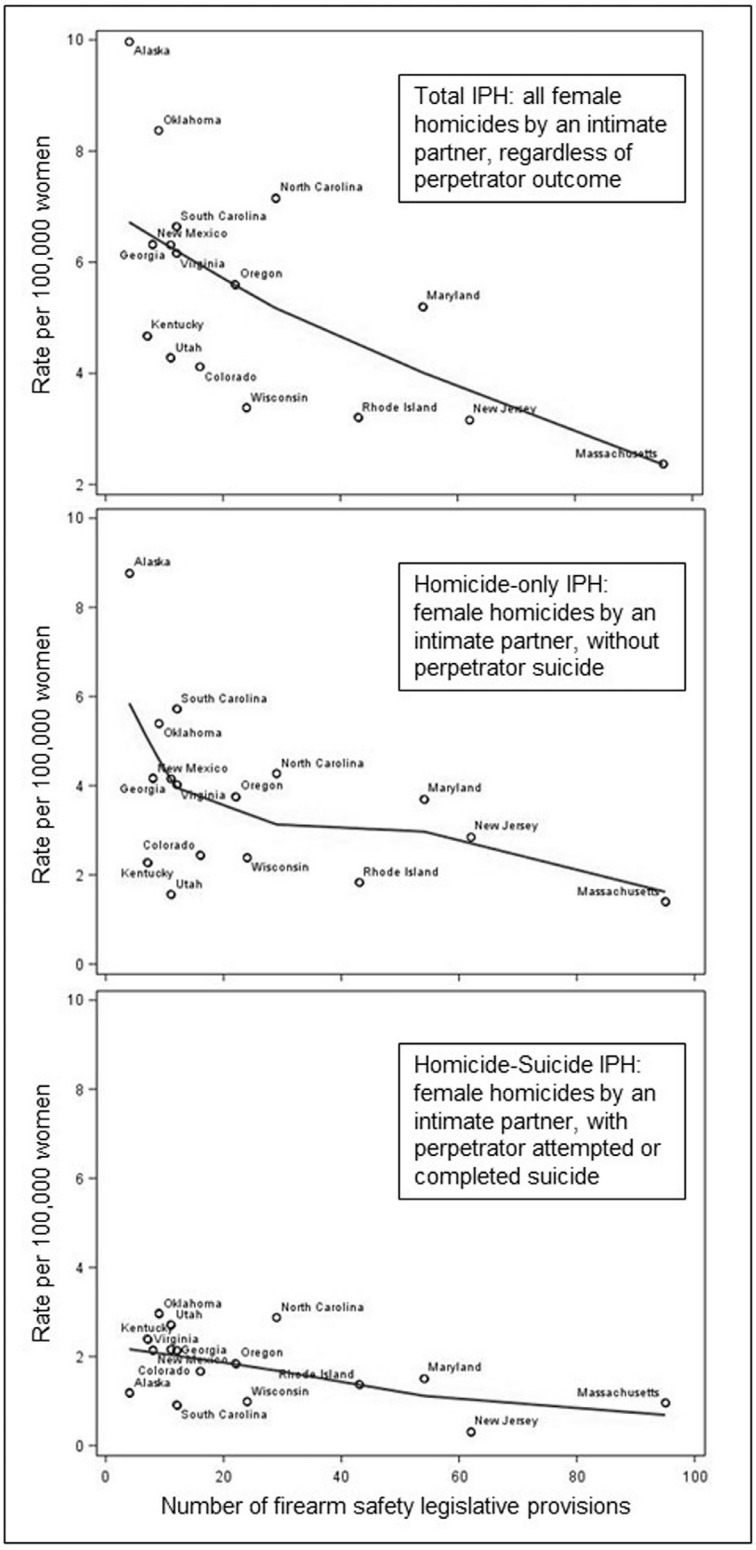

Figure 1. Number of state-level firearm safety legislative provisions and female IPH in 16 states, 2010–2014.[a]

[a]Number of firearm safety legislative provisions in 2010 and the unadjusted 5-year female IPH rates.

IPH, intimate partner homicide.

Table 2. Association Between State-Level Restrictive Firearm Legislative Provisions and Female IPH in 16 States, 2010–2014

Outcome/number of legislative provisions	Homicides, *n*	Unadjusted IRR (95% CI)	Adjusted IRR (95% CI)
Total IPH[a]			
Continuous increments of 10	1,693	0.91 (0.87, 0.94)	0.92 (0.84, 1.00)
Categorical			
0–19	916	1	1
20–39	467	0.93 (0.67, 1.29)	1.08 (0.90, 1.29)
≥40	310	0.57 (0.40, 0.81)	0.48 (0.28, 0.81)
Binary			
0–39	1,383	1	1
≥40	310	0.59 (0.41, 0.83)	0.44 (0.28, 0.68)
Homicide-only IPH[b]			
Continuous increments of 10	1,128	0.91 (0.87, 0.97)	0.87 (0.79, 0.96)
Categorical			
0–19	608	1	1
20–39	288	0.86 (0.63, 1.18)	1.01 (0.85, 1.20)
≥40	232	0.64 (0.43, 0.96)	0.37 (0.21, 0.66)
Binary			
0–39	896	1	1
≥40	232	0.68 (0.46, 1.00)	0.37 (0.21, 0.64)
Homicide-suicide IPH[c]			
Continuous increments of 10	565	0.88 (0.80, 0.97)	1.01 (0.91, 1.13)
Categorical			
0–19	308	1	1
20–39	179	1.06 (0.67, 1.66)	1.19 (0.84, 1.68)
≥40	78	0.43 (0.22, 0.82)	0.61 (0.27, 1.39)
Binary			
0–39	487	1	1
≥40	78	0.42 (0.22, 0.81)	0.50 (0.22, 1.14)

[a]All female homicides by an intimate partner, regardless of perpetrator outcome.
[b]Female homicides by an intimate partner, without perpetrator suicide.
[c]Female homicides by an intimate partner, with perpetrator attempted or completed suicide.
IPH, intimate partner homicide; IRR, incident rate ratios.

IPH rates (IRR=0.92, 95% CI=0.84, 1.00; Table 2). Results were similar for categories of 20 legislative provisions (Table 2). For binary exposure at the 40 legislative provision cutpoint, the total IPH rate in states with 0–39 legislative provisions was 1.16 (95% CI=1.10, 1.22) per 100,000 PY vs 0.68 (95% CI=0.61, 0.72) per 100,000 PY in states with >40 legislative provisions. After adjusting for potential confounders and restricting to firearm-specific homicides, states with >40 legislative provisions were associated with 67% lower total IPH rates (IRR=0.33, 95% CI=0.18, 0.59; Table 3) and 82% lower homicide-only IPH rates (IRR=0.18, 95% CI=0.08, 0.40).

The unadjusted results for homicide–suicide IPH (*n*=565) indicated that states with >40 legislative provisions were associated with 58% lower rates (IRR=0.42, 95% CI=0.22, 0.81; Table 2, Figure 1). After adjustment the association was attenuated (IRR=0.50, 95% CI=0.22, 1.14; Table 2) and remained similar after restriction to firearm-specific deaths (IRR=0.57, 95% CI=0.23, 1.43; Table 3).

For all three outcomes, sensitivity analyses using the quartile-based exposure variable indicated similar findings (Appendix Table 2, available online). Other sensitivity analyses to address potential residual confounding because of state-level anxiety were also similar to those presented in the main results (Appendix Table 3, available online). The sensitivity analysis using time-varying violent crime rates was also substantively similar (Appendix Table 4, available online), as was the sensitivity analysis incorporating 1-year time lags (Appendix Table 5, available online). The protective association of restrictive firearm legislation appeared to differ by presence or absence of stand your ground laws (Appendix Table 6, available online). However, this analysis was made less interpretable because of a positivity violation in this data set of 16 states: states with stand your ground

Table 3. Association Between State-Level Restrictive Firearm Legislative Provisions and Female IPH in 16 States, 2010–2014, Firearm-Specific

Outcome/number of legislative provisions	Firearm homicides, *n*	Unadjusted IRR (95% CI)	Adjusted IRR (95% CI)
Total IPH[a]			
Continuous increments of 10	1,025	0.84 (0.79, 0.89)	0.90 (0.79, 1.01)
Categorical			
0–19	604	1	1
20–39	305	0.92 (0.63, 1.33)	1.08 (0.87, 1.35)
≥40	116	0.32 (0.20, 0.53)	0.36 (0.18, 0.70)
Binary			
0–39	909	1	1
≥40	116	0.33 (0.20, 0.55)	0.33 (0.18, 0.59)
Homicide-only IPH[b]			
Continuous increments of 10	547	0.81 (0.76, 0.87)	0.80 (0.68, 0.94)
Categorical			
0–19	334	1	1
20–39	156	0.85 (0.61, 1.18)	0.99 (0.84, 1.18)
≥40	57	0.28 (0.16, 0.51)	0.18 (0.08, 0.40)
Binary			
0–39	490	1	1
≥40	57	0.30 (0.17, 0.53)	0.18 (0.08, 0.40)
Homicide-suicide IPH[c]			
Continuous increments of 10	478	0.86 (0.78, 0.96)	1.01 (0.91, 1.13)
Categorical			
0–19	270	1	1
20–39	149	1.00 (0.58, 1.71)	1.18 (0.83, 1.69)
≥40	59	0.37 (0.17, 0.79)	0.70 (0.28, 1.76)
Binary			
0–39	419	1	1
≥40	78	0.37 (0.17, 0.79)	0.57 (0.23, 1.43)

[a]All female homicides by an intimate partner, regardless of perpetrator outcome.
[b]Female homicides by an intimate partner, without perpetrator suicide.
[c]Female homicides by an intimate partner, with perpetrator attempted or completed suicide.
IPH, intimate partner homicide; IRR, incident rate ratios.

legislation only had ≤30 restrictive firearm legislative provisions.

DISCUSSION

In this study of the association between state-level restrictive firearm legislative provisions and IPH rates, the authors found that having more than 40 state-level provisions was associated with a 56% decline in the total IPH rates and a 63% decline in homicide-only IPH rates.

This is the first analysis to examine whether the cumulative number of firearm legislative provisions is associated with female IPH, and the first to examine restrictive firearm provision counts using the SFLD. There was also evidence of a dose–response relationship between increasing numbers of legislative provisions and lower rates of IPH. This suggests that although increasing numbers of restrictive firearm legislative provisions may be related to lower IPH rates, many states are currently below the threshold of this association.

The association between more restrictive firearm legislative provisions and IPH rate was weaker for homicide–suicide IPH. A recent review suggests that premeditation and perpetrator characteristics vary between homicide-only and homicide–suicide IPH.[25] It is plausible that if IPH homicide–suicide events involve higher levels of premeditation, they may be more resistant to legislation intended to curb firearm-related mortality.

The authors caution that these state-level associations do not imply causality. Notably, these results will be affected by confounding by group bias (one type of ecologic bias)[35] if states with lower IPH rates tended to adopt stricter firearm laws. However, the study's results are consistent with past evaluations of restrictive firearm legislation. Fleegler et al.[15] observed that the third quartile of the total number of firearm laws (though not the fourth) was

associated with 35% lower overall homicide rates. Similarly, Simonetti and colleagues[16] observed that the highest tertile of the number of firearm laws was associated with 40% lower nonfatal firearm injury rate. Both of these studies used Brady Center data, which is more limited than the data used in this study. Prior studies also support that state-level restrictive firearm laws may impact other unintended subpopulations. Kivisto et al.[17] found that child and consumer safety lock laws were most strongly associated with lower rates of fatal police shootings. They theorize that different types of firearm legislation likely influence mortality rates through distinct mechanisms—some by decreasing the overall firearm ownership levels in the community, and some by keeping firearms away from people who misuse them. A similar mechanism may be reflected in the current study.

Limitations

In addition to the potential for state-level confounding bias discussed here, this study has other limitations. First, the design does not incorporate state-level implementation and enforcement of the laws. Second, there may be measurement error in the IPH outcomes because of differences in surveillance systems by state. Also, the NVDRS surveillance system captures perpetrator suicides following homicides up to 24 hours after the homicide, which may miss some delayed suicides and lead to underestimation of homicide–suicide IPHs.

CONCLUSIONS

This study supports the concept that more restrictive firearm legislation may be a means of preventing female IPH. Further research is needed to understand which specific provisions—individually and in combination—were associated with lower rates. Future studies also need to focus on better understanding modeling homicide-only IPH versus homicide–suicide IPH, examining the impact of other contextual variables on the relationship between firearm legislative provisions and IPH, and evaluating the impact of specific types of firearm restrictions on IPH.

ACKNOWLEDGMENTS

This research was funded by the Raluca Iosif Intimate Partner Research Award, sponsored by IntraHealth International. This contributor had no role in the study design, collection, analysis, interpretation, or in the writing or our decision to submit for publication. The University of North Carolina IRB granted an exemption for this study because of the secondary and de-identified nature of the data.

Josie Sivaraman contributed to the research concept, study analysis, interpretation of results, and manuscript writing. Shabbar Ranapurwala contributed advice related to the study analysis, interpretation of results, and manuscript writing. Kathryn Moracco and Steve Marshall contributed advice related to the interpretation of results and manuscript writing.

This article contents were previously presented at a talk at IntraHealth International in October 2017, and as a poster at the American Public Health Association conference in November 2017.

Josie Sivaraman's work on this study was funded in part by the Raluca Iosif Intimate Partner Research Award. No other conflicts of interest or financial disclosures were reported by the authors of this paper.

SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2018.09.007.

REFERENCES

1. Smith SG, Chen J, Basile KC, et al. The National Intimate Partner and Sexual Violence Survey—State Report. www.cdc.gov/violenceprevention/nisvs/summaryreports.html. Published 2017. Accessed August 1, 2017.
2. Basile KC, Hall JE, Walters ML. Expanding resource theory and feminist-informed theory to explain intimate partner violence perpetration by court-ordered men. *Violence Against Women.* 2013;19(7):848–880. https://doi.org/10.1177/1077801213497105.
3. Violence Policy Center. *When Men Murder Women: An Analysis of 2011 Homicide Data.* Washington, DC: Violence Policy Center; 2013. https://www.issuelab.org/resource/when-men-murder-women-an-analysis-of-2011-homicide-data.html.
4. Fox JA, Fridel EE. Gender differences in patterns and trends in U.S. homicide, 1976–2015. *Violence Gend.* 2017;4(2):37–43. https://doi.org/10.1089/vio.2017.0016.
5. Gun Ban for Individuals Convicted of a Misdemeanor Crime of Domestic Violence, 18 U.S.C. § 922(g)(9).
6. Violence Against Women Act 18 U.S.C. ch. 110A.
7. Violent Crime Control and Law Enforcement Act of 1994, 42 U.S.C. ch. 136.
8. Gun Control Act of 1968, 18 U.S.C. ch. 44.
9. Vigdor ER, Mercy JA. Do laws restricting access to firearms by domestic violence offenders prevent intimate partner homicide? *Eval Rev.* 2006;30(3):313–346. https://doi.org/10.1177/0193841X06287307.
10. Diez C, Kurland RP, Rothman EF, et al. State intimate partner violence-related firearm laws and intimate partner homicide rates in the United States, 1991 to 2015. *Ann Intern Med.* 2017;167(8):536–543. https://doi.org/10.7326/M16-2849.
11. Dugan L, Nagin DS, Rosenfeld R. Exposure reduction or retaliation? The effects of domestic violence resources on intimate-partner homicide. *Law Soc Rev.* 2003;37(1):169–198. https://doi.org/10.1111/1540-5893.3701005.
12. Zeoli AM, McCourt A, Buggs S, Frattaroli S, Lilley D, Webster DW. Analysis of the strength of legal firearms restrictions for perpetrators of domestic violence and their association with intimate partner homicide. *Am J Epidemiol.* 2018;187(7):1449–1455. https://doi.org/10.1093/aje/kwx362.
13. Zeoli AM, Webster DW. Effects of domestic violence policies, alcohol taxes and police staffing levels on intimate partner homicide in large U.S. cities. *Inj Prev.* 2010;16(2):90–95. https://doi.org/10.1136/ip.2009.024620.

14. CDC National Violent Death Reporting System. www.cdc.gov/ViolencePrevention/NVDRS/index.html. Published 2016. Accessed August 1, 2017.
15. Fleegler EW, Lee LK, Monuteaux MC, Hemenway D, Mannix R. Firearm legislation and firearm-related fatalities in the United States. *JAMA Intern Med.* 2013;173(9):732–740. https://doi.org/10.1001/jamainternmed.2013.1286.
16. Simonetti JA, Rowhani-Rahbar A, Mills B, Young B, Rivara FP. State firearm legislation and nonfatal firearm injuries. *Am J Public Health.* 2015;105(8):1703–1709. https://doi.org/10.2105/AJPH.2015.302617.
17. Kivisto AJ, Ray B, Phalen PL. Firearm legislation and fatal police shootings in the United States. *Am J Public Health.* 2017;107(7):1068–1075. https://doi.org/10.2105/AJPH.2017.303770.
18. Regoeczi W, Banks D. The Nation's Two Measures of Homicide. U.S. Department of Justice, Office of Justice Programs. www.bjs.gov/content/pub/pdf/ntmh.pdf. Published 2014. Accessed September 19, 2018.
19. Uniform Crime Reporting Program Data: Supplementary Homicide Reports, 2012. www.icpsr.umich.edu/icpsrweb/NACJD/studies/35023. Published 2012. Accessed August 1, 2017.
20. Petrosky E, Blair JM, Betz CJ, Fowler KA, Jack SPD, Lyons BH. Racial and ethnic differences in homicides of adult women and the role of intimate partner violence—United States, 2003−2014. *MMWR Morb Mortal Wkly Rep.* 2017;66(28):741–746. https://doi.org/10.15585/mmwr.mm6628a1.
21. Crim Advisor. The Brady Campaign state scorecard. http://crimadvisor.com/data/Brady-State-Scorecard-2015.pdf. Published 2015. Accessed August 1, 2017.
22. Siegel M, Pahn M, Xuan Z, et al. Firearm-related laws in all 50 U.S. states, 1991−2016. *Am J Public Health.* 2017;107(7):1122–1129. https://doi.org/10.2105/AJPH.2017.303701.
23. National Vital Statistics System, National Center for Health Statistics, CDC. Vintage 2016 bridged-race population estimates. www.cdc.gov/nchs/nvss/bridged_race/data_documentation.htm. Accessed August 1, 2017.
24. Fowler KA, Dahlberg LL, Haileyesus T, Gutierrez C, Bacon S. Childhood firearm injuries in the United States. *Pediatrics.* 2017;140(1):e20163486. https://doi.org/10.1542/peds.2016-3486.
25. Heron C. *Exploring the Difference Between Domestic Homicide and Homicide-Suicide: Implications for Risk Assessment and Safety Planning*. London, Ontario: University of Western Ontario; 2017. [dissertation] https://ir.lib.uwo.ca/etd/4473. Accessed August 1, 2017.
26. Greenland S, Pearl J, Robins JM. Causal diagrams for epidemiologic research. *Epidemiology.* 1999;10(1):37–48. https://doi.org/10.1097/00001648-199901000-00008.
27. Harrington JR, Gelfand MJ. Tightness-looseness across the 50 United States. *Proc Natl Acad Sci U S A.* 2014;111(22):7990–7995. https://doi.org/10.1073/pnas.1317937111.
28. Bureau of Economic Analysis. Annual State Personal Income and Employment. www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=6#reqid=70&step=1&isuri=1. Accessed August 1, 2017.
29. Uniform Crime Reporting Statistics. UCR data online. www.ucrdatatool.gov/. Accessed August 1, 2017.
30. Kalesan B, Villarreal MD, Keyes KM, Galea S. Gun ownership and social gun culture. *Inj Prev.* 2016;22(3):216–220. https://doi.org/10.1136/injuryprev-2015-041586.
31. U.S. Census Bureau. 2011−2015 American Community Survey 5 year estimates. www.census.gov/programs-surveys/acs/. Accessed August 1, 2017.
32. Bureau of Labor Statistics. Civilian Noninstitutional Population and Associated Rate and Ratio Measures for Model-Based Areas. www.bls.gov/lau/rdscnp16.htm. Published 2017. Accessed August 1, 2017.
33. Robins JM, Hernan MA, Brumback B. Marginal structural models and causal inference in epidemiology. *Epidemiology.* 2000;11(5):550–560.
34. Humphreys DK, Gasparrini A, Wiebe DJ. Evaluating the impact of Florida's "Stand Your Ground" self-defense law on homicide and suicide by firearm: an interrupted time series study. *JAMA Intern Med.* 2017;177(1):44–50. https://doi.org/10.1001/jamainternmed.2016.6811.
35. Greenland S, Morgenstern H. Ecological bias, confounding, and effect modification. *Int J Epidemiol.* 1989;18(1):269–274. https://doi.org/10.1093/ije/18.1.269.