The Effect of the Australian National Firearms Agreement on Suicide and Homicide Mortality, 1978–2015

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Objectives. To investigate the impact of the Australian National Firearms Agreement (NFA) on suicide and assault mortality.

Methods. We conducted a retrospective cross-sectional difference-in-difference study of the impact of the NFA on national mortality rates in the Australian population from 1961 to 2015.

Results. The NFA had no additional statistically observable impact on firearm-related suicides in women ($P = .09$) and was associated with a statistically significant increase in the trend in men ($P < .001$). Trends in non–firearm-related suicide deaths declined by 4.4% per year (95% confidence interval [CI] = 4.1%, 4.8%) in men after the introduction of the NFA and increased in women by 0.3% (95% CI = 0.1%, 0.7%). Trends in non–firearm-related homicides declined by 2.2% per year (95% CI = 1.5, 3.8%) in women and 2.9% per year (95% CI = 2.0%, 3.7%) in men after the introduction of the NFA, with a statistically significant improvement in trends for women ($P = .04$) but not for men ($P = .80$).

Conclusions. The NFA had no statistically observable additional impact on suicide or assault mortality attributable to firearms in Australia. (*Am J Public Health.* 2018;108:1511–1516. doi:10.2105/AJPH.2018.304640)

See also Siegel, p. 1438.

Firearm-related mortality remains a significant public health problem in the United States. More than 30 000 people die every year from a firearm-related injury, primarily because of suicide,[1] and firearm mortality rates in the United States are orders of magnitude higher than are those in other high-income countries.[2] Laws restricting gun access are known to reduce firearm-related mortality[3] but remain limited in the United States.[4] Mass shootings are a subset of firearm-related homicide that, although only a tiny proportion of the total burden of firearms-related mortality and hospitalization,[5] attract greater media attention and public alarm, and gun control efforts are often revived in their wake. Laws to prevent mass shootings are seen as more politically palatable than broader laws targeting all forms of firearm-related mortality, but their effectiveness in the United States has not been confirmed.[6] Public health experts have recently added urgency to calls for action on both mass shootings and broader firearm-related mortality,[7] but after 2 decades of restrictions on research into the cause of gun violence in the United States,[8] the national debate depends heavily on evidence from successful policy enacted overseas.

In this context, the Australian National Firearms Agreement (NFA) is often presented as a model for a minimal set of firearms laws for the United States.[9] This agreement restricted access to some classes of firearms, regularized and tightened state-level licensing laws, and introduced a gun buyback scheme and amnesty that led to the recall of approximately 640 000 guns.[10] Although it was designed to prevent mass shootings and may have been effective in this goal,[11] some researchers have claimed that the NFA also had a quantifiable impact on firearms-related suicide and homicide. A 2010 study found an 80% reduction in suicide mortality attributable to the NFA[12] but failed to adjust for the long-standing declining trend in firearm-related mortality and used ordinary least squares regression, limiting the validity of its findings.

The most recent study, published in 2016, found that firearm-related suicides and homicides declined more rapidly after the introduction of the NFA and concluded that the NFA was particularly effective against gun-related suicide deaths.[13] This study did not provide a comprehensive statistical analysis of mortality, however, and suffered from a significant flaw that may have led to misleading results: it did not compare the impact of the NFA on intentional gun-related deaths after adjusting for changes in nonfirearm mortality that occurred in the same period. One 2006 study considered the possibility that there was a general downward trend in suicide deaths at the time the NFA was introduced but did not compare trends statistically and had only limited post-NFA data on which to make this comparison.[14]

We analyzed changes in trends and levels of intentional firearms-related mortality in Australia. On the basis of the assumption that nonfirearm deaths were unaffected by the

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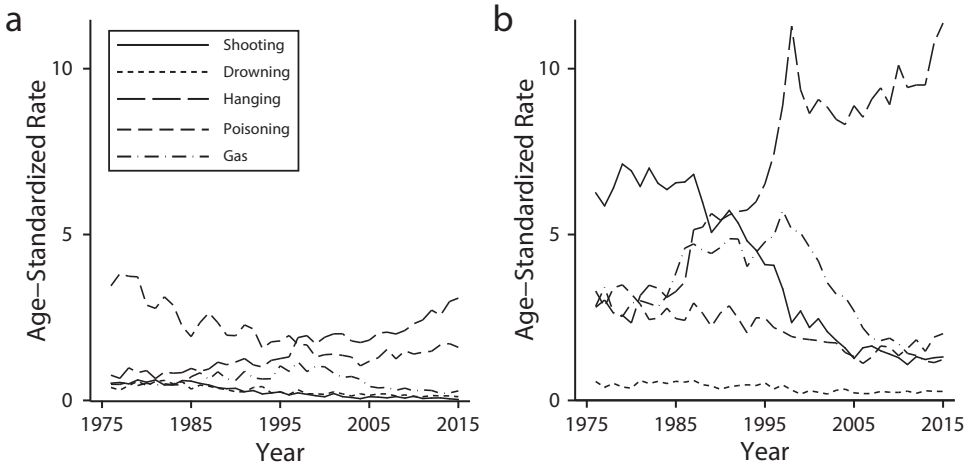

Note. Figure A (available as a supplement to the online version of this article at http://www.ajph.org) shows the same data by broad categories of suicide method.

FIGURE 1—Trend in Firearm- and Non–Firearm-Related Age-Standardized Suicide Mortality Rate Among (a) Women and (b) Men: Australia, 1975–2015

NFA, we reassessed the impact of the NFA using a difference-in-difference (DiD) approach and treated nonfirearm deaths as a control group to obtain a more accurate, scientifically robust estimate of the impact of the NFA on intentional firearm-related deaths in Australia.

METHODS

We obtained mortality data by gender, year, cause, and 5-year age group from the Australian Institute of Health and Welfare for all suicide and assault deaths in Australia from the earliest year available. We separated deaths by firearm versus nonfirearm cause and additionally for suicide by 5 narrow categories of shooting, drowning, gas, hanging, and poisoning. We defined suicide and assault and the specific categories of suicide using *International Classification of Diseases* codes appropriate to the specific era (Table A [available as a supplement to the online

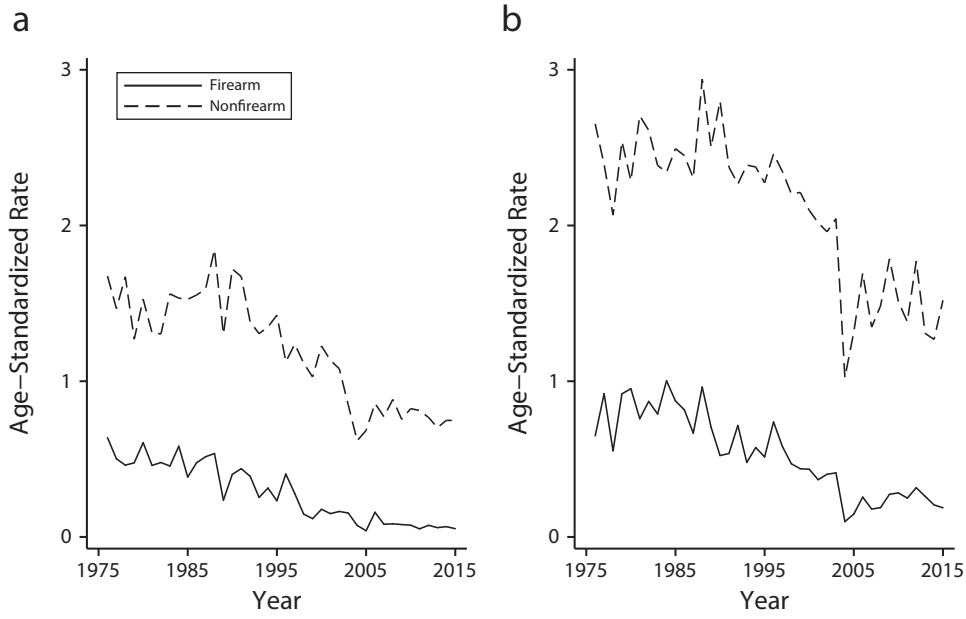

FIGURE 2—Trend in Firearm- and Non–Firearm-Related Age-Standardized Assault Mortality Rate Among (a) Women and (b) Men: Australia, 1975–2015

TABLE 1—Difference-in-Difference Analysis of Suicide Mortality by Gender: Australia, 1978–2015

Variable	RR (95% CI)
Women	
Age group, y	
15–29	1 (Ref)
30–44	1.33 (1.27, 1.38)
45–59	1.42 (1.35, 1.49)
≥ 60	1.15 (1.10, 1.20)
Method	
Nonfirearm	1 (Ref)
Firearm	0.19 (0.15, 0.24)
Year	0.987 (0.983, 0.992)
Period	
Before NFA	1 (Ref)
After NFA	0.72 (0.62, 0.84)
Firearm–year interaction	
Nonfirearm	1 (Ref)
Firearm	0.952 (0.938, 0.967)
NFA–year interaction	
Before NFA	1 (Ref)
After NFA	1.016 (1.010, 1.021)
NFA–method interaction	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	1.54 (0.63, 3.77)
NFA–method–year interaction (DiD term)	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	0.974 (0.955, 1.004)
Men	
Age group, y	
15–29	1 (Ref)
30–44	1.19 (1.16, 1.21)
45–59	1.06 (1.03, 1.08)
≥ 60	1.02 (0.99, 1.04)
Method	
Nonfirearm	1 (Ref)
Firearm	1.25 (1.16, 1.35)
Year	1.032 (1.029, 1.035)
NFA period	
Before NFA	1 (Ref)
After NFA	3.15 (2.89, 3.44)
Firearm–year interaction	
Nonfirearm	1 (Ref)
Firearm	0.942 (0.938, 0.947)
NFA–year interaction	
Before NFA	1 (Ref)
After NFA	0.956 (0.952, 0.959)
NFA–method interaction	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	0.31 (0.24, 0.39)
NFA–method–year interaction (DiD term)	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	1.027 (1.019, 1.036)

Note. CI = confidence interval; DiD = difference in difference; NFA = Australian National Firearms Agreement; RR = rate ratio.

version of this article at http://www.ajph.org] provides details of the *International Classification of Diseases* codes by period).

Population data were also provided on the basis of the nearest available census year to the year in which mortality occurred. All data were provided as counts of death in the specific year–age group–gender–cause category, with the population by year–age group–gender from the nearest census point. We standardized summary data series by age using the 1996 census as a reference population. No individual identifying data were provided, and we obtained all data subject to the Australian Institute of Health and Welfare data approval process.

Data Analysis

We constructed a DiD model using Poisson log-linear regression to allow small counts of deaths in some years, ages, and genders. We entered age group, year, and cause of death in the model along with a data indicator indicating whether the NFA was in effect. We then included (1) interactions for year and cause of death to allow different trends between firearm and nonfirearm deaths or between suicide modalities, (2) an interaction between NFA indicator and year to allow a general change in trend across both firearm and nonfirearm deaths at the time of the NFA, (3) an interaction between NFA indicator and cause of death to allow a change in level after implementation of the NFA, and (4) an additional 3-way interaction between year, cause of death, and the NFA period to model the specific additional effect of the NFA on trends in firearm deaths compared with nonfirearm deaths. This 3-way interaction term is the specific measure of the impact of the NFA. Details of the model equation and the specific interpretation of all terms are given in the appendix (available as a supplement to the online version of this article at http://www.ajph.org), with specific interpretation of key terms described in Table B (available as a supplement to the online version of this article at http://www.ajph.org).

We categorized age to avoid small counts, and we excluded children younger than 15 years from the data owing to the very low rate of suicide and homicide in this age group. For suicide, we developed 2 sets of models, 1 comparing firearm- and non–firearm-related suicides and 1 comparing firearm-related suicides with narrower categories of method. We conducted modeling separately by gender, because men and women have different patterns of suicide and assault mortality and use different suicide methods.[15] We analyzed all models for the period 1978 to 2015, which enabled a period of 19 years after the NFA (1997–2015) and 19 years before the NFA (1978–1996). Because the NFA was introduced in September 1996 and the gun buyback ran from October 1996 through September 1997, the NFA indicator variable was set to zero until 1996 and then to 1 from 1997 onward. We calculated linear combinations of the key variables (year, suicide or assault method, and NFA agreement) to give an estimate of the annual change in the mortality rate before and after the NFA was implemented, with 95% confidence interval (CI), separately for firearm- and non–firearm-related mortality. We conducted all analyses in Stata/IC version 15 (StataCorp LP, College Station, TX).

Sensitivity Analysis

To consider the possibility that an arbitrary start date for a data series can influence the outcome of modeling, we ran all models using

a longer pre-NFA data series, starting at 1961 and testing every year until 1977. We plotted the DiD coefficient (the 3-way interaction term) and its 95% CI for all start years for comparison. We also tested models with the NFA indicator variable set to start in 1998 rather than 1997, reflecting the possibility of a 1-year period before the NFA took effect and started its influence only after the gun buyback was completed. All sensitivity analyses are presented in the appendix.

RESULTS

Figure 1 shows the age-standardized suicide rates for narrow categories of suicide method by gender for the period 1975 to 2015. In this figure firearm-related deaths are shown by a solid black line. Among both men and women, firearm-related suicides appeared to peak in the late 1980s and then declined steadily. Among men the rates of hanging and gas-related suicides rose above firearm-related suicides in the early 1990s, peaking at about the time that the NFA was introduced and then suddenly declining. This pattern can also be seen in gas-related suicides among women, but poisoning suicides in women declined until 2005, whereas hanging-related suicides increased consistently across the whole period of the study. Figure A (available as a supplement to the online version of this article at http://www.ajph.org) shows the age-standardized suicide rate with narrower categories of non–firearm-related suicide collapsed into a single non–firearm-related category. We applied the regression models presented in the main text to these broad categories of non–firearm-related suicide for ease of interpretation.

Figure 2 shows the age-standardized assault mortality rate separately by gender from 1975 to 2015. All assaults have shown a long-term decline, which began long before the introduction of the NFA. Firearm-related assault deaths show a trend pattern broadly similar to that of firearm-related suicides.

Table 1 shows the result of the DiD analysis for firearm- and non–firearm-related suicides, with all coefficients presented as rate ratios (RRs). Among women mortality rates were declining for both firearm- and non–firearm-related suicides before the NFA. After the NFA was introduced non–firearm-related suicides began to increase, whereas there was no statistically significant effect on firearm-related suicides (the DiD term, which is 0.982; $P = .3$). For men, non–firearm-related suicides were increasing before the NFA was introduced (RR = 1.032; $P < .001$); after the NFA was introduced, the annual trend in non–firearm-related suicides declined by 0.955 ($P < .001$), but a positive DiD term indicates that the NFA had less effect on the trend for firearm-related deaths (DiD term 1.013; $P < .001$). Results for narrow categories of suicide method are shown in Table C (available as a supplement to the online version of this article at http://www.ajph.org), which shows widely diverging trends in mortality rates by suicide category but preserves the overall finding of no additional effect of the NFA on firearm-related suicide mortality.

Table 2 shows the results of DiD analysis of homicide deaths. For both men and women, the NFA had a nonsignificant effect on trends in firearm-related assault mortality over and above a broad decline in rates observed for both firearm- and non–firearm-related deaths. Estimates of the annual RR for both suicides for men and women separately, obtained from combining all main effect 2- and 3-way interaction terms are presented in Tables D and E (available as a supplement to the online version of this article at http://www.ajph.org). Tables F and G (available as a supplement to the online version of this article at http://www.ajph.org) show that there was no impact on the analysis of changing the implementation date of the NFA to 1998. Figures B and C (available as a supplement to the online version of this article at http://www.ajph.org) show the impact of changing the start year of the data on the DiD coefficient for suicide and assault mortality, respectively. These figures show that the analysis is mostly unaffected by changes in start date for the series or changes in the assumed implementation start point of the NFA.

DISCUSSION

We found broad changes in suicide and homicide mortality at the time the NFA was implemented that extended across mortality methods. We found that the NFA had no additional effect on firearm-related suicide among women and that among men the NFA had a smaller effect on the trend in firearm-related suicides than in non–firearm-related suicides. We also found that the effect of the NFA on firearm-related homicides could not be distinguished statistically from the trend in non–firearm-related homicides, for men or women.

To our knowledge, this is the first study to analyze the NFA using a DiD method to distinguish the impact of the NFA separately from other changes happening in unrelated suicide and assault categories at the time of its implementation.[16] It is the first study, to our knowledge, to properly adjust for age, to analyze the impact of the NFA separately by gender, and to compare firearm-related suicide mortality with trends in other methods of suicide occurring at the same time in Australia.[17] These improvements allow us to properly account for the shared effect of other possible unexplored social changes occurring at the time,[16] to adjust for the known differences in suicide modality and frequency between the genders,[15] and to account for age-related differentials in suicide risk.[17]

Previous studies have identified a statistically significant impact of the NFA,[11,12] but we also saw similar or larger changes in non–firearm-related deaths. Australia's first national youth suicide strategy was introduced in 1995,[18] followed by a full suicide prevention strategy in 2001.[19] Individual states also introduced suicide prevention strategies in the 1990s in response to a rapid growth in male suicide mortality occurring in the previous 20 years. Although evaluation results for these strategies have been mixed,[20] it is possible that they began to take effect contemporaneously with the NFA. It is also possible that trends in urbanization and immigration over this period further affected non–firearm-related suicides, which have lower rates among urban residents.[21] DiD analysis enables us to separate these broad effects from the specific effects of firearms policy and shows that any changes in this single suicide method were likely not attributable to the NFA. Although it is considered possible that the NFA did reduce deaths related to mass shootings, and the withdrawal of a large number of long arms from circulation may have had some impact on these highly publicly visible events, this DiD analysis does not support claims about the broader effects of the law on suicide and homicide mortality.

TABLE 2—Difference-in-Difference Analysis of Assault Mortality by Gender: Australia 1978–2015

Variable	RR (95% CI)
Women	
Age group, y	
15–29	1 (Ref)
30–44	1.03 (0.96, 1.11)
45–59	0.72 (0.66, 0.78)
≥ 60	0.48 (0.44, 0.53)
Method	
Nonfirearm	1 (Ref)
Firearm	0.41 (0.31, 0.53)
Year	0.992 (0.984, 1.000)
Period	
Before NFA	1 (Ref)
After NFA	1.37 (0.98, 1.92)
Firearm–year interaction	
Nonfirearm	1 (Ref)
Firearm	0.978 (0.962, 0.995)
NFA–year interaction	
Before NFA	1 (Ref)
After NFA	0.980 (0.967, 0.992)
NFA–method interaction	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	1.96 (0.76, 5.08)
NFA–method–year interaction (DiD term)	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	0.967 (0.936, 0.999)
Men	
Age group, y	
15–29	1 (Ref)
30–44	1.16 (1.10, 1.22)
45–59	0.84 (0.79, 0.90)
≥ 60	0.49 (0.46, 0.53)
Method	
Nonfirearm	1 (Ref)
Firearm	0.45 (0.37, 0.55)
Year	1.003 (0.997, 1.009)
NFA period	
Before NFA	1 (Ref)
After NFA	1.77 (1.39, 2.53)
Firearm–year interaction	
Nonfirearm	1 (Ref)
Firearm	0.976 (0.964, 0.988)
NFA–year interaction	
Before NFA	1 (Ref)
After NFA	0.971 (0.963, 0.980)
NFA–method interaction	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	1.01 (0.56, 1.82)
NFA–method–year interaction (DiD term)	
Before NFA–nonfirearm	1 (Ref)
Before NFA–firearm	1 (Ref)
After NFA–nonfirearm	1 (Ref)
After NFA–firearm	0.997 (0.977, 1.018)

Note. CI = confidence interval; DiD = difference in difference; NFA = Australian National Firearms Agreement; RR = rate ratio.

It is well understood that restricting access to the means of suicide can reduce suicide mortality[22] and that, specifically in the case of firearms, restricting impulsive purchasing can reduce suicide mortality.[3] In Australia the long-term decline in poisoning-related suicides likely reflects changes in barbiturate prescribing and purchasing practices,[23] and changes in vehicle emissions laws may have led to reductions in suicide by gas.[24,25] However, the NFA only affected a small proportion of the firearms in circulation in Australia, leading to the repurchase by the government of 640 000 of an estimated 3.2 million firearms in public possession at that time.[26] The majority of firearms reported used in crimes in Australia before the NFA's introduction were not covered by the NFA,[27] and the implementation of this policy was unlikely to affect the injuries and deaths caused by these kinds of firearms. By contrast to the limited scope of the NFA, in 1990 the federal government commissioned a wide-ranging review of antiviolence strategies in response to a series of horrific shootings that occurred in 1987 and 1988.[28] This review included detailed and comprehensive gun control policy proposals developed by the Australian Institute of Criminology,[27] which affected the guns most likely to be used in homicides and suicides and were adopted at the 1991 Australian Police Ministers' Conference.[29]

Although not analyzed statistically, the data presented in this study does show a consistent change in trend in firearm-related suicide and homicide mortality starting in the very late 1980s, which is not reflected in non–firearm-related mortality and could be attributable to these policy changes. Considering the uniformity of trends in firearm-related suicides and homicides we observed for both genders, it is likely that these more comprehensive and detailed 1991 changes played a greater role in reducing firearms-related suicide and homicide than did the NFA, which was implemented solely for the purpose of eliminating mass shootings.

Limitations

Like all studies that use secondary data, this study suffers from several limitations. There is known concern about the quality of some suicide data,[30] and no covariates other than age and gender were available for confounder adjustment. We used the gender of the victim of assault, but the gender of the perpetrator likely differed, which may invalidate the results for women. This limitation does not affect the findings on suicide, however. Because the model we used was a complex 3-way interaction model, the data were not disaggregated by state, which might provide more detailed information on the role of firearms law in preventing mortality.

The complexity of the model and the large number of statistical tests also raises the risk of findings of spurious significance, but this was unavoidable because of the nature of the DiD design and unlikely to significantly change the key findings because the experimental variable was not found to be statistically significant. Also, we were not able to identify the extent to which any substitution of methods may have occurred after the introduction of the NFA. If substitution did occur, it would affect the validity of the underlying assumption of the DiD model that changes in non–firearm-related suicide were unrelated to the introduction of the NFA. However, if substitution did occur, it would only be relevant to our conclusions if we had found a positive effect of the NFA. Because our DiD model

found no effect of the NFA, any substitution of methods would not have changed this finding. In addition to the problem of substitution, our study was limited in its ability to test the effect of a subsequent buyback that occurred in 2003 and a second amnesty instituted in 2013. Both of these interventions were much smaller in scale than was the 1996 amnesty[31,32]—likely limiting our ability to study their impact on mortality counts of the size available in Australian data. The small number of years in the data set after 2013 likely made identification of the 2013 amnesty's impact statistically impossible. Further study of the impact of these amnesties is needed, using state-level data controlled for detailed information on the availability of the specific kinds of firearms recalled.

Public Health Implications

Many claims have been made about the NFA's far-reaching effects and its potential benefits if implemented in the United States.[33] However, more detailed analysis of the law shows that it likely had a negligible effect on firearm suicides and homicides in Australia and may not have as large an effect in the United States as some gun control advocates expect. In the context of recent mass shootings in the United States, public health researchers and advocates for gun policy reform have identified a changed political environment in which real changes to gun control policy may be possible.[34] There have been calls for action on the basis of evidence that can have a tangible impact on the crisis of firearms-related mortality in the United States.[35]

It is imperative that this political moment, which is so rare in the face of 20 years of political action to restrain real action on firearms-related mortality,[7] not be squandered on a law that will have limited impact. To achieve real, sustained reductions in the majority of causes of firearm-related mortality, the United States needs a broader, more comprehensive range of gun control measures than those in the NFA.[28] If American public health policymakers focus on policy on the basis of Australia's full suite of gun policy laws, they may be able to achieve real and sustainable public health benefits and make real progress toward minimizing this completely preventable and uniquely American problem. AJPH

CONTRIBUTORS

S. Gilmour conceptualized the study and wrote the first draft of the article. K. Wattanakamolkul and M. K. Sugai contributed to the writing of the article and edited the article. All authors analyzed the data.

HUMAN PARTICIPANT PROTECTION

Institutional review board approval was not needed for this study as it used aggregated publicly available secondary data.

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