JAMA | Original Investigation

Association Between Gun Law Reforms and Intentional Firearm Deaths in Australia, 1979-2013

Simon Chapman, PhD; Philip Alpers; Michael Jones, PhD

IMPORTANCE Rapid-fire weapons are often used by perpetrators in mass shooting incidents. In 1996 Australia introduced major gun law reforms that included a ban on semiautomatic rifles and pump-action shotguns and rifles and also initiated a program for buyback of firearms.

OBJECTIVE To determine whether enactment of the 1996 gun laws and buyback program were followed by changes in the incidence of mass firearm homicides and total firearm deaths.

DESIGN Observational study using Australian government statistics on deaths caused by firearms (1979-2013) and news reports of mass shootings in Australia (1979–May 2016). Changes in intentional firearm death rates were analyzed with negative binomial regression, and data on firearm-related mass killings were compared.

EXPOSURES Implementation of major national gun law reforms.

MAIN OUTCOMES AND MEASURES Changes in mass fatal shooting incidents (defined as ≥5 victims, not including the perpetrator) and in trends of rates of total firearm deaths, firearm homicides and suicides, and total homicides and suicides per 100 000 population.

RESULTS From 1979-1996 (before gun law reforms), 13 fatal mass shootings occurred in Australia, whereas from 1997 through May 2016 (after gun law reforms), no fatal mass shootings occurred. There was also significant change in the preexisting downward trends for rates of total firearm deaths prior to vs after gun law reform. From 1979-1996, the mean rate of total firearm deaths was 3.6 (95% CI, 3.3-3.9) per 100 000 population (average decline of 3% per year; annual trend, 0.970; 95% CI, 0.963-0.976), whereas from 1997-2013 (after gun law reforms), the mean rate of total firearm deaths was 1.2 (95% CI, 1.0-1.4) per 100 000 population (average decline of 4.9% per year; annual trend, 0.951; 95% CI, 0.940-0.962), with a ratio of trends in annual death rates of 0.981 (95% CI, 0.968-0.993). There was a statistically significant acceleration in the preexisting downward trend for firearm suicide (ratio of trends, 0.981; 95% CI, 0.970-0.993), but this was not statistically significant for firearm homicide (ratio of trends, 0.975; 95% CI, 0.949-1.001). From 1979-1996, the mean annual rate of total nonfirearm suicide and homicide deaths was 10.6 (95% CI, 10.0-11.2) per 100 000 population (average increase of 2.1% per year; annual trend, 1.021; 95% CI, 1.016-1.026), whereas from 1997-2013, the mean annual rate was 11.8 (95% CI, 11.3-12.3) per 100 000 (average decline of 1.4% per year; annual trend, 0.986; 95% CI, 0.980-0.993), with a ratio of trends of 0.966 (95% CI, 0.958-0.973). There was no evidence of substitution of other lethal methods for suicides or homicides.

CONCLUSIONS AND RELEVANCE Following enactment of gun law reforms in Australia in 1996, there were no mass firearm killings through May 2016. There was a more rapid decline in firearm deaths between 1997 and 2013 compared with before 1997 but also a decline in total nonfirearm suicide and homicide deaths of a greater magnitude. Because of this, it is not possible to determine whether the change in firearm deaths can be attributed to the gun law reforms.

← Editorial

+ Author Audio Interview at jama.com

Author Affiliations: School of Public Health, University of Sydney, Sydney, Australia (Chapman, Alpers); Department of Psychology, Macquarie University, Sydney, Australia (Jones).

Corresponding Author: Simon Chapman, PhD, School of Public Health, University of Sydney, Edward Ford Bldg A27, Sydney, NSW 2006, Australia (simon.chapman@sydney.edu.au).

I n 1996, Australia's state and federal governments introduced sweeping uniform gun laws that were progressively implemented in all 6 states and 2 territories between June 1996 and August 1998. The enactment of these laws followed a massacre on April 28, 1996, in which a man used 2 semiautomatic rifles to kill 35 people and wound 19 others. The new gun laws banned rapid-fire long guns (including those already in private ownership), explicitly to reduce their availability for mass shootings.[1,2]

In addition, by January 1, 1997, all 8 governments commenced a mandatory buyback at market price of prohibited firearms. As of August 2001, 659 940 newly prohibited semiautomatic and pump-action rifles and shotguns had been purchased by the federal government from their civilian owners at market value, funded by a one-off levy on income tax, and destroyed.[3,4] From October 1, 1997, large criminal penalties, including imprisonment and heavy fines, applied to possession of any prohibited weapon.

During a second firearm buyback in 2003, 68 727 handguns were collected and destroyed.[5,6] Thousands of gun owners also voluntarily surrendered additional, nonprohibited firearms without compensation, and since 1996 thousands more privately owned firearms are known to have been surrendered, seized, and melted down.[7]

In 2006 an analysis indicated that no mass shootings had occurred during the decade after the enactment of the 1996 gun laws and the buyback programs.[8] The purpose of the present study was to update the data and test 2 specific hypotheses: (1) whether the rate of decline in firearm-related deaths accelerated after the introduction of gun control laws in 1996 and (2) whether there was a step change in which the mortality rate increased or decreased immediately after the introduction of gun control laws. Total all-cause homicides and all-method suicides were also examined to assess the possibility that substitution of other lethal methods may have occurred: that is, with reduced access to firearms, whether those with homicidal or suicidal intent used other methods such as knives or hanging to commit homicide or suicide.

Methods

Data on intentional (suicide and homicide) deaths caused by firearms were obtained from the National Injury Surveillance Unit, sourced from the Australian Bureau of Statistics (ABS) mortality data collection 1979-2013, coded by *International Classification of Diseases, Ninth Revision*, and *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*.[9] These are the latest available data adjusted from preliminary numbers following subsequent findings by a coroner about intent that can occur several years after the death is first registered. All sudden deaths in which the deceased person had not been under medical care are subject to mandatory determination of death by state coronial investigations. This always occurs with suicides and homicides. These data represent a census of all intentional firearm deaths in Australia for those 35 years, other than shootings by police. Population data representing person-years at risk of death were

Key Points

Question What happened to the trend in firearm deaths after Australia introduced extensive gun law reform in 1996, including a ban on semiautomatic rifles and pump-action shotguns?

Findings In the 18 years before the ban, there were 13 mass shootings, whereas in the 20 years following the ban, no mass shootings occurred, and the decline in total firearm deaths accelerated.

Meaning Implementation of a ban on rapid-fire firearms was associated with reductions in mass shootings and total firearm deaths.

obtained from the ABS for the same period, and intentional firearm death rates per 100 000 were calculated.

Changes in these rates for the 18 years up to and including the year in which the new firearm laws were announced (1979-1996) were compared with rates of change for the following 17 years (1997-2013) to examine the hypothesis that the passage of the new gun laws was associated with an acceleration in the existing decline in rates of firearm homicides, firearm suicides, and total intentional firearm deaths, excluding police shootings. Fatal "legal intervention" shootings by police were excluded because these shootings were not the focus of the gun laws enacted in 1996-1997. For the period after 1996, rates of total all-cause (and nonfirearm) homicides and suicides were also examined to consider whether perpetrators may have substituted other lethal means if the gun laws reduced their access to firearms.

Numbers of deaths by category (total and components) have been viewed as arising from an overdispersed Poisson process and analyzed using negative binomial regression with annual Australian person-years at risk, obtained from the ABS, used as an offset. In practical terms, an offset acts to convert the number of deaths to a death rate that is comparable across time regardless of how many individuals are at risk of death. Mean death rates averaged over a period are reported as death rate × 100 000 to yield number of deaths per 100 000 people.

Given that the rate of firearm deaths had been decreasing prior to the national reform and harmonization of gun laws, 2 hypotheses were tested:
- A change in annual trend for death rates
- A step change in which there is an abrupt change in mortality rates immediately after the introduction of gun control laws

Because counts are of deaths, it can be assumed that observations are independent across years. Three models were fitted for each type of firearm death.
Model a:

$$\ln(d_i) = \ln(n_i) + \beta_{00} + \beta_{10} \, year_i + e_i, \ i = 1979, ..., 1996$$

Model b:

$$\ln(d_i) = \ln(n_i) + \beta_{01} + \beta_{11} \, year_i + e_i, \ i = 1997, ..., 2013$$

Model c:

$$\ln(d_i) = \ln(n_i) = \beta_{02} + \beta_{12} \, year_i + \beta_{22} Law_i + \beta_{32} \, year_i \times Law_i + e_i$$

where i is 1, 2, ..., 35 and Law is 0 if the year is 1996 or earlier and 1 if the year is 1997 or later.

The variable $year$ indicates calendar year but was coded as calendar year minus 1996 in model c. This makes 1996 the year at which the model intercept is estimated. The variable d_i indicates the number of deaths by a given cause in year i, and n_i indicates the person-years at risk in year i. The term e_i indicates the residual (error in prediction) in year i.

Models a and b are included for descriptive purposes and were used to estimate the trend (measured as the average relative change in death rates per year) in deaths in the periods prior to (1979-1996) and after (1997-2013) the introduction of new gun laws, through $e^{\beta10}$ and $e^{\beta11}$, respectively.

Model c was used to estimate both the change in annual trends in firearm-related deaths associated with the introduction of revised gun laws through the interaction term $year \times Law$ and the step change in mortality immediately after the introduction of gun control laws through the Law main effect.

The 3 models are related because the model is parameterized, $\beta_{32} = \beta_{11} - \beta_{10}$, and therefore, $e^{\beta22}$ estimates the ratio of annual trend (denoted as RT in this article) in deaths after introduction to before the introduction of the gun laws. Similarly, β_{22} represents the change in intercept (level of annual death rate) around the time of gun control law introduction, and $e^{\beta22}$ represents the ratio of intercepts (denoted as ratio of levels [RL] in the article).

All statistics are reported with 95% confidence intervals. Statistical testing involved calculating 2-tailed P values, and $P < .05$ is considered statistically significant. All statistical analyses were performed using Stata version 14.

Analyses were undertaken separately within firearm-related and non–firearm-related deaths as well as total deaths for homicide and suicide to investigate possible substitution of other lethal means instead of firearms. If substitution occurred (ie, other lethal means were used to commit homicides or suicides), the expected findings would be an increasing downward trend in firearm deaths after the introduction of gun control laws but a compensatory lesser downward or even upward trend in non–firearm-related deaths over the same period.

To determine whether the mass gun-related homicides that occurred prior to the introduction of Australia's new gun laws might have distorted the comparison with gun-related homicides after implementation of the gun laws, a sensitivity analysis was conducted in which the number of deaths due to mass homicide was subtracted from the total firearm gun deaths for that calendar year. The resulting counts were then analyzed using the same procedure.

Using several online news media databases (Factiva, ProQuest, NewsText, and News Store online) as well as web search engine queries for mass shootings, one author (P.A.) verified reports of all mass shooting incidents in Australia (defined here, as in a previous analysis,[8] as ≥5 victims killed by gunshot, not including the perpetrator). These media reports were used to compare the reported numbers of such shootings that occurred before (1979-1996) and after (1997 and later) the introduction of the new gun laws. These searches were most recently repeated on May 10, 2016.

The study activities were reviewed by the research integrity and ethics administration of the University of Sydney according to the National Statement of Ethical Conduct in Human Research (2007). As only official, public government, nationally aggregated data and news reports were used, no human ethics committee approval was required.

Results

From 1979 until and including 1996 (ie, the 18 years prior to enactment of the ban on rapid-fire firearms), there were 13 mass fatal shootings (involving ≥5 victims) in Australia. In these events, 104 victims were killed and at least another 52 wounded (**Table 1**). From 1997 to May 2016 (ie, 20 years after the 1996 massacre and 19 years after enactment of the ban), no mass fatal shootings have occurred in Australia.

Intentional deaths from firearm discharge and total non-firearm suicides and homicides in Australia between 1979 and 2013 are presented in **Table 2**. Overall deaths due to firearms declined during this period. From 1979-1996, the mean annual rate of total firearm deaths was 3.6 (95% CI, 3.3-3.9) per 100 000 population, and from 1997-2013, the mean rate of total firearm deaths was 1.2 (95% CI, 1.0-1.4) per 100 000 population. From 1979-1996, the mean annual rate of total nonfirearm suicide and homicide deaths was 10.6 (95% CI, 10.0-11.2) per 100 000 population, and from 1997-2013, the mean rate was 11.8 (95% CI, 11.3-12.3) per 100 000 population.

Total Firearm and Nonfirearm Suicide and Homicide Deaths
Overall suicide and homicide deaths from firearm involvement for the period 1979 to 2013 are reported in the **Figure**, panels G, H, and I. An increasing trend in total deaths (total homicide and suicide deaths) in the years 1979-1996 was followed by a decreasing trend in 1997-2013 (Figure, panel G), resulting in a negative ratio of annual trends (RT = 0.975; 95% CI, 0.968-0.983) but not a negative step change (RL = 0.991; 95% CI, 0.918-1.071) (**Table 3**). Although total firearm deaths were already declining in 1979-1996, the trend accelerated in 1997-2013 (Figure, H), resulting in a negative ratio of trends (RT = 0.981; 95% CI, 0.968-0.993) as well as a negative step change (RL = 0.669; 95% CI, 0.589-0.760) (Table 3). The annual rate of total nonfirearm deaths was increasing in 1979-1996 but declined in the period 1997-2013 (Figure, I), although only after an initial positive step change. This resulted in a negative ratio of trends (RT = 0.966; 95% CI, 0.958-0.973) but a nonsignificant step change (RL = 1.054; 95% CI, 0.974-1.141) (Table 3).

Total Suicide Deaths
Total (firearm + nonfirearm) suicide annual death rates had been increasing by a mean of 1.0% per year before the introduction of the gun control laws, for an overall mean of 12.3 (95% CI, 11.9-12.7) per 100 000 population, but declined by a mean of 1.5% per year after the introduction of the 1996 gun laws (Table 3), for an overall mean of 11.7 (95% CI, 11.1-12.3) per 100 000 (Figure, A). The ratio of the prelaw-to-postlaw trends was statistically significant (RT = 0.975; 95% CI,

Table 1. Mass Fatal Shootings in Australia, January 1979 to May 2016[a]

Date	Location and State	Victims Killed by Gunshot	Perpetrators Killed	Total Killed by Gunshot	Victims Wounded
April 28, 1996	Port Arthur, Tasmania	35	0	35	19
January 25, 1996	Hillcrest, Queensland	6	1	7	0
March 31, 1993	Cangai, New South Wales	5	1	6	0
October 27, 1992	Terrigal, New South Wales	6	0	6	1
August 17, 1991	Strathfield, New South Wales	6	1	7	7
August 30, 1990	Surry Hills, New South Wales	5	0	5	0
September 25, 1988	Oenpelli, Northern Territory	6	0	6	0
December 8, 1987	Queen Street, Victoria	8	1	9	5
October 10, 1987	Canley Vale, New South Wales	5	1	6	1
August 9, 1987	Hoddle Street, Victoria	7	0	7	19
June 19, 1987	Top End, Northern Territory and Western Australia	5	1	6	0
June 1, 1984	Wahroonga, New South Wales	5	1	6	0
September 24, 1981	Campsie, New South Wales	5	1	6	0

[a] Definitions of "mass fatal shooting" have ranged from 3 to 5 victims killed by gunshot.[8,10,11] To exclude most of the more common firearm-related spousal and family violence killings, "mass fatal shooting" is defined here as one in which ≥5 firearm-related homicides are committed by 1 or 2 perpetrators in proximate events in a civilian setting, not counting any perpetrators killed by their own hand or otherwise. There were 2 neighbor-dispute homicides with 3 victims each (April 29, 2011, at Hectorville, South Australia, and October 22, 2014, at Logan, Victoria) and 1 family murder-suicide with 4 victims and a perpetrator suicide (September 8, 2015, at Lockhart, New South Wales). Details of each case were collected from police and coroners' files, by personal communication with police and counsel involved, or as a last resort from corroborating newspaper reports. Although no mass shootings occurred in 1979-1980, Table 1 covers the same time span as the data in the Results section.

0.968-0.982), but the step change was not statistically significant (RL = 1.004; 95% CI, 0.931-1.083) (Table 3).

Total Homicide Deaths

Total (firearm + nonfirearm) homicide annual death rates had been decreasing by a mean of 0.3% per year before the introduction of the gun control laws for an overall mean of 1.93 (95% CI, 1.86-2.00) per 100 000 population, but this decline accelerated to a mean of 3.1% per year after the introduction of the 1996 gun laws (Table 3) for an overall mean of 1.29 (95% CI, 1.17-1.43) per 100 000 (Figure, D). The ratio of the prelaw-to-postlaw trends was statistically significant (RT = 0.972; 95% CI, 0.958-0.986), but there was no significant step change (RL = 0.908; 95% CI, 0.784-1.050) (Table 3).

Firearm Suicides

Firearm suicides represent the largest component cause of total intentional firearm deaths in Australia (83.9% between 1979-2013) (Table 2). In the 18 years 1979-1996, the mean annual rate of firearm suicide was 3.0 (95% CI, 2.8-3.3) per 100 000 population. In the 17 years following the announcement of the new gun laws, this declined to a mean of 0.99 (95% CI, 0.87-1.13) per 100 000. The rate of firearm suicide was declining by an average of 3% per year before gun law reforms, and this decline increased to 4.8% per year after the introduction of revised gun laws (Figure, B; Table 3). The ratio of trend estimates was 0.981 (95% CI, 0.970-0.993). There was evidence of a step change in the level of firearm-related suicide deaths (RL = 0.652; 95% CI, 0.582-0.731) (Table 3).

Firearm Homicides

In the 18 years 1979-1996, the mean annual rate of firearm homicide was 0.57 (95% CI, 0.51-0.63) per 100 000 population. In the 17 years following the announcement of the new gun laws, this rate declined to 0.20 (95% CI, 0.17-0.25) per 100 000 persons. The rate of firearm homicide was declining by a mean of 3% per year; this rate of decline accelerated to a mean of 5.5% per year after the introduction of new gun laws, although this change was not statistically significant (RT = 0.975; 95% CI, 0.949-1.001) (Figure, E; Table 3). The ratio of trends in annual death rate was slightly reduced when the mass homicides that occurred during 1979-1996 were removed (RT = 0.985; 95% CI, 0.962-1.009). In addition, there was a nonsignificant negative step change (RL = 0.769; 95% CI, 0.590-1.004) (Table 3).

Nonfirearm Suicides

The rate of total nonfirearm suicides increased by a mean of 2.3% per year before the introduction of the gun control laws, for an overall mean of 9.2 (95% CI, 8.7-9.8) per 100 000 population, but declined by a mean of 1.2% per year after the introduction of the 1996 gun laws, for an overall mean of 10.7 (95% CI, 10.3-11.2) per 100 000 (Figure, C; Table 3). The ratio of the prelaw-to-postlaw trends was statistically significant (RT = 0.965; 95% CI, 0.958-0.973), but there was no statistically significant step change (RL = 1.070; 95% CI, 0.988-1.159) (Table 3). The data do not support any suicide method substitution hypothesis.

Nonfirearm Homicides

The rate of total nonfirearm homicides increased by a mean of 0.9% per year before the introduction of gun control

Table 2. Intentional Deaths From Firearm Discharge and Total Nonfirearm Suicides and Homicides, Australia 1979-2013[a]

Year of Death	Australian Person-Years at Risk	Deaths Due to Firearms, No. (Crude Rate per 100 000 Population)			Deaths Not Due to Firearms, No. (Crude Rate per 100 000 Population)		Total Deaths, No. (Crude Rate per 100 000 Population)	
		Suicide	Homicide	Mass Firearm Homicide[b]	Suicide	Homicide	Suicide	Homicide
1979	14 515 729	516 (3.55)	109 (0.75)	0	1112 (7.66)	202 (1.39)	1628 (11.2)	311 (2.14)
1980	14 695 356	529 (3.59)	96 (0.65)	0	1116 (7.59)	141 (0.95)	1645 (11.1)	237 (1.61)
1981	14 923 260	490 (3.28)	83 (0.55)	5	1214 (8.13)	207 (1.38)	1704 (11.4)	290 (1.94)
1982	15 184 247	552 (3.63)	112 (0.73)	0	1217 (8.01)	188 (1.23)	1769 (11.6)	300 (1.97)
1983	15 393 472	512 (3.32)	86 (0.55)	0	1185 (7.69)	189 (1.22)	1697 (11.0)	275 (1.78)
1984	15 579 391	542 (3.47)	120 (0.77)	5	1212 (7.77)	195 (1.25)	1754 (11.2)	315 (2.02)
1985	15 788 312	549 (3.47)	100 (0.63)	0	1313 (8.31)	215 (1.36)	1862 (11.7)	315 (1.99)
1986	16 018 350	552 (3.44)	106 (0.66)	0	1495 (9.33)	206 (1.28)	2047 (12.7)	312 (1.94)
1987	16 263 874	566 (3.48)	123 (0.75)	25	1598 (9.82)	224 (1.37)	2164 (13.3)	347 (2.13)
1988	16 532 164	503 (3.04)	84 (0.50)	6	1670 (10.1)	254 (1.53)	2173 (13.1)	338 (2.04)
1989	16 814 416	451 (2.68)	73 (0.43)	0	1618 (9.62)	239 (1.42)	2069 (12.3)	312 (1.85)
1990	17 065 128	490 (2.87)	77 (0.45)	5	1712 (10.0)	300 (1.75)	2202 (12.9)	377 (2.20)
1991	17 284 036	488 (2.82)	87 (0.50)	6	1804 (10.4)	259 (1.49)	2292 (13.2)	346 (2.00)
1992	17 478 635	475 (2.71)	88 (0.50)	6	1780 (10.1)	218 (1.24)	2255 (12.9)	306 (1.75)
1993	17 634 808	441 (2.50)	71 (0.40)	5	1601 (9.07)	259 (1.46)	2042 (11.5)	330 (1.87)
1994	17 805 468	411 (2.30)	70 (0.39)	0	1873 (10.5)	255 (1.43)	2284 (12.8)	325 (1.82)
1995	18 004 882	393 (2.18)	66 (0.36)	0	1970 (10.9)	258 (1.43)	2363 (13.1)	324 (1.79)
1996	18 224 767	391 (2.14)	105 (0.57)	41	2035 (11.1)	218 (1.19)	2426 (13.3)	323 (1.77)
1979-1996 (mean)		8851 (3.03)	1656 (0.56)	104	27 525 (9.23)	4027 (1.35)	36 376 (12.24)	5683 (1.92)
1997	18 423 037	296 (1.60)	74 (0.40)	0	2351 (12.7)	253 (1.42)	2647 (14.4)	327 (1.83)
1998	18 607 584	248 (1.33)	56 (0.30)	0	2393 (12.8)	243 (1.35)	2641 (14.1)	299 (1.65)
1999	18 812 264	261 (1.39)	51 (0.27)	0	2229 (11.8)	247 (1.36)	2490 (13.2)	298 (1.63)
2000	19 028 802	222 (1.17)	60 (0.32)	0	2170 (11.4)	246 (1.35)	2392 (12.5)	306 (1.67)
2001	19 274 701	262 (1.36)	48 (0.25)	0	2208 (11.4)	268 (1.40)	2470 (12.8)	316 (1.66)
2002	19 495 210	213 (1.10)	50 (0.26)	0	2115 (10.8)	243 (1.29)	2328 (11.9)	293 (1.55)
2003	19 720 737	188 (0.95)	46 (0.23)	0	1976 (10.0)	228 (1.18)	2164 (10.9)	274 (1.41)
2004	19 932 722	171 (0.86)	18 (0.09)	0	1948 (9.77)	147 (0.74)	2119 (10.63)	165 (0.83)
2005	20 176 844	145 (0.72)	20 (0.1)	0	1951 (9.67)	171 (0.85)	2096 (10.39)	191 (0.95)
2006	20 450 966	192 (0.94)	36 (0.18)	0	1952 (9.54)	210 (1.03)	2144 (10.48)	246 (1.2)
2007	20 827 622	188 (0.9)	29 (0.14)	0	2072 (9.95)	199 (0.96)	2260 (10.85)	228 (1.09)
2008	21 249 199	184 (0.87)	26 (0.12)	0	2141 (10.08)	229 (1.08)	2325 (10.94)	255 (1.2)
2009	21 691 653	165 (0.76)	37 (0.17)	0	2196 (10.12)	232 (1.07)	2361 (10.88)	269 (1.24)
2010	22 031 750	174 (0.79)	39 (0.18)	0	2239 (10.16)	202 (0.92)	2413 (10.95)	241 (1.09)
2011	22 340 024	145 (0.65)	32 (0.14)	0	2329 (10.43)	240 (1.07)	2474 (11.07)	272 (1.22)
2012	22 728 254	176 (0.77)	41 (0.18)	0	2374 (10.45)	221 (0.97)	2550 (11.22)	262 (1.15)
2013	23 117 353	166 (0.72)	35 (0.15)	0	2454 (10.62)	184 (0.8)	2620 (11.33)	219 (0.95)
1997-2013 (mean)		3396 (0.99)	698 (0.2)	0	37 098 (10.69)	3763 (1.11)	40 494 (11.68)	4461 (1.31)
Total (mean)		12 247 (2.03)	2354 (0.39)	104	64 623 (9.94)	7790 (1.23)	76 870 (11.97)	10 144 (1.63)

[a] Data were provided by the Australian Institute of Health and Welfare (AIHW) National Injury Surveillance Unit using records from the AIHW National Mortality Database. Deaths recorded in the database were certified by coroners; registered by Registries of Births, Deaths, and Marriages; and cause-coded by the Australian Bureau of Statistics. Inclusion criteria: *International Classification of Diseases, Ninth Revision* (*ICD-9*), codes for suicide, E950-E569; homicide, E960-E969; *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision* (*ICD-10*), codes for suicide, X60-X84; and homicide, X85-Y09. The dip in case numbers in the 3 years before 2006 is largely due to a change in data collection method, which resulted in some cases being coded to other categories, mostly accidental injury due to firearms. For further information, see Harrison and Henley.[12] Case counts for 2004 and later years are from Data-cube 14 (causes of death by year of occurrence) in ABS 3303.0: Causes of Death, Australia, 2014 (release date, March 8, 2016).

[b] Not including perpetrators.

Figure. Suicide and Homicide Death Rates According to Firearm Involvement (1979-2013)
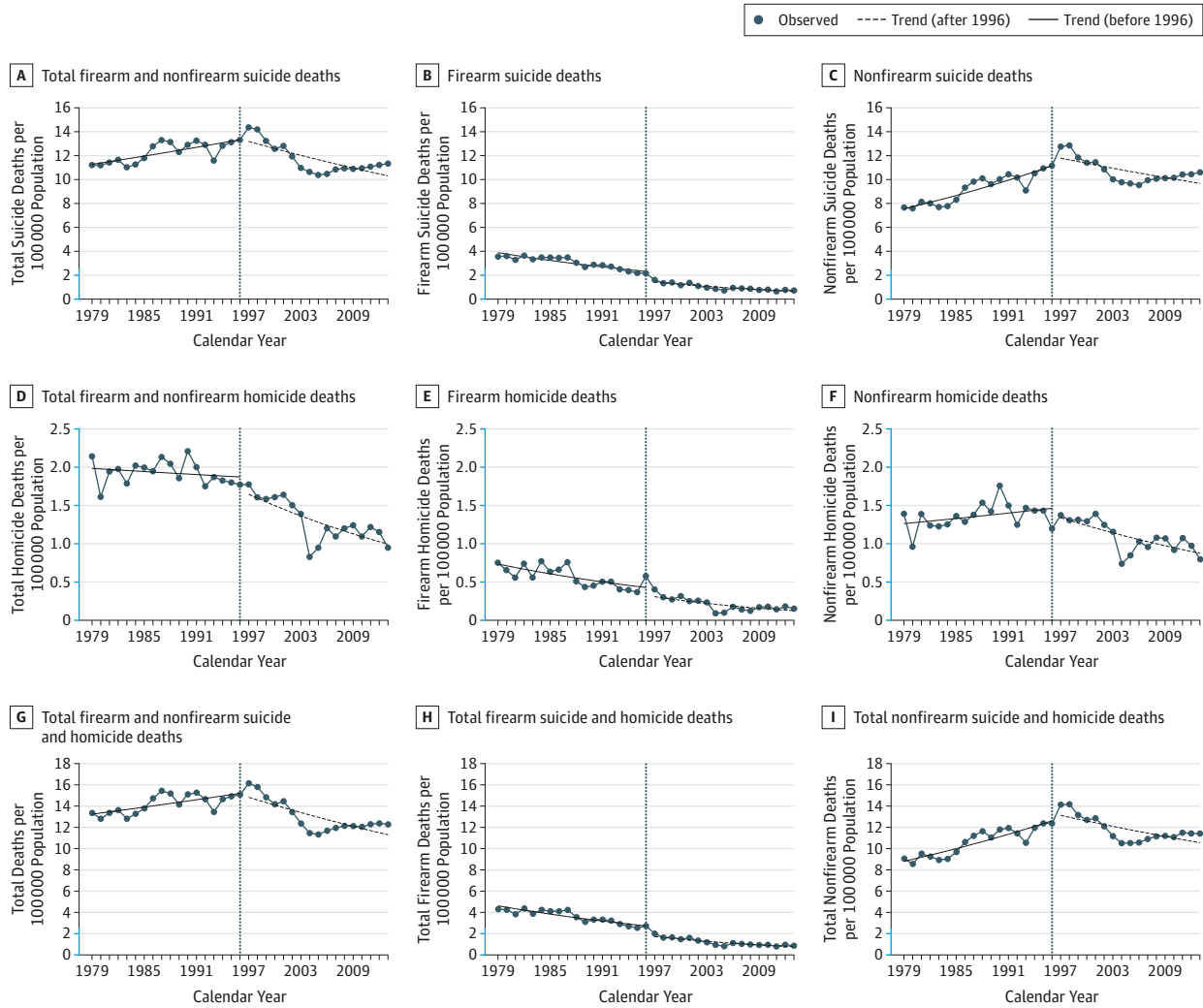
The shape of the fitted lines involves 2 components. One component of interest is how much the slopes of the change in annual death rates differ between the periods before and after the gun law enactment (vertical dotted lines). Although it can be difficult to judge the magnitude from the graph itself, this is quantified in the RT column of Table 3, which provides estimates of the relative slopes (ratio: postlaw slope to prelaw slope) of the postlaw-to-prelaw trends in annual death rates. A ratio <1.0 indicates a stronger decline in annual death rates after the introduction of new gun laws compared with before. The second component of interest is the change in level of death rate, which is reported in the RL column of Table 3. This value represents the ratio of death rate at the start of the period 1997 onward to the death rate at the end of the period up to 1996. The distinction between these 2 components is illustrated by comparing panel C (nonfirearm suicide) and panel F (nonfirearm homicide). From C, the positive upward trend in annual death rates becomes negative shortly after the introduction of gun laws (hence, ratio of trends in Table 3 is <1.0), but the death rate immediately after gun law introduction is higher than immediately before (hence, the ratio of levels is >1.0). The y axis shown in blue indicates the range of deaths of 0 to 2.5 per 100 000 population.

laws, for an overall mean of 1.36 (95% CI, 1.29-1.44) per 100 000 population, and decreased by a mean of 2.6% per year after the introduction of the new gun laws to an overall mean of 1.09 (95% CI, 1.00-1.19) per 100 000 (Figure, F; Table 3). The ratio of the prelaw-to-postlaw trends was statistically significantly different (RT = 0.965; 95% CI, 0.950-0.981), but there was no statistically significant step change (RL = 0.941; 95% CI, 0.803-1.103) (Table 3). The data do not support any homicide method substitution hypothesis.

Discussion

In the 20 years (May 1996-May 2016) since the gun law reforms and buyback programs, no mass shootings (ie, ≥5 victims) have occurred in Australia. In addition, there was a more rapid decline in total firearm deaths after gun law reforms (1997-2013) compared with before gun law reforms (1979-1996). The prelaw reform decline in firearm suicides increased significantly after the reforms, and the decline in

Table 3. Trends in Intentional Firearm Mortality and Nonfirearm Suicide and Homicide Rates Before and After 1996 and Ratio of Trends[a]

Mortality	Trend in Annual Death Rate per 100 000 Population (95% CI)		Annual Death Rate, RT (95% CI)[b]	P Value	Annual Death Rate, RL (95% CI)[c]	P Value
	1979-1996	1997-2013				
Firearm deaths						
Total	0.970 (0.963-0.976)	0.951 (0.940-0.962)	0.981 (0.968-0.993)	.003	0.669 (0.589-0.760)	<.001
Suicide	0.970 (0.964-0.976)	0.952 (0.942-0.962)	0.981 (0.970-0.993)	.001	0.652 (0.582-0.731)	<.001
Homicide	0.969 (0.955-0.983)	0.945 (0.922-0.969)	0.975 (0.949-1.001)	.06	0.769 (0.590-1.004)	.05
Homicide (nonmass)[d]	0.958 (0.947-0.969)	0.945 (0.922-0.969)	0.985 (0.962-1.009)	.20	0.920 (0.727-1.163)	.05
Nonfirearm deaths						
Total	1.021 (1.016-1.026)	0.986 (0.980-0.993)	0.966 (0.958-0.973)	<.001	1.054 (0.974-1.141)	.20
Suicide	1.023 (1.018-1.028)	0.988 (0.982-0.994)	0.965 (0.958-0.973)	<.001	1.070 (0.988-1.159)	.10
Homicide	1.009 (0.998-1.019)	0.974 (0.962-0.988)	0.965 (0.950-0.981)	<.001	0.941 (0.803-1.103)	.50
Total homicide and suicide deaths	1.008 (1.004-1.012)	0.983 (0.977-0.990)	0.975 (0.968-0.983)	<.001	0.991 (0.918-1.071)	.80
Total suicide	1.010 (1.006-1.014)	0.985 (0.979-0.991)	0.975 (0.968-0.982)	<.001	1.004 (0.931-1.083)	.90
Total homicide	0.997 (0.990-1.003)	0.969 (0.956-0.982)	0.972 (0.958-0.986)	<.001	0.908 (0.784-1.050)	.20

Abbreviations: RL, ratio of levels; RT, ratio of trends.

[a] Table 3 reports the slopes (trend) in annual death rate per 100 000 population up to and including 1996 and after 1996; the ratio of slopes, calculated as slope for 1997 and later divided by slope for 1996 and earlier; and the ratio of level of death rate, which compares the death rates immediately around 1996. All estimates are obtained from negative binomial models.

[b] Ratio of trends calculated as trend in annual death rate in 1997-2013 divided by trend in annual death rate in 1979-1996 with 95% CI.

[c] Ratio of levels is estimated from the main effect of *Law* in model c and represents the shift in annual death rates around the time of the introduction of gun control laws.

[d] Mass gun-related homicides removed from counts of deaths in corresponding calendar year.

firearm homicides also increased, although this did not reach statistical significance. Total suicides (all methods including firearms) increased by a mean of 1% per year before the introduction of the 1996 gun laws and decreased by a mean of 1.5% per year after the introduction of the new gun laws. Although the annual trend in total homicide was slightly declining in 1979-1996 by less than 1%, this trend accelerated to a 3.1% decline after the introduction of gun control laws (1997-2013). The ratio of the prelaw-to-postlaw trends was statistically significant for both total suicide (*P* < .001) and total homicide (*P* < .001) (Table 3).

Although the mean annual rates of total nonfirearm suicides and homicides were lower from 1979-1996 compared with mean annual rates from 1997-2013, the rates increased by an average of 2.1% per year before gun law reform and decreased by an average of 1.4% per year after gun law reform (Figure, C). In addition, the post-1996 decrease in the rates of nonfirearm suicide and homicide was larger than the decreases for suicide and homicide involving firearms. An examination of the decline in suicide in Australia between 1994-2007 concluded that much of the decline was explained by changes toward the use of less fatal methods.[13] There was a decrease in suicide by motor vehicle exhaust, which explained nearly half of the overall decline in suicide deaths. Suicide using firearms had the highest fatality rate (74%), and self-poisonings had the lowest rate at 1.4%. The study noted that "the decline in firearm deaths over the study period was due primarily to a decline in attempts; lethality remained relatively flat."[13]

To our knowledge, no other Australian studies have examined the decline in nonfirearm homicide deaths. However, this decline may reflect historical factors over the period examined, such as improved trauma care for less lethal assault methods and reduced times in victims accessing and receiving out-of-hospital and hospital emergency services. For instance, a 1997 study[14] of 2233 adults found that 92 of 764 cell phone users (12%) had used their phone to call emergency services to a road crash and 46 (6%) to a nonroad medical emergency. With increasing cell phone use over the past 2 decades, it is plausible that ambulances will have increasingly attended traumatic incidents like assaults and suicide attempts earlier than in previous times when landlines were only or more commonly used to make such calls. There have also been improvements in emergency care, and the lower lethality of nonfirearm assault and suicide may explain the greater reductions in nonfirearm homicide and suicide rates. For example, a US study of the effect of emergency care using data from the National Trauma Data Bank[15] found that firearm injury was 1 factor predicting death after admission and noted that prehospital fatalities were excluded in such analyses: persons who sustain firearm injuries are more likely to die both before and after hospital admission than from suicide or homicide methods such as self-poisoning, assault, stabbing, gas inhalation, or hanging.[13,16] However, these observations are speculative.

Considering that firearms have a very high lethality index (or "completion rate") in both homicide and suicide,[16] it is possible that had the gun law reforms not occurred, more Australians contemplating suicide might have more easily accessed firearms and completed suicide. The data in this study show that the declining rate of suicide by firearm accelerated significantly after the 1996 gun laws, with no apparent substitution to other lethal methods, or if there was substitution, it may have been into less lethal methods.

Despite a surge of postlaw gun buying to replace destroyed semiautomatic and other rapid-fire weapons with single-shot rifles and shotguns,[17] in a trend that preceded the Australian firearm buyback but seems to have been accelerated by this initiative, the proportion of Australian households reporting private gun ownership declined by 75% between 1988 and 2005.[18]

We are unaware of any other nation that has enacted such a substantial change in gun laws as has been implemented in Australia. Comparative studies of Australia's experience with broadly comparable nations would provide further evidence of the effects of such law reform.

This study has several issues related to terminology and limitations that should be considered in the interpretation of these findings. First, there is no authoritative international consensus on the definition of a "mass" fatal shooting. We defined mass shooting as a killing involving 5 or more victims, not including the perpetrator. However, many firearm deaths with more than 1 victim are domestic homicides and murder-suicides. These commonly involve up to 3 victims, plus the suicide or police shooting of the perpetrator. A footnote to Table 1 lists all 3 known fatal shooting incidents in which 3 or 4 victims were killed with firearms after 1996.

Second, the observational nature of the data in this article precludes assigning causality between enactment of the 1996 gun laws along with the buyback program and subsequent elimination of mass shootings and reduction in rates of total firearm-related deaths and gun-related suicide. Even though the rates of firearm-related homicides and suicides were declining before gun law reforms, banning rapid-fire weapons, and removal of a substantial number of firearms, it is plausible that reducing the availability of weapons may have been related to the acceleration in the rates of declines for these deaths after gun reform.

Third, data on unintentional ("accidental") deaths in this article were not included because the proportion of such deaths in total firearm deaths in Australia is small (<5%) but mainly because the main intent of the 1996 gun law reforms was to prevent mass shootings. Homicide and suicide mortality are associated with age and sex. The distribution of these characteristics could have shifted over the period of time reported. Because of the complexities of obtaining relevant data and matching them meaningfully with the death data, this shift in distribution has not been addressed in this study.

Table 2 comprises case numbers from the ABS-coded national death data collection, the official source of death data in Australia. Some firearm deaths that are coded as "accidental" in the official statistics (and were omitted from Table 2) were assigned that intent status because the relevant records in the National Coronial Information System (NCIS), on which the ABS relied when coding the cases, were not complete when inspected by the ABS. Later inspection of the NCIS records showed that the intent of most of these shooting deaths had by then been reclassified as homicide or suicide, with some remaining undetermined.[12] The annual number of firearm deaths coded as accidental in the official statistics but as homicide, suicide, or undetermined intent in the finalized NCIS records was about 20, 30, 40, and 40 per year, respectively, from 2002 to 2005 (see Figure 4.18 of Harrison and Henley[12]). Some data in the previous report on the tenth anniversary of the gun law reforms[8] have now slightly changed, reflecting these updates from delayed coronial findings.

A similar problem affected the initial release of data for the deaths registered in 2006, which was processed by the ABS in the same way that they had used for earlier years. Later, in recognition of the problem, the ABS processed the same set of deaths again, by which time the NCIS records were more complete. In the revised release (used when preparing Table 1), most firearm deaths that had been coded as accidental in the initial release were coded as suicide or homicide. A revised method, used by the ABS for registration years 2007 onwards, largely overcomes this problem.[12]

Conclusions

Following the enactment of gun law reforms in Australia in 1996, there were no mass firearm killings through May 2016. There was a more rapid decline in firearm deaths between 1997 and 2013 compared with before 1997, but also a decline in total nonfirearm suicide and homicide deaths of a greater magnitude. Because of this, it is not possible to determine whether the change in firearm deaths can be attributed to the gun law reforms.

REFERENCES

1. Chapman S. *Over Our Dead Bodies: Port Arthur and Australia's Fight for Gun Control.* Sydney, Australia: Sydney University Press; 2013:117-152. http://bit.ly/1WydC4M. Accessed June 17, 2016.

2. Peters R. Rational firearm regulation: evidence-based gun laws in Australia. In: Webster DW, Vernick JS, eds. *Reducing Gun Violence in America: Informing Policy With Evidence and Analysis.* Baltimore, MD: Johns Hopkins University Press; 2013: 195-204. http://bit.ly/1PZ24DL. Accessed June 17, 2016.

3. Reuter P, Mouzos J. Australia: A massive buyback of low-risk guns. In: Ludwig J, Cook P. *Evaluating*

Gun Policy: Effects on Crime and Violence. Washington, DC: Brookings Institution; 2003:Table 4-3,132. http://bit.ly/1Wy00Gw. Accessed June 17, 2016.

4. Alpers P. The Big Melt: how one democracy changed after scrapping a third of its firearms. In: Webster DW, Vernick JS, eds. *Reducing Gun Violence in America: Informing Policy With Evidence and Analysis*. Baltimore, MD: Johns Hopkins University Press; 2013:205-211. http://bit.ly/1PZ24DL. Accessed June 17, 2016.

5. Bricknell S. Firearm trafficking and serious and organised crime gangs. Australian Institute of Criminology. http://www.aic.gov.au/publications/current%20series/rpp/100-120/rpp116.html. Accessed June 17, 2016.

6. Hudson P. Victoria leads way in gun buyback. *The Age*. August 8, 2004. http://www.theage.com.au/articles/2004/08/07/1091732142762.html. Accessed June 17, 2016.

7. Alpers P, Rossetti R. Australian firearm amnesty: buyback and destruction totals. GunPolicy.org, Sydney School of Public Health. http://www.gunpolicy.org/documents/5337-australia-firearm-amnesty-buyback-and-destruction-totals. Accessed June 17, 2016.

8. Chapman S, Alpers P, Agho K, Jones M. Australia's 1996 gun law reforms: faster falls in firearm deaths, firearm suicides, and a decade without mass shootings. *Inj Prev*. 2006;12(6):365-372.

9. Quality declaration: causes of death data. Australian Bureau of Statistics. http://www.abs.gov.au/Ausstats/abs@.nsf/0/D4A300EE1E04AA43CA2576E800156A24?OpenDocument. Accessed June 17, 2016.

10. Morton RJ, Hilts MA. Serial murder: multi-disciplinary perspectives for investigators. National Center for the Analysis of Violent Crime, Federal Bureau of Investigation. https://www.fbi.gov/stats-services/publications/serial-murder. Accessed June 17, 2016.

11. Duwe G. The patterns and prevalence of mass murder in twentieth-century America. *Justice Q*. 2004;21(4):729-761.

12. Harrison J, Henley G. Injury deaths data, Australia: technical report on issues associated with reporting for reference years 1999–2010. Australian Institute of Health and Welfare. http://www.aihw.gov.au/publication-detail/?id=60129550967. Accessed June 17, 2016.

13. Spittal MJ, Pirkis J, Miller M, Studdert DM. Declines in the lethality of suicide attempts explain the decline in suicide deaths in Australia. *PLoS One*. 2012;7(9):e44565.

14. Chapman S, Schofield WN. Lifesavers and Samaritans: emergency use of cellular (mobile) phones in Australia. *Accid Anal Prev*. 1998;30(6):815-819.

15. Clark DE, Doolittle PC, Winchell RJ, Betensky RA. The effect of hospital care on early survival after penetrating trauma [published online September 17, 2014]. *Inj Epidemiol*. doi:10.1186/s40621-014-0024-1.

16. Beaman V, Annest JL, Mercy JA, Kresnow MJ, Pollock DA. Lethality of firearm-related injuries in the United States population. *Ann Emerg Med*. 2000;35(3):258-266.

17. Alpers P. Australian civilian gun imports, 1988-2015 (ABS). GunPolicy.org, Sydney School of Public Health. http://www.gunpolicy.org/documents/5343-australia-firearm-imports-1988-2012-abs. Accessed June 17, 2016.

18. Alpers P, Rossetti A. Australia: Proportion of households with firearms. GunPolicy.org, Sydney School of Public Health. http://www.gunpolicy.org/firearms/compareyears/10/proportion_of_households_with_firearms. Accessed June 17, 2016.