Geospatial, racial, and educational variation in firearm mortality in the USA, Mexico, Brazil, and Colombia, 1990–2015: a comparative analysis of vital statistics data

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Summary

Background Firearm mortality is a leading, and largely avoidable, cause of death in the USA, Mexico, Brazil, and Colombia. We aimed to assess the changes over time and demographic determinants of firearm deaths in these four countries between 1990 and 2015.

Methods In this comparative analysis of firearm mortality, we examined national vital statistics data from 1990–2015 from four publicly available data repositories in the USA, Mexico, Brazil, and Colombia. We extracted medically-certified deaths and underlying population denominators to calculate the age-specific and sex-specific firearm deaths and the risk of firearm mortality at the national and subnational level, by education for all four countries, and by race or ethnicity for the USA and Brazil. Analyses were stratified by intent (homicide, suicide, unintentional, or undetermined). We quantified avoidable mortality for each country using the lowest number of subnational age-specific and period-specific death rates.

Findings Between 1990 and 2015, 106·3 million medically-certified deaths were recorded, including 2 472 000 firearm deaths, of which 851 000 occurred in the USA, 272 000 in Mexico, 855 000 in Brazil, and 494 000 in Colombia. Homicides accounted for most of the firearm deaths in Mexico (225 000 [82·7%]), Colombia (463 000 [93·8%]), and Brazil (766 000 [89·5%]). Suicide accounted for more than half of all firearm deaths in the USA (479 000 [56·3%]). In each country, firearm mortality was highest among men aged 15–34 years, accounting for up to half of the total risk of death in that age group. During the study period, firearm mortality risks increased in Mexico and Brazil but decreased in the USA and Colombia, with marked national and subnational geographical variation. Young men with low educational attainment were at increased risk of firearm homicide in all four countries, and in the USA and Brazil, black and brown men, respectively, were at the highest risk. The risk of firearm homicide was 14 times higher in black men in the USA aged 25–34 years with low educational attainment than comparably-educated white men (1·52% [99% CI 1·50–1·54] *vs* 0·11% [0·10–0·12]), and up to four times higher than in comparably-educated men in Brazil, Colombia, and Mexico. In the USA, the risk of firearm homicide was more than 30 times higher in black men with post-secondary education than comparably educated white men. If countries could achieve the same firearm mortality rates nationally as in their lowest-burden states, 1 777 800 firearm deaths at all ages and in both sexes could be avoided, including 1 028 000 deaths in men aged 15–34 years.

Interpretation Firearm mortality in the USA, Mexico, Brazil, and Colombia is highest among young adult men, and is strongly associated with race and ethnicity, and low education levels. Reductions in firearm deaths would improve life expectancy, particularly for black men in the USA, and would reduce racial and educational disparities in mortality.

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Introduction

Firearms have remained a persistent cause of death in the Americas for the past 25 years.[1,2] Firearm mortality in the USA is markedly higher than in any other high-income country,[3,4] and in several Central and South American countries, firearm mortality is even higher than in the USA.[5,6] Globally, firearm mortality is highest in countries in which firearms are easily accessible.[2,7]

The comparative epidemiological and demographic determinants of firearm deaths in the Pan-American region are poorly documented, which is surprising since these events are common and attract considerable media and public attention, especially following mass shootings.[6] Although the number of firearm deaths has been reported at the national level,[2] the marked variation in firearm mortality in the Americas at the country level, subnational level, by race or ethnicity and education level, and the impact of these deaths on life expectancy among subpopulations, have not previously been examined.[1,6] Race, place of residence, and socioeconomic opportunity might contribute to variation in the sex-specific rates of injuries and deaths from firearms between and within

Research in context

Evidence before this study

Firearms are a persistent cause of death globally, and the rates of firearm mortality vary substantially between countries. We searched PubMed for articles in English, Spanish, or Portuguese published between Sept 1, 1980, and Sept 1, 2018, using the search terms "(firearm* OR gun OR guns) AND (mortality OR death*) AND ((US OR USA OR United States) OR Colombia OR Mexico OR Brazil)". We found that geographical and demographic variation in firearm mortality within and between countries in the Americas was mostly undocumented. Furthermore, the contribution of firearm deaths to the overall mortality among different demographic groups has not been investigated. A detailed understanding of firearm mortality in the Americas is required to inform public health responses.

Added value of this study

In this study, we used high-quality and complete vital registration data to assess demographic determinants and patterns in firearm mortality between 1990 and 2015 in the USA, Mexico, Brazil, and Colombia, and the contribution of firearms to overall mortality, and estimated the number of avoidable firearm deaths. We focused on the racial and educational differences in risk of firearm mortality. We found that firearm mortality is a leading, and largely avoidable, cause of death in young men (aged 15–34 years) in the USA, Mexico, Brazil, and Colombia, and is the leading contributor to mortality at these ages. The risk of firearm mortality within countries is highest among young men, and is strongly associated with place of residence, race and ethnicity, and level of education. Poorly educated black men in the USA were at the highest risk of mortality of any age group, sex, ethnicity, or educational subgroup across the four countries.

Implications of all the available evidence

Our study highlights the substantial public health impact of firearms in the USA, Mexico, Colombia, and Brazil. The extreme variation in the risk of firearm mortality among subpopulations and the rapid fluctuations in death rates provides strong evidence of avoidability, and also of the importance of educational level and race. Changes in firearm mortality rates explain most of the reductions in overall mortality among young men in the study countries observed in the past 25 years. In the USA, firearm deaths were the main contributor to the marked differences in the overall risk of mortality between young white and black men, regardless of educational level.

countries. Quantification of subnational variations could help our understanding of firearm deaths, highlight populations at risk, and identify opportunities for intervention, including reducing firearm exposure.[8]

We quantified the temporal and spatial trends in firearm mortality among different subpopulations in the USA, Mexico, Brazil, and Colombia between 1990 and 2015. We selected these four countries because they have high-quality and complete cause-of-death data and high firearm mortality. We assessed national and subnational variation in overall and intent-specific firearm mortality and calculated the individual risks and population-based rates of firearm mortality by sex, age, time period, educational level, and race or ethnicity. We estimated the number of avoidable deaths from firearms in each of these groups between 1990 and 2015.

Methods

Data sources

We obtained age-specific, sex-specific, and cause-specific mortality data from 1990–2015 for the USA, Mexico, Brazil, and Colombia from national vital statistics databases: the US National Center for Health Statistics,[9] Instituto Nacional de Estadística y Geografía,[10] Sistema de Informação sobre Mortalidade,[11] and Departamento Administrativo Nacional de Estadística (DANE).[12] In each country, the underlying cause of death was assigned during routine medical death certification and coded according to the International Classification of Diseases, ninth or tenth revision (ICD-9 or ICD-10). Nearly all deaths in the USA and Mexico are medically certified. In Brazil, medically-certified cause of death coverage was 97% in 2014 (an increase from 87% in the 1990s and 90–95% in the 2000s), and in Colombia mean coverage was 98% in the past decade.[13] Ill-defined causes of death in individuals aged 70 years or younger, which provide a crude assessment of the quality of medical certification, account for less than 2% of all deaths at these ages in the USA, Mexico, and Colombia. In Brazil, ill-defined causes of death accounted for 10% of deaths at these ages between 1990 and 2015, but only around 5% between 2005 and 2015. We obtained population denominators for the USA, Mexico, Brazil, and Colombia from the National Cancer Institute's Surveillance, Epidemiology, and End Results database[14] (which provides more current estimates than the US census), the Mexican Population Council,[15] the Instituto Brasileiro de Geografia e Estatística's Demographic Census data,[16] and DANE,[12] respectively.

See Online for appendix

Data analysis

Our primary analysis compared overall firearm deaths and mortality rates in the four countries at the national and subnational level, stratified by age, sex, education level, and race or ethnicity. Secondary analyses were firearm deaths and mortality rates subclassified by intent: homicide, suicide, unintentional, or undetermined (appendix p 2). Our primary analysis of firearm mortality

and comparison with overall all-cause mortality should not be biased by misclassification from death certificate information, in view of the near complete registration data in each country. Firearm deaths are often reported by intent rather than as a common mechanism or exposure risk.[17] Analysis of firearm deaths by both intent and as a single exposure risk enables a more nuanced development of public health responses.

For each country, we calculated the total number of firearm deaths by year, intent, sex, and age group (0–14 years; 15–34 years; 35–54 years; 55–74 years; ≥75 years) based on the mean of the 5-year age groups, representing linear age standardisation.[18,19] We calculated age-standardised mortality rates for all-cause deaths and firearm deaths, stratified by sex and subnational-level geographical division (referred to hereafter as state). The USA and Brazil record race or ethnicity and education on death certificates. The education variable has been collected in both countries since 2000, and in Brazil, ethnicity has been collected since 2000. We stratified mortality rates by race or ethnicity in the USA (non-Hispanic black [black], non-Hispanic white [white], and Hispanic subpopulations), and in Brazil (white, black, and brown subpopulations) for the relevant years. We defined education in all countries as either high school or less, or post-secondary.

We standardised mortality data at ages 15–34 years to a uniform age distribution by averaging the age-specific death rates at age 15–19, 20–24, 25–29, and 30–34 years. The death rate (R per 1000) was the mean of these four age-specific rates. The 20-year risk of dying for a 15-year-old at age 15–34 years is equal to 1–exponential (–20R/1000).[18,19] We applied this procedure separately to firearm deaths and to all-cause mortality, examining the proportional contribution of firearms to all-cause mortality risk. We defined high-burden and low-burden states in each country as those with the highest and lowest quintiles of firearm death rates, respectively (appendix pp 3–14). We applied the same procedure to estimate firearm and all-cause risk of mortality stratified by sex, age, place of residence, education level, and race or ethnicity. We used Stata (version 15.1) and ArcMap (version 10.5) for statistical analyses.

Avoidable mortality refers to deaths that could have been avoided either through individual and population level prevention measures (also referred to as preventable deaths) or deaths that could have been avoided through optimum quality health care (amenable deaths).[20–22] We quantified avoidable mortality in three ways. First, we estimated firearm deaths in excess of those observed in the states of each country with the lowest age-specific firearm death rates in any 5-year time period. Second, we calculated avoidable firearm deaths among men as the excess over those observed among women of the same age group and time period. Third, we calculated firearm deaths for the whole of the USA and Brazil in excess of the death rates among white individuals, who were observed in both countries to have the lowest age-specific firearm death rates. Avoidable deaths are presented as total deaths for each country from 1990–2015.

Role of the funding source

The funders of the study had no role in the study design, data collection, analysis, interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Between 1990 and 2015, 106·3 million deaths were recorded in the USA, Mexico, Brazil, and Colombia, of which 2 472 000 were firearm deaths: 851 000 occurred in the USA, 272 000 in Mexico, 855 000 in Brazil, and 494 000 in Colombia (table 1). Of the 2 472 000 firearm deaths, 1 796 000 (72·6%) were homicides, and 540 000 (21·8%) were suicides, with most suicides occurring in the USA (appendix p 15). Homicide accounted for most of

	USA	Mexico	Brazil	Colombia
Population in 2015 (thousands)	321 538	120 838	201 234	48 203
Male population aged 15–34 years in 2015 (thousands)	44 765	19 946	34 929	8158
Life expectancy at birth in 2015 (years)	80	77	76	75
Total deaths from all causes in 2015 (thousands)	2718	638	1220	219
Total deaths from all causes, 1990–2015 (thousands)	62 583	12 723	26 158	4847
Total firearm deaths, 1990–2015 (thousands)	851	272	855	494
Homicides (%)	342 (40·1%)	225 (82·7%)	766 (89·5%)	463 (93·8%)
Suicides (%)	479 (56·3%)	17 (6·2%)	31 (3·6%)	13 (2·7%)
Unintentional deaths (%)	22 (2·6%)	17 (6·2%)	11 (1·3%)	2 (0·4%)
Undetermined deaths (%)	8 (0·9%)	13 (5·0%)	48 (5·6%)	15 (3·1%)
Firearm deaths in men, 1990–2015 (thousands)				
All ages (%)	730 (2·3%)	252 (3·5%)	799 (5·3%)	459 (16·3%)
0–14 years (%)	10 (1·7%)	4 (0·5%)	11 (0·9%)	5 (2·0%)
15–34 years (%)	332 (22·1%)	144 (16·9%)	579 (28·5%)	305 (53·1%)
35–54 years (%)	210 (5·2%)	82 (6·3%)	173 (5·8%)	125 (27·0%)
55–74 years (%)	121 (1·1%)	19 (0·9%)	32 (0·7%)	21 (2·8%)
Firearm deaths in women, 1990–2015 (thousands)				
All ages (%)	121 (0·4%)	20 (0·4%)	56 (0·5%)	35 (1·8%)
0–14 years (%)	4 (0·8%)	2 (0·2%)	4 (0·4%)	2 (1·0%)
15–34 years (%)	45 (7·8%)	11 (3·6%)	35 (5·9%)	21 (15·7%)
35–54 years (%)	46 (1·9%)	6 (0·9%)	14 (0·9%)	10 (4·1%)
55–74 years (%)	21 (0·3%)	2 (0·1%)	3 (0·1%)	2 (0·3%)

Data are n or n (%). Numbers are rounded to the nearest thousand. Data obtained from UN World Population Prospects 2017 Revision.[23] The number of sex-specific and age-specific firearm deaths do not sum to total firearm death counts because some values were missing for age-specific counts.

Table 1: **Characteristics of the study population in the USA, Mexico, Brazil, and Colombia**

Figure 1: **Subnational geographic variation in the risk of mortality from firearms in the USA, Mexico, Brazil, and Colombia among men aged 15–34 years, 1990-2015**

the firearm deaths in Colombia (463 000 [93·8%] of 494 000 deaths), Brazil (766 000 [89·5%] of 855 000 deaths), and Mexico (225 000 [82·7%] of 272 000 deaths). Of the 851 000 firearm deaths in the USA, 342 000 (40·1%) deaths were homicides and 479 000 (56·3%) were suicides, with suicide becoming slightly more predominant over time. Table 1 shows the characteristics of the study populations in the four countries.

The overall mortality rates and risk of firearm death differed markedly between states and demographic groups in different countries. Every death per 1000 population corresponds, roughly, to a 2% risk of death in the 15–34 year age group. Among men aged 15–34 years, variability was observed across the four countries with regard to which 5-year age group had the highest firearm mortality rates. In the USA and Brazil, firearm mortality rates were highest

Figure 2: Risk of mortality from firearms among men aged 15–34 years by race, in the USA (A) and Brazil (B), 1990–2015

Figure 3: **Risk of mortality from firearm homicide and from all causes among men aged 25–34 years by (A) education, nationally and (B) in selected subpopulations in the USA, Mexico, Brazil, and Colombia, 2000–15**

99% CIs and the numerical values are shown in the appendix.

among men aged 20–24 years, whereas in Colombia and Mexico, the highest rates of firearm mortality were observed in older age groups (appendix pp 16–20). The 99% CIs were generally narrow, since the numbers of deaths in the major strata were quite large (appendix p 21). Firearm mortality rates were low and generally declined among women, whereas mortality rates in men were higher in all four countries with marked increases and decreases observed between 1990 and 2015 (appendix p 22). In Brazil, the rates of firearm suicide decreased, whereas the rates of firearm homicide increased during the study period. In the USA, the rates of firearm homicide decreased, whereas the rate of suicides increased during the study period. The highest risk of firearm mortality among men aged 15–34 years of any country was observed in Colombia in the 1990s, reaching 4·68% (99% CI 4·67–4·70). However, these high risks declined sharply after 2000, corresponding to a sharp decline in drug-related violence in the country.[5] By 2015, across the four countries, Colombian men aged 15–34 years had the highest risk of firearm mortality (1·88%, 1·87–1·89; appendix pp 16–20). The coding change from ICD-9 to ICD-10 did not materially alter the observed trends (data not shown).

The risk of mortality from firearms varied considerably between states among the 108 million men aged 15–34 years in the four countries (figure 1). In this age group, mortality risk from firearms was highest in the Colombian state of Antioquia (14·15% [99% CI 14·10–14·21]) in the early 1990s. In Mexico, the risk of mortality from firearms markedly increased in high-burden states between 2010 and 2015 (in particular, between 2009 and 2012), driven by large increases in firearm deaths in Chihuahua, Guerrero, Sinaloa, and Durango. In Brazil, the rates of firearm mortality among men increased most in the northeastern region and decreased in the two most populous states of São Paulo and Rio de Janeiro. The high-burden states changed over time in Colombia, Brazil, and Mexico, but remained more stable in the USA (appendix pp 3–14). The subnational variation in firearm mortality was lower in the USA than in Mexico, Colombia, and Brazil, but still remained substantial. In the USA, the District of Columbia had the highest risk of firearm mortality (around 6%) in the 1990s, which was nearly 10 times higher than the comparable national risk, followed by Louisiana and Alaska.

In the USA, differences in risk of mortality stratified by race or ethnicity were even more pronounced at the state level (figure 2). Among males aged 15–34 years, the risk of firearm mortality was highest in black men, which was four times higher than in white men. The risk of firearm mortality was similar in Hispanic and white men during the study period, but slightly higher among Hispanic men than among white men between 1990 and 2009, and slightly lower between 2010 and 2015 (figure 2).

Analysis stratified by race, intent, and education showed sharper differences among 15–34 year-old men. In the USA, the risk of firearm suicide was higher among young white men than black or Hispanic men, but when focusing on homicide, the pattern changed. The homicide analysis focused on the highest risk age group (men aged 25–34 years). At these ages, black men in the USA with high school or less education had a 1·52% risk (99% CI 1·50–1·54) of mortality from firearm homicide between 2000 and 2015. This risk was 14 times higher than that for comparably educated US white men (0·11% [0·10–0·12]), two to four times higher than for

Figure 4: **Risk of mortality from firearms and from all causes among men at ages 15–34 years in the USA, Mexico, Brazil, and Colombia**
Red boxes indicate the risk of firearm mortality for men aged 15–34 years. White boxes indicate risk of all-cause mortality for men aged 15–34 years. Total death counts (thousands) for firearms and for total deaths from any cause are shown in brackets.

	USA	Mexico	Brazil	Colombia	All countries
Total firearm deaths 1990–2015, all ages	851	272	855	494	2472
Avoidable firearm deaths using lowest local rates, all ages and both sexes	535	211	626	406	1778
Avoidable firearm deaths in men aged 15–34 years using lowest local rates	208	116	449	255	1028
Avoidable firearm deaths using lowest female rates, all ages and both sexes	710	246	792	446	2194
Avoidable firearm deaths in men aged 15–34 years using lowest female rates	299	136	559	291	1285

Data are n (thousands). Avoidable mortality was calculated uisng the mortality rates in the lowest burden states for each 5-year time period or the the lowest female mortality rates for each time period applied to the national totals. Low-burden states are listed in the appendix (pp 3–14).

Table 2: **Total and avoidable mortality from firearms in the USA, Mexico, Brazil, and Colombia, 1990–2015**

comparably educated Brazilian brown, black, or white men, or Mexican men (range 0·38–0·67%), and 1·5 times higher than comparably educated Colombian men (1·05% [1·03–1·06]; figure 3). Among US men with high school or lower education, firearm homicides accounted for three-quarters of the nearly 2% absolute difference in overall mortality risk between black and white men. In the 25–34 year age group, the risk of firearm homicide was five times lower in US black men with post-secondary education than black men with high school or lower education. The risk of firearm homicide was ten times lower in US white men with post-secondary education than white men with high school or lower education. The risk of mortality from firearm homicide was 30 times higher for US black men with university or higher education than comparably educated US white men (0·30% [99% CI 0·28–0·32] *vs* 0·01% [0·01–0·02]). By contrast, differences in the risk of mortality from firearm homicide in Brazilian men aged 25–34 years were mostly due to differences in education, regardless of race. Between 2000 and 2015, mortality risks from firearm homicides decreased or remained relatively stable in each country and in most subgroups, with the exception of brown men in Mexico and Brazil with high school or lower education, which increased (figure 3; appendix p 23).

Firearm deaths (homicide, suicide, and other) accounted for a large proportion of the all-cause mortality in the 15–34 year age group in all countries (figure 4). In Colombia, firearm deaths accounted for more than half of all deaths from any cause in men aged 15–34 years across the 25-year period. The absolute risk of firearm mortality decreased by 2·8% in Colombia between 1990 and 2015, which accounted for most of the 3·7% absolute decline in all-cause mortality rates (figure 4). In the high-burden states of Colombia, the absolute risk of firearm mortality decreased by 5% between 2000 and 2015, which substantially reduced overall mortality (appendix p 24). In Mexico between 2010 and 2015, firearm deaths accounted for about a quarter of all deaths nationally (figure 4), but an even greater proportion in the high-burden states. In these high-burden states, the variation in firearm deaths seemed to drive changes in all-cause mortality for men aged 15–34 years. In Brazil, the risk of mortality from firearms increased over the 25-year period (from 1·0% to 1·6%) despite an overall decrease in the all-cause mortality risks (figure 4). In the high-burden states of Brazil, firearm deaths accounted for less than a third of all-cause mortality at the start of the study period, but between 2010 and 2015 accounted for almost half. Between 1990 and 2015, firearm mortality and overall mortality declined steadily in the USA (figure 4). In the USA, differences in the risk of firearm mortality between black and white men accounted for most of the overall difference in the risk of mortality among men aged 15–34 years (appendix p 24). About 41%, 17%, and 31% of the absolute decline in all-cause mortality risk among black, white, and Hispanic men aged 15–34 years, respectively, between 1990 and 2015, was attributable to a reduction in firearm

mortality rates. In Brazil, firearm deaths made a smaller overall contribution to all-cause mortality rates than in the other three countries.

Across all four countries, we estimated that 1777800 firearm deaths were avoidable at all ages and in both sexes between 1990 and 2015 (table 2), of which 1028000 deaths were among men aged 15–34 years. Of the 535000 avoidable firearm deaths in the USA, 208000 (38·9%) were in men aged 15–34 years. We also estimated that 211000 deaths in Mexico (116000 [55·0%] in men aged 15–34 years), 406000 deaths in Colombia (255000 [62·8%] in men aged 15–34 years), and 626000 deaths in Brazil (449000 [71·7%] in men aged 15–34 years) could have been avoided. Using a different definition of avoidable deaths, we calculated the excess age-specific and time-specific firearm mortality rates for men compared with women. This method yielded 2194000 avoidable firearm deaths over the 25 years across all four countries, of which 1285000 deaths were among men aged 15–34 years. More conservatively, if the age-specific, sex-specific, and time-specific firearm mortality rates for the whole of the USA were the same as those among white individuals, 650000 (76%) of the firearm deaths that occurred between 1990 and 2015 would have been avoided (data not shown). Similarly, in Brazil, using white individuals as the comparison group, we found that 507000 (88%) of Brazilian firearm deaths that occurred between 2000 and 2015 would have been avoided (data not shown).

Discussion

Firearms are a major cause of premature mortality in the USA, Mexico, Brazil, and Colombia, accounting for nearly 2·5 million deaths in these four countries between 1990 and 2015. Homicide was the most common intent in Mexico, Brazil, and Colombia, whereas suicide was the most common intent in the USA. Around 1·4 million firearm deaths occurred in men aged 15–34 years. Our national-level estimates are consistent with published estimates from the Global Burden of Disease Study,[2] however, our study expands the analysis to investigate the effects of social and economic determinants or subnational geographical factors on firearm mortality risk. We showed that subnational variation in firearm mortality, which can vary by more than ten times among different risk groups, is often greater than cross-national variation.

Place of residence, race, and educational achievement influence an individual's risk of firearm mortality in all countries. In each country, most firearm deaths occurred within a few high-burden states, but the states with the highest firearm mortality rates varied over the 5-year intervals of our analysis. In Brazil and Colombia, several areas that were defined as high-burden states in earlier periods became low-burden states and vice versa. These changes highlight the volatility of firearm violence and mortality within countries over relatively short periods of time and provide evidence of avoidability. Education and race were pervasive factors affecting an individual's risk of firearm mortality. In all four countries, firearm mortality was substantially higher among young men with only a high school or less education than those with higher levels of education. This difference in mortality was most evident in Colombia and might reflect the socioeconomic factors associated with participation in violent organised crime and drug trafficking in the country, which has contributed to the high rate of firearm homicides in the country.[5]

Firearm homicide was highest among US black men aged 25–34 years with low educational attainment, and the effect of race on mortality was much greater in the USA than in Brazil. High educational attainment only partially protects young black men from firearm homicide in the USA; the risk of firearm mortality was three times higher among black men with post-secondary education than poorly educated white men, and 30 times higher than comparably educated white men.

Firearms are associated with high case fatality rates compared with other weapons, regardless of intent. For both suicide and homicide, weapon lethality matters; in the USA, mortality occurred in 85–96% of suicide attempts in which a firearm was used, but only 7% of attempts in which a bladed weapon or poison was used.[24] Most people who attempt suicide once and survive do not attempt suicide again; thus, reducing lethality at the initial attempt is crucial to reduce overall mortality.[25]

Although access to firearms might explain intercountry differences, firearm ownership alone is too simplistic an explanation for the subnational and demographic variation in firearm mortality risk within the USA. Ownership and access restrictions are central within broader interventions. In the USA, personal firearm ownership and household access to a firearm is higher in white populations than black populations and personal ownership and household access to firearms are highest among those with at least some post-secondary education.[26] Most of this variation in the difference between white and black men in survival at these ages can be explained by the differences in firearm mortality between the two groups. Failure to address firearms as a major cause of mortality for black men in the USA will hamper the country's ability to reduce disparities in mortality and improve overall life expectancy for black men. Interventions that reduce exposures to firearms are crucial, and well supported by research and international comparisons. There is also a clear need to address the broader cultural, social, and economic factors that contribute to such marked differences in mortality. Interventions that reduce exposures to firearms must be part of any effective solution.[7,8]

Reducing firearm deaths to the lowest observed state-level, age-specific, and sex-specific rates in each country during this period would have avoided almost 1·80 million deaths. The definition of avoidable death

rates in subnational regions within each country is arbitrary. However, the strength of this approach is that it represents actual lowest rates, pointing to a combination of determinants such as access to guns, enforcement of laws, social factors, and drug violence that are specific to each country and time period. Theoretically, all of the 2·5 million firearm deaths could be defined as avoidable, but this does not represent a pragmatic approach to understanding variations in mortality rate and risk of mortality at the subnational level. Our approach, in which we used the lowest mortality rates observed within each country, is consistent with public health approaches for calculating avoidable mortality from other major causes of death.[21,22] Even using a more conservative comparator, applying the firearm mortality risks of white individuals to the whole of the USA and Brazil would avoid about three-quarters and nine-tenths of firearm deaths in each country, respectively.

This study was limited to four Pan-American countries with both high firearm mortality and high-quality cause of death data. Honduras, El Salvador, and Guatemala also have high firearm mortality, but their vital registration systems have gaps in coverage and quality, and do not consistently report on educational attainment or race.[5,27] A limitation in fully understanding the patterns of firearm mortality is that even state-level data mask variation in smaller areas, such as extremely high firearm mortality in specific cities and among demographic groups. For example, firearm mortality in the state of Illinois, which peaked in the 1990s, is mostly driven by firearm homicide in Chicago among young black men. Hospital-based gun violence admissions and deaths data[28] are available in the USA and broadly confirm the racial and age distributions of firearm homicide and suicide death documented in this study. Although coverage with vital registration was high in the study countries at the national level, state level variation does exist with lower coverage among low education groups and non-white races in Brazil and in particular states. The proportion of ill-defined all-cause and ill-defined injury deaths decreased over time across education and racial groups in Brazil. Some states of Brazil do not report specific injury among all injury deaths, and in these states firearm deaths might have been underestimated.[11] Hence, we restricted our analyses of educational and racial groups to the national level because these disparities might be less reliable at the state level.

Firearms are not only a leading and persistent cause of mortality in the USA, Mexico, Colombia, and Brazil—and as such must be considered a major public health concern—but the extreme variations in firearm mortality among subpopulations represent a societal challenge. Changes in firearm mortality explain most of the variation in mortality among young men in the study countries over the past 25 years, and in the USA, can be considered the primary driver for the marked differences in the overall mortality observed between young white and black men, regardless of educational level.

Contributors

AJD and PJ conceived the study. AJD, HG, PJ, and HI did the data analyses. AJD, HG, and PJ wrote the initial drafts. All authors contributed to the conception or design of the work, data acquisition, data analysis, or data interpretation, drafted the manuscript, or critically revised the manuscript. PJ is the overall guarantor.

Declaration of interests

We declare no competing interests.

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