Income inequality and firearm homicide in the US: a county-level cohort study

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ABSTRACT

Objective Income inequality has been rising in the US and thought to be associated with violence especially homicide. About 75% of homicides involve firearms. We quantified the association between county-level income inequality and all-race/ethnicity and race/ethnicity-specific firearm homicide rates among individuals aged 14–39 years.

Methods We conducted a cohort study of US counties to examine the association of Gini Index (ranging from 0 [perfect income equality] to 1.0 [perfect income inequality]) separately measured in 1990 and 2000 with all-race/ethnicity and race/ethnicity-specific firearm homicide rates in 2005–2015. Generalised linear mixed models with Poisson distribution including a random intercept for state provided IRRs and 95% CIs. Bayesian Poisson-lognormal hierarchical modelling with integrated nested Laplace approximations was used in exploratory spatial analyses. Models accounted for county-level age, sex and race/ethnicity composition, crime rate, deprivation, social capital, urbanicity, and firearm ownership.

Findings The Gini Index was associated with firearm homicide rates among all races/ethnicities. After accounting for contextual determinants of firearm homicide, the association persisted among African–Americans. In this group, a 1 SD greater Gini Index in 1990 (IRR=1.09; 95% CI 1.02 to 1.16) and 2000 (IRR=1.09; 95% CI 1.01 to 1.17) was associated with greater firearm homicide rates in 2005–2015. Exploratory spatial analyses did not materially change the results.

Conclusion Policies addressing the gap between the rich and the poor deserve further considerations for reducing firearm homicide rates. Incorporating income inequality to refine measures of socioeconomic position may advance public health and clinical research and practice for firearm violence prevention.

INTRODUCTION

Income inequality in the US is among the greatest of all high-income countries, and has steadily increased since the 1970s.[1 2] The average income of the top 1% has been about 45 times greater than that of the bottom 99% in several counties in recent years.[3 4] The widening income inequality has extensive societal and health consequences. Relative deprivation is associated with shortened life span, poor health and lower levels of well-being beyond the influence of absolute deprivation.[5–9]

Violence, a major public health problem in the US, is a sensitive indicator of social relations.[10 11] Violence is most prevalent in societies that permit large disparities in the material standards of its citizens' living.[11 12] At each point in life transitions (eg, schooling, labour market entry, job security), relative deprivation produces adverse outcomes in the most vulnerable segments of the population.[11 13] In 2017, nearly 19 500 individuals died by homicide in the US.[14] Homicide is the leading cause of death among African–American males aged 15–34 years. About 75% of homicide deaths in the US involve firearms.[14] Commentaries have encouraged moving beyond an individualistic approach to firearm violence prevention by acknowledging the role of broader social factors that fuel or sustain it.[15 16]

A body of prior research has examined the relationship between income inequality and violent crime.[12] Some of those investigations were largely theoretical, and several others were empirical cross-sectional studies. Those studies have shown that this relationship is especially strong for severe forms of violent crime such as homicide. However, to our knowledge, the most recent national empirical evaluation of the specific relationship between income inequality and *firearm* homicide dates back to 1990s.[17] A quantification of this specific relationship can enhance our understanding of the broader social determinants of firearm violence, and provide estimates that can be used in future theoretical assessment and empirical investigations of other determinants of firearm violence in which income inequality is treated as a covariate.

We conducted a study of US counties to examine the association of income inequality with all-race/ethnicity and race/ethnicity-specific firearm homicide victimisation (hereafter referred to as 'firearm homicide') rates. Our overarching goal was to provide contemporary estimates of the association of income inequality with firearm homicide and build on prior work by conducting the investigation at the county level and examining race/ethnicity-specific patterns.

METHODS

Study design, setting and population

We conducted a cohort study of county-level firearm homicide rates during years 2005–2015 in relation to county-level income inequality in years 1990 and 2000 within the contiguous US. We included firearm homicide rates among individuals aged 14–39 years since this age group has the highest homicide rate in the US.[14]

Exposure

The county-level Gini Index in years 1990 and 2000 was obtained from the US Census. This index ranges from 0 (perfect income equality) to 1.0 (perfect income inequality). We hypothesised that income inequality may exert its effect on firearm homicide following some lag period.[18 19] Specifically, we chose two lag periods of at least 5 and 15 years between income inequality (measured in 1990 and 2000) and firearm homicide (measured in 2005–2015). It is important to avoid measuring income inequality and health outcomes contemporaneously. Concurrent examinations of income inequality and health outcomes may be subject to reverse causality. Higher rates of violence can increase inequality by diminishing the stock of physical capital and development of human capital, raising segregation and eroding social capital, and affecting the capacity of local governments and economic activity.[11] Additionally, the aetiologically relevant period of time for income inequality to exert its effect on health must be accounted. The mechanisms by which income inequality influences health are unlikely to be short term; there should be a lag time during which income inequality affects mediators, which in turn affect health. Prior evidence suggests that income inequality may exert its effect on population health after at least a few years have already elapsed.[18]

Outcome

To obtain county-level firearm homicide rates, we used All-County Mortality Microdata from the National Center for Health Statistics at the CDC for years 2005–2015 with geographical indicator of county and state of residence of the decedents.[20] Data for years 2005–2015 were combined to provide more stable estimates of firearm homicide rates. We used the International Classification of Diseases-10 codes X93-X95 to identify firearm homicides. Homicide rates are notably different across race/ethnicity subgroups.[14] Therefore, counts of homicide for each county were calculated in cross-classified subgroups of race/ethnicity (including non-Hispanic white, non-Hispanic African–American, non-Hispanic American Indian and Alaskan Native, non-Hispanic Asian Pacific Islander and Hawaiian, or Hispanic) to examine the outcome within them. Total counts of homicide for each county were also used to assess the outcome over all race/ethnicity subgroups combined. Information from the Census and its intercensal estimates for each year was used to provide the corresponding denominator for each subgroup.

Covariates

We included several county-level covariates measured in 1990 or 2000 to avoid the inclusion of downstream effects of income inequality. That is, in the analysis of the association between the Gini Index in 1990 and firearm homicide rates in 2005–2015, we included county-level covariates capturing information from 1990. Similarly, in the analysis of the association between the Gini Index in 2000 and firearm homicide rates in 2005–2015, we included county-level covariates capturing information from 2000.

Information on specific county-level demographic variables was obtained from the Census. These variables included the proportion of age subgroups (<1 year, 1–4 years, 5-year age groups from 5 to 84 years, and 85 years or older), males, race/ethnicity subgroups and urbanicity (defined as the proportion of the population living in urban areas) within the entire county population. We used the Federal Bureau of Investigation's Uniform Crime Reporting database to calculate the rate of violent (ie, rapes, robberies and assaults) and non-violent (ie, burglaries, larcenies, motor vehicle thefts and arsons) crime perpetration per 100 000 population of the county. Prevalence of firearm ownership in each county was estimated using the proportion of all suicides (S) in that county that involved a firearm (FS). In the absence of direct information on firearm ownership at the county level, this measure (FS/S) remains one of the most viable options to capture variations in firearm ownership especially across larger geographical areas.[21]

A County-Level Deprivation Index (CDI) was constructed from several Census variables including median household income, household income >$50 000, median value of owner-occupied homes, percentage with at least a high school degree, percentage with at least a bachelor's degree, percentage with managerial/professional occupations, and percentage with interest and dividend or net rental income within the entire county population in both 1990 and 2000. These variables were selected from previous research that conducted principal components analyses (PCAs) from a much larger set of Census tract-level variables in the entire US.[22] Although our study used county-level data, prior investigations have shown minimal differences in neighbourhood deprivation indices when comparing tract-level and county-level variables.[23] Furthermore, we found that summary statistics from the 1990 and 2000 CDI had a similar distribution to those used in the original index. The variables in the index were standardised using Z-scores. Higher values of the index indicate less deprivation.

County-level measures of social capital were selected based on prior work on the production of social capital in the US.[24] A Social Capital Index was created by conducting a PCA of the following variables in the county: total civic associations per 10 000 people, number of not-for-profit organisations per 10 000 people, decennial Census mail response proportion and the proportion of voters who cast a vote for presidential elections, and then standardising the variables using Z-scores. Higher values of the index indicate greater social capital.[25]

Statistical analysis

All covariates and outcomes were initially examined descriptively by quartiles of Gini Index for 1990 and 2000. The Gini Index in 1990 and 2000 was plotted against county-level firearm homicide rates in 2005–2015; using locally weighted scatterplot smoothing curves, smoothed lines were added to assist with interpretation.

To examine the association of the Gini Index in 1990 and 2000 with firearm homicide rates in years 2005–2015, we constructed generalised linear mixed models with Poisson distribution that included a random intercept for state and an offset term representing the county population aged 14–39 years during 2005–2015. IRRs and their corresponding 95% CIs were obtained from three prespecified models that incrementally included distinct sets of covariates. Model 1 included the Gini Index only. Model 2 additionally included covariates for county-level age and sex distribution. Model 3 further included covariates for county-level race/ethnicity composition, crime perpetration rate (violent and non-violent), Deprivation Index, Social Capital Index, urbanicity and firearm ownership. In these analyses, the Gini Index was treated as a continuous variable and standardised using Z-scores; thus, in the regression models, a one-unit change represents 1 SD in the Gini Index (ie, equivalent to about 0.04 change in the index value). Bayesian Poisson-lognormal hierarchical modelling with integrated nested Laplace approximations was used in exploratory spatial analyses (online supplementary appendix 1). Analyses

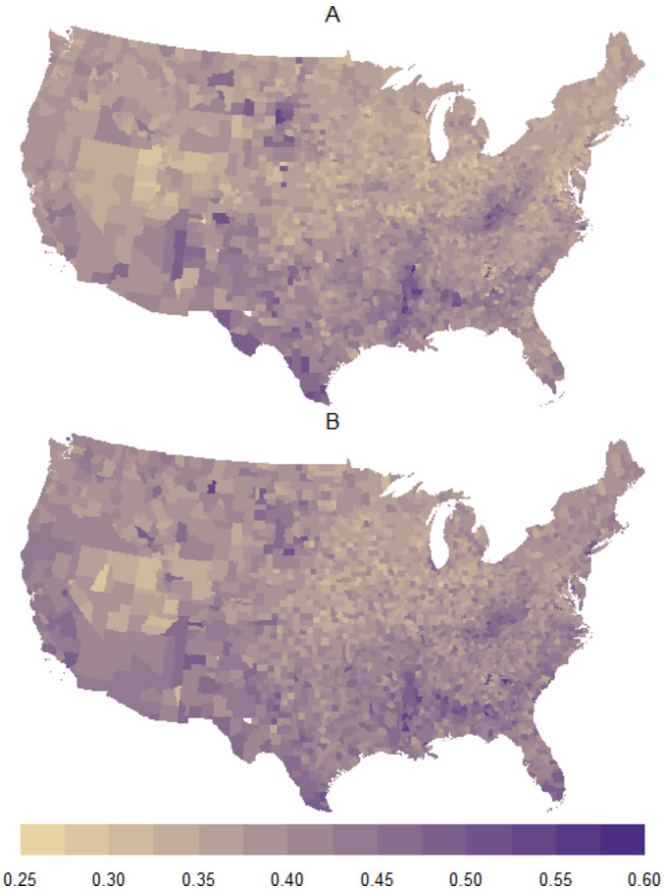

Figure 1 County-level Gini Index distribution in the US. (A) 1990 and (B) 2000.

were conducted using Stata (Version 15; StataCorp LLC) and R (R Foundation for Statistical Computing).

RESULTS

After excluding counties in Alaska and Hawaii (due to unavailability of data for several counties across different study years and for allowing comparisons with exploratory spatial analyses of contiguous US) and those with missing Gini Index information or changes in the boundary during the study years (Broomfield County, Colorado; Miami-Dade County, Florida; and Loving County, Texas), data on a total of 3106 counties were available for the analyses. There were wide variations across counties in their Gini Index both in 1990 (figure 1A) and 2000 (figure 1B). The mean (minimum, maximum) Gini Index in 1990 and 2000 was, respectively, 0.38 (0.25, 0.56) and 0.40 (0.30, 0.58).

In both 1990 and 2000, counties in the higher quartiles of the Gini Index had higher rates of firearm homicide as well as violent and non-violent crime perpetration, and a greater percentage of African–American residents, than those in the lower quartiles of the Gini Index. Similarly, counties in the higher quartiles of the Gini Index had higher deprivation and lower social capital levels than counties in the lower quartiles of the Gini Index. Across the two decades, county-level crime perpetration rates declined within each Gini Index quartile; however, firearm homicide rates did not change notably over that period (table 1).

The Gini Index in 1990 and 2000 and firearm homicide rates in 2005–2015 were positively correlated (figure 2). In bivariable regression analyses (model 1), the Gini Index was associated with firearm homicide rates among all races/ethnicities (figures 3 and 4). In multivariable regression analyses (models 2 and 3), the association between the Gini Index and firearm homicide rates persisted in all models only among African–Americans (figures 3 and 4). In this group, a 1 SD greater Gini Index in 1990 and 2000 was respectively associated with 9% (IRR=1.09; 95% CI 1.02 to 1.16) and 9% (IRR=1.09; 95% CI 1.01 to 1.17) greater rates of firearm homicide in 2005–2015. Findings of exploratory spatial analyses did not materially differ from those of the main analyses (online supplementary appendix 1).

DISCUSSION

In this national county-level investigation, we found that greater income inequality as measured by the Gini Index was associated with higher rates of firearm homicide among individuals aged 14–39 years in all races/ethnicities. After accounting for several contextual determinants of firearm homicide, income inequality remained significantly associated with higher rates of firearm homicide among African–Americans.

The findings did not materially change with lag periods of 5 and 15 years between income inequality and firearm homicide rate measurements. Prior evidence suggests that income inequality measured within up to past 15 years may be more strongly associated with health outcomes than the one measured contemporaneously.[18] Our findings suggest that within that 15-year period, the influence of income inequality on the mediators of its relationship with firearm homicide may not meaningfully vary once 5 years have elapsed.

Income inequality in the US reached a peak in 1928 before declining rapidly in the 1930s and 1940s, and then more gradually until the late 1970s. The unequal income growth since the late 1970s has brought the top 1% income share to near its 1928 peak.[3] Income inequality, as a measure of relative deprivation, captures the effect of the individual's relationship to the larger society, whereas poverty, as a measure of absolute deprivation, captures the effect of resource deprivation on individuals.[17] Findings of this investigation on the expansive scope of income inequality in all regions of the US coupled with its association with firearm homicide add to an increasing body of evidence suggesting the importance of developing policies that promote equity to benefit the most vulnerable members of society.[3 16]

In a pooled analysis of data from the General Social Surveys, rising income inequality was found to be significantly associated with declining trust in others.[26] In turn, a decline in social trust was predictive of diminished levels of group membership. A critical factor responsible for the high incidence of crime in urban settings has been the loss of social buffers such as formal and informal networks of organisations (eg, church groups, business groups, neighbourhood associations), as well as the presence of social norms concerning work and education.[27 28] This depletion of social buffers and erosion of social capital in inner city areas as a result of the increasing residential segregation of the underserved communities have especially affected under-represented minorities such as African–Americans.[29–31] We found that the association between income inequality and firearm homicide in this group persisted even after controlling for the percentage of the population living in urban areas, suggesting that income inequality may have a broader social impact that extends beyond high-risk urban settings.[17]

We used measures of deprivation and social capital as covariates in the model due to their relationship with violence. Several theories have been proposed to explain why inequitable allocations of resources may be associated with violence.[28 32–34] The concentration of poor economic conditions leads to social

Table 1 County-level characteristics by Gini Index quartiles in 1990 and 2000 in the US

County-level characteristic*	Gini Index quartiles							
	1990				2000			
	Low	Low-medium	Medium-high	High	Low	Low-medium	Medium-high	High
	(0.251–0.353)	(0.354–0.375)	(0.376–0.403)	(0.404–0.561)	(0.296–0.371)	(0.372–0.396)	(0.397–0.423)	(0.424–0.585)
	(n=777)	(n=773)	(n=782)	(n=774)	(n=804)	(n=779)	(n=752)	(n=771)
Firearm homicide victimisation rate†	2.48 (3.37)	3.62 (4.48)	5.64 (6.32)	9.65 (9.71)	2.38 (3.70)	3.73 (4.60)	5.57 (5.67)	9.83 (9.85)
Deprivation Index	2.71 (5.58)	0.85 (5.39)	−0.76 (4.86)	−3.22 (5.20)	1.82 (4.19)	0.42 (4.44)	−0.40 (5.96)	−2.29 (6.80)
Social Capital Index	0.27 (0.67)	0.16 (0.68)	−0.09 (0.60)	−0.35 (0.54)	0.64 (1.41)	0.21 (1.43)	−0.24 (1.30)	−0.66 (1.24)
Crime perpetration rate†								
Non-violent crime	2674.4 (1748.7)	2767.4 (1683.0)	3125.5 (2078.6)	3119.7 (2455.4)	1631.3 (1250.6)	2036.0 (1517.7)	1353.2 (1611.3)	2600.6 (1976.9)
Violent crime	200.9 (209.2)	255.1 (265.1)	348.3 (330.9)	437.0 (457.4)	142.4 (160.7)	208.5 (225.1)	291.9 (327.8)	382.0 (341.3)
% Population by age (years)								
<14	22.8 (2.9)	22.0 (2.6)	21.8 (2.6)	23.2 (3.64)	23.45 (5.64)	22.93 (5.08)	23.00 (4.64)	23.11 (4.71)
15–24	13.2 (2.9)	13.5 (3.3)	13.8 (3.7)	14.7 (4.0)	14.36 (3.44)	14.80 (4.15)	15.43 (4.63)	15.84 (4.90)
25–34	15.7 (2.4)	15.1 (2.1)	14.8 (2.0)	14.8 (2.0)	13.05 (4.10)	13.31 (3.65)	13.89 (3.80)	13.91 (3.74)
35–44	14.9 (1.9)	14.5 (1.6)	14.2 (1.5)	13.6 (1.6)	17.57 (4.33)	17.12 (3.31)	17.13 (3.55)	16.31 (3.19)
45–64	19.3 (2.1)	19.7 (2.1)	19.9 (2.2)	19.1 (2.3)	25.62 (4.43)	26.40 (4.50)	27.03 (5.01)	25.20 (5.24)
65+	14.1 (4.7)	15.3 (4.2)	15.5 (4.2)	14.7 (4.2)	16.02 (3.41)	16.54 (4.23)	16.77 (4.52)	15.35 (4.34)
% Population by race								
African–American	2.79 (5.93)	4.86 (8.84)	8.39 (12.61)	18.25 (20.33)	2.82 (6.56)	4.90 (8.09)	8.90 (11.94)	19.53 (20.91)
Asian/Native Hawaiian/Pacific Islander	0.57 (0.94)	0.62 (1.39)	0.57 (1.19)	0.45 (1.39)	0.62 (0.83)	0.75 (1.23)	0.95 (1.59)	1.17 (2.64)
American Indian/ Alaskan Native	0.46 (1.26)	0.89 (2.20)	1.36 (3.89)	2.64 (10.38)	0.76 (1.95)	1.51 (5.25)	1.68 (4.93)	2.47 (10.10)
Hispanic	1.96 (3.75)	2.30 (4.69)	3.98 (8.36)	9.38 (18.83)	2.91 (4.67)	4.44 (7.93)	6.60 (10.53)	11.19 (18.90)
White	94.23 (7.63)	91.33 (10.60)	85.70 (14.38)	69.29 (22.63)	92.89 (8.73)	88.40 (12.23)	81.88 (15.20)	65.64 (22.83)
% Population male	49.4 (1.5)	49.2 (1.5)	48.9 (1.4)	48.5 (1.9)	49.8 (1.6)	49.6 (1.64)	49.5 (1.97)	49.2 (2.31)
% Urban population	44.2 (30.5)	41.6 (31.7)	41.6 (31.6)	38.4 (31.6)	37.2 (27.9)	41.0 (30.5)	42.5 (32.0)	45.3 (34.6)

Note: Numbers in the table reflect mean/percentage and SD for county characteristics by each quartile of Gini Index. The Gini Index and % population by age, race, male and urban were all obtained from the US Census. Firearm homicide victimisation rates were obtained from the All County Mortality data maintained by the CDC. Deprivation Index and Social Capital Index were constructed using principal components analyses of several pertinent indicators. Crime perpetration rates were obtained from the Federal Bureau of Investigation.

*County-level characteristics were measured in 1990 and 2000 for the Gini Index measured in 1990 and 2000, respectively.

†Per 100 000.

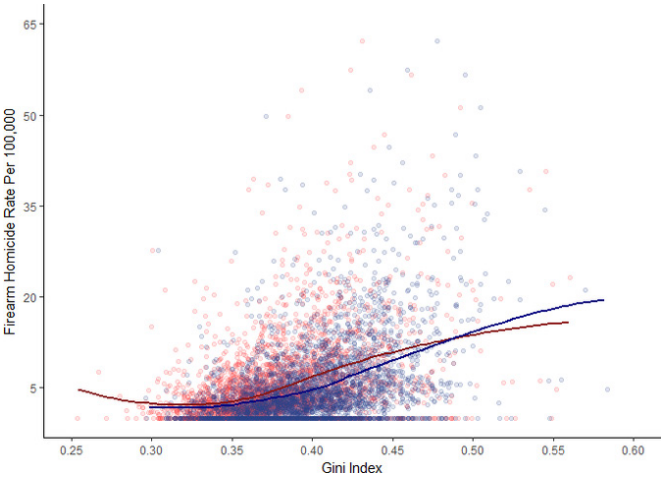

Figure 2 Scatterplot of the association of Gini Index in 1990 and 2000 with firearm homicide rates among individuals aged 14–39 years in the US in 2005–2015. Red: 1990; blue: 2000.

disorganisation through a breakdown of social cohesion. It is hypothesised that communities lacking in social capital are less effective in exerting informal means of social control through establishing and maintaining norms to reduce violence compared with communities with higher levels of social capital.[17 35]

More than two decades ago, Kennedy and colleagues[17] found that state-level income inequality was strongly correlated with firearm homicide (r=0.76). These relationships held when controlling for poverty and a proxy variable for access to firearms. Our study builds on those findings by (1) examining the association between income inequality and firearm homicide at the county level; (2) adding several other contextual determinants of firearm homicide; and (3) focusing on race/ethnicity-specific patterns. A difference between our study and theirs is in the choice of income inequality measure. Kennedy and colleagues[17] chose the Robin Hood Index for their investigation, while we used the Gini Index for this study. The Gini Index has been used extensively in the public health and clinical literature, and remains the most popular measure of income inequality.[36]

This study is subject to some limitations. First, the Gini Index does not distinguish different kinds of income inequalities; two

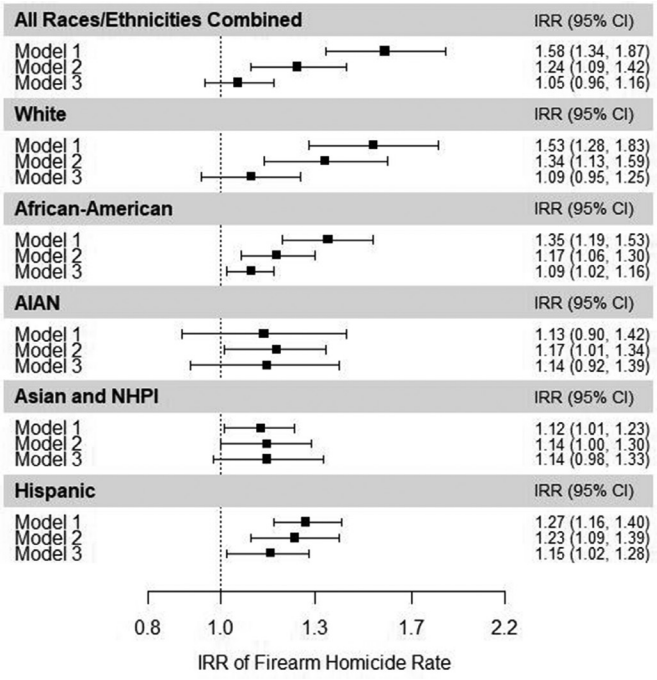

Figure 3 IRRs for the association of Gini Index in 1990 with firearm homicide rates among individuals aged 14–39 years in the US in 2005–2015. Model 1 includes the Gini Index only. Model 2 additionally includes county-level age and sex composition. Model 3 additionally includes county-level race/ethnicity composition, crime rate, Deprivation Index, Social Capital Index, urbanicity and firearm ownership level. AIAN, American Indian/Alaska Native; NHPI, Native Hawaiian/Pacific Islander.

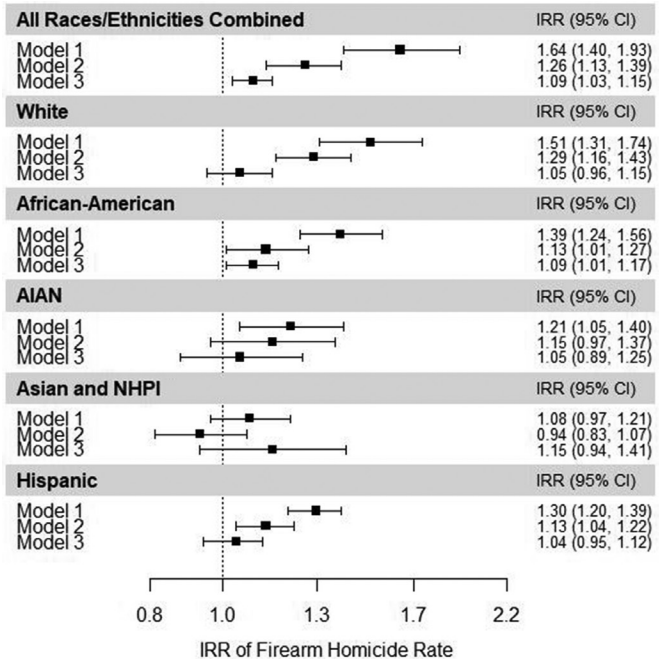

Figure 4 IRRs for the association of Gini Index in 2000 with firearm homicide rates among individuals aged 14–39 years in the US in 2005–2015. Model 1 includes the Gini Index only. Model 2 additionally includes county-level age and sex composition. Model 3 additionally includes county-level race/ethnicity composition, crime rate, Deprivation Index, Social Capital Index, urbanicity and firearm ownership level. AIAN, American Indian/Alaska Native; NHPI, Native Hawaiian/Pacific Islander.

counties may have the same Gini Index but different income distributions. Also, the Gini Index is most sensitive to inequalities in the middle part of the income spectrum. For these reasons, this index is best seen as one of the many strategies available for the operationalisation of income inequality. Kawachi and Kennedy compared six different measures of income inequality, including the Gini Index and the Robin Hood Index, in terms of their relationship with mortality.[29] Their analysis indicated that the measures were all highly correlated with each other and strongly associated with mortality even after adjustment for median income and poverty, indicating that the choice of income inequality indicator is unlikely to notably influence the results of empirical tests of mortality in relation to income inequality.

Second, there may have been some degrees of misclassification in the analyses since the classification of fatal injury intent and race/ethnicity is subject to error. Third, we did not examine non-fatal firearm assault victimisations; the potential impact of income inequality on firearm violence and its associated morbidity can be comprehensively quantified by including non-fatal victimisation by firearm assaults as well as other forms of firearm-involved violent crime (eg, robbery). Nonetheless, studying firearm homicides is important as those are the most extreme outcome of many types of more common forms of community violence that may be harder to measure because of variations in reporting events. Fourth, not all county-years included in this analysis experienced all race/ethnicity-specific homicides, leading to lower precision in some of the race/ethnicity-specific estimates of the relationship between income inequality and firearm homicide.

Our findings add to an increasing body of evidence suggesting that, in addition to existing hospital-based and community-based firearm violence prevention programmes focusing on high-risk individuals, attempting to shift the underlying societal forces giving rise to violence at the population level is warranted.[37 38] Poverty and access to firearms are strong predictors of firearm violence, and policies to reduce the burden on families living in impoverished settings and those that restrict access to firearms among individuals who pose a threat to others may be important means to reduce violent deaths. Nonetheless, our

What is already known on the subject

- Income inequality has steadily risen in the US since 1970s.
- Increase in income inequality can compromise health and is thought to be associated with severe forms of violence including homicide.

What this study adds

- In this cohort study of US counties, greater income inequality was associated with higher rates of firearm homicides victimisation among all races/ethnicities; after accounting for several contextual determinants of firearm homicide, this relationship persisted among African–Americans.
- Policies addressing the gap between the rich and the poor deserve further considerations for reducing firearm homicide rates, especially among the most vulnerable populations.

findings suggest that policies addressing macrosocial forces such as those which reduce the gap between the rich and the poor (eg, earned income tax credit, universal basic income) also deserve further considerations to reduce firearm violence. Additionally, refinement of socioeconomic deprivation measures to include elements of income inequality may meaningfully advance public health and clinical research and practice.

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Contributors AR-R and FPR contributed to the study concept and design. All authors contributed to acquisition, analysis or interpretation of data. AR-R drafted the manuscript. All authors contributed to critical revision of the manuscript for important intellectual content. DAQ and ERM conducted statistical analyses. All authors provided administrative, technical or material support. AR-R and FPR contributed to study supervision.

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