Family Firearm Ownership and Firearm-Related Mortality Among Young Children: 1976–2016

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abstract

BACKGROUND: Firearm-related fatalities are a top 3 cause of death among children in the United States. Despite historical declines in firearm ownership, the firearm-related mortality rate among young children has risen over the past decade. In this study, we examined changes in firearm ownership among families with young children from 1976 to 2016, exploring how such changes relate to recent increases in firearm-related mortality among 1- to 5-year-olds.

METHODS: Individual-level data from the National Vital Statistics System were merged with household-level data from the General Social Survey to create national-level estimates of firearm-related child mortality and family firearm ownership from 1976 to 2016 (n = 41 years). Vector autoregression models were used to examine the association between firearm ownership and child mortality.

RESULTS: The proportion of non-Hispanic white families with young children who owned firearms declined from 50% in 1976 to 45% in 2016 and from 38% to 6% among non-Hispanic African American families. The proportion of white families with young children who owned handguns, however, increased from 25% to 32%; 72% of firearm-owning families with young children now own a handgun. Increases in handgun ownership partially explained the recent rise in firearm-related white child mortality (B = 0.426), net of economic conditions, and sociodemographic characteristics of firearm-owning families.

CONCLUSIONS: Changes in the types of firearms in the homes of US families may partially explain recently rising firearm-related mortality among young white children. These findings hold relevance for pediatricians and policy makers aiming to reduce firearm-related mortality and promote firearm safety in children's homes.

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Dr Prickett conceptualized and designed the study, constructed the national-level General Social Survey firearm ownership estimates, performed the analytical analyses, and drafted the initial manuscript; Dr Gutierrez constructed the national-level National Vital Statistics System mortality rates and assisted in drafting the initial manuscript; Dr Deb reviewed the statistical data and selected the statistical models; and all authors reviewed and revised the manuscript.

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WHAT'S KNOWN ON THIS SUBJECT: The decreasing rate of firearm deaths among children stagnated over the past decade, with this reversal partially driven by rising firearm-related mortality among 1- to 5-year-olds. Firearms in the homes of children, however, continued to decline over this period.

WHAT THIS STUDY ADDS: In examining whether changes in firearm ownership in children's homes were associated with trends in firearm-related mortality among young children, we found that changes in firearm ownership from predominantly rifles to handguns may pose heightened risk for young children.

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Firearm-related fatalities are the third leading cause of injury-related death among children aged 0 to 17 in the United States, with close to 1300 deaths and 5790 injuries each year.[1] Despite the risk firearms pose for American children today,[2] the firearm-related child mortality rate has declined over the past several decades.[3,4] Because a substantial proportion of these deaths take place within homes,[1] much of the decline in firearm-related child mortality may be owed to observed reductions in firearm ownership over the latter half of the 21st century through the 2000s.[5] Recently, however, researchers have uncovered that the decreasing rate of firearm deaths among children has stagnated over the past decade for younger age groups (0–12 years).[1] Of particular concern, estimates from the National Center for Health Statistics indicate that this reversal in the downward trend was primarily driven by mortality among 1- to 4-year-olds because the rate of firearm-related fatalities among this group actually increased (almost doubling from 2006 to 2016 [a crude death rate of 0.36–0.63 per 100 000]).[6],* Firearm-related injury is currently the fifth most common cause of injury-related deaths among this age group (101 deaths in 2016), behind drowning (425), motor vehicle-related deaths (334), suffocation (118), and fire and/or burn injuries (107).[6,7] Given that firearm ownership has historically been 1 of the strongest predictors of child firearm-related mortality,[3,8] the mortality rate among the youngest children has not kept pace with the general decline in ownership.

One explanation for the increase in firearm-related mortality among young children centers on changes in the types of firearms in families' homes. For young children, shootings are more likely to be unintentional,[1,9] making the ease at which firearms can be accessed and used a more important determinant of mortality than perhaps for older children. For example, smaller firearms, such as handguns, are easier for young children to handle, given evidence suggesting that children as young as 2 possess the tensile strength to operate a handgun.[10] Moreover, relative to other firearms like hunting rifles, handguns, because they are more likely to be purchased for personal protection, are more likely to be stored loaded with ammunition, unlocked, and in a more easily accessible place, such as a bedroom drawer.[11] Indeed, states with larger proportions of gun owners who stored their firearms loaded and unlocked also had higher rates of unintentional firearm deaths among both children and adults.[12] Therefore, an important yet underexplored and policy-relevant mechanism for understanding population-level trends in firearm-related mortality among young children might not just be changes in firearm ownership among families, generally, but changes in the types of firearms in homes, specifically.

Our aims in this study are threefold. First, we document national-level trends in firearm ownership, generally, and by types of firearms, specifically, in the homes of families with young children from 1976 through 2016. Second, we examine whether trends in firearm ownership were associated with the firearm-related mortality rate (unintentional and intentional) among young children. Third, we examine whether types of firearms, specifically handguns, were more strongly associated with young child firearm-related mortality compared with firearm ownership generally. Although we examine these trends by race (ie, white, African American), because of cell size limitations in the General Social Survey (GSS) (from which we created national estimates of firearm ownership), we present the multivariate findings for non-Hispanic white children only, although we present descriptive trends for non-Hispanic African American children.

In addressing these aims, we provide new knowledge about the characteristics of firearms in the homes of US children and evidence for the importance of considering how the types of firearms in family homes pose heightened risks for young children's health. Understanding these trends and risks can inform the ongoing debate surrounding child firearm access prevention laws and regulations on pediatricians' rights and responsibilities to inform parents about firearm safety.

METHODS

Data and Sample

National fatality estimates were derived by using the Multiple Cause-of-Death Mortality Data from the National Vital Statistics System.[6] These data represent information drawn from death certificates occurring among all US residents. Data from the US Census were used to calculate age-specific mortality rates.

Information on firearm ownership and the characteristics of families with firearms was derived from the GSS, a nationally representative data set of US households.[13] We included survey years in which questions were asked about firearms in the home, which included 1976, 1977, 1980, 1982, 1984, and 1985, annually from 1987 to 1991, 1993, and biennially from 1994 to 2016.

* For example, among 1- to 4-year-olds, firearm-related injury mortality rose from 0.31 deaths per 100 000 children (63 deaths) in 2006 to 0.57 deaths per 100 000 children (113 deaths) in 2016;[6] the largest increase in mortality among all age groups of children.

To construct national-level estimates of firearm ownership in families with young children, we limited the sample to GSS respondents who indicated having a child 5 years or younger in the home.[†] In addition, we restricted the sample to respondents who reported being of African American or white race only, given that detailed Hispanic ethnicity coding in the National Vital Statistics System did not begin until 1996. As mentioned, small cell sizes among firearm-owning African American families limited a multivariate examination of associations between firearm ownership and African American child mortality. Supplemental Table 2 displays the GSS sample size used to create the annual estimates. Sampling weights were used in the construction of the national estimates.[‡] To account for missing firearm ownership rates and sociodemographic variables for years when either the GSS was not administered or firearm questions were not survey items (17 years), we employed the imputeTS package in R.[14] The final analytical time series data set consisted of 41 data points, reflecting years 1976 to 2016.

Measures

Outcomes

Our primary outcome measure, firearm-related mortality rate among 1- to 5-year-olds, was constructed by using the causes of death coding regimes from the International Classification of Diseases.[§] Deaths captured in this measure included all injury-related deaths caused by firearms, including undetermined, unintentional, intentional, self-inflicted, and injuries due to legal intervention by firearms.[‖] Data from the US Census bridged-race population estimates were used to calculate rates per 100 000 in the population.[15,16,¶]

Firearm Ownership

The focal independent variable was the proportion of families with young children with firearms in the home (by race) based on the proportion who answered affirmatively to the question "Do you happen to have in your home (or garage) any guns or revolvers?" The secondary focal variable captured the type of firearm. If respondents reported having a firearm, they were then asked: "Is it a pistol, shotgun, rifle, or what?" Respondents could identify multiple types of firearms. From this question, we created 3 mutually exclusive variables indicating the proportion of families that had (1) no firearm in the home, (2) a rifle and/or shotgun only, or (3) a pistol and/or revolver, with or without a rifle and/or shotgun.

Covariates

We controlled for 4 potentially important sociodemographic variables given both their association with firearm ownership and child injury risk. Proportion of firearm-owning families living in a rural area was included given its well-documented link between both firearm ownership and higher rates of firearm-related mortality.[17,18] The proportion of firearm-owning families in which neither parent had a college degree and the proportion of firearm-owning families with household incomes in the bottom quartile were included given their associations with firearm ownership and child injury risk.[19] The proportion of firearm-owning families living in the South was included to account for the higher rates of firearm mortality and ownership in this region.[17,20] Finally, the annual national unemployment rate by race was included as an indicator of the broader economic context.[21] Descriptive statistics for these measures are included Supplemental Table 3.

Analytical Plan

To examine trends in firearm ownership among families with young children, we first identified how firearm ownership and the types of firearms in the home have changed from 1976 to 2016. Second, we examined whether firearm ownership was correlated with the firearm-related mortality rate among white 1- to 5-year-olds (net of changes in the sociodemographic composition of firearm-owning families) by using vector autoregression (VAR) models, which are more appropriate than linear regression models when using

[†] Although we examine child mortality rates among children 1 to 5 years of age, the GSS collects information on the presence and age of children in the home in categories ranging from 0 to 5 years, 6 to 12 years, and 13 to 17 years, and hence, our measure of firearm-owning families with young children also may include families with infants.

[‡] For survey years before 2004, the GSS is self-weighted for household-level variables. A 2-stage subsampling design was introduced to account for nonresponse in 2004 (and used in all subsequent years). To account for this change, we used the sampling weight (WTSSNR) to create household-level variable estimates for survey years 2004 to 2016.

[§] *International Classification of Diseases Adjusted, Eighth Revision* was used for deaths occurring from 1973 to 1978, the *International Classification of Disease, Ninth Revision* was used for deaths occurring from 1979 to 1998, and *International Classification of Disease, 10th Revision* was used for deaths occurring from 1999 to 2014.

[‖] Firearm-related deaths included the following codes classifying all mechanisms of intent: *International Classification of Diseases Adjusted, Eighth Revision* (E922, E955, E965, E970, and E985), *International Classification of Disease, Ninth Revision* (E922, E955[.0–.4], E965[.0–.4], E970, and E985[.0–.4]), and *International Classification of Disease, 10th Revision* (U01.4, W32-W34, X72–74, X93-X95, Y22-Y24, Y35.0).

[¶] The age cutoff for "young children" was chosen to match the GSS coding scheme, which identifies the age of respondents' children within set ranges, specifically, the presence of children aged between 0 to 5 years, 6 to 12 years, and 13 to 17 years. Moreover, we chose to limit our measure of firearm-related fatalities to those among 1 to 5 years, given that 1- to 5-year-olds are at increased risk of firearm-related mortality due to household firearms.

time series data.[22,#] Finally, we explored the extent to which this pattern held or was stronger among types of firearms that may pose a particular risk to young children's safety.

In addition to the main analyses, we tested the robustness of our findings by examining whether firearm ownership predicted the non–firearm-related injury mortality rate and mortality rate, generally, and examined in our main models whether the firearm-related mortality rate predicted firearm ownership.

[#] Often applied in analyses using time series data, a VAR model of order P assumes that observations at each time point are dependent on values of all variables from a certain number of past P years. More formally, if we use Y_t to denote the vector of observations (eg, firearm ownership, firearm-related mortality rates, proportion of firearm-owning families living in a rural area) at time t, then a VAR model of order P can be described by the following: $Y_t = c_t + A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + e_t$, $t = 1, \ldots, T$ In the equation above, c_t is a deterministic term that captures the trend portion of the variables, whereas e_t is the residual error term (considered to be normally distributed at approximately 0 and independent for different time points). The A_j term represents the coefficient matrix that identifies the effect of the autoregression for lag j. That is, the effect a given year has j years later, with the effect diminishing as values of j become larger (ie, as years go by). In line with previous research, p is typically small, and throughout this study, we used $p = 1$, with the assumption that the variables will not significantly affect each other after 2 years or more. Lagged variables (versus estimating contemporaneous associations) are necessary given that cross-lagged and autoregressive pathways are being estimated simultaneously, whereby the rate of firearm-related mortality is a function of the firearm-related mortality in the previous year, in addition to the proportion of families owning firearms (and their sociodemographic characteristics). In turn, the associations between independent variables (eg, firearm ownership, sociodemographic characteristics) are also being simultaneously estimated. The trend term c_t captures the self-dependence of the response variable, reflecting the change in the response variable Y_t due to usual changes over time. The Box-Ljung test was conducted after models were fitted to test for autocorrelation of the residuals that might threaten the assumption of independence. None of the variables within our models violated this assumption at statistically significant levels ($P < .05$). Results available on request.

Analyses were conducted by using the statistical software R.[23]

RESULTS

Figure 1 A and B displays the firearm-related injury death rate per 100 000 children among 1- to 5-year-olds for whites and African Americans, respectively. Consistent with previous findings, the firearm-related mortality rate among young white children declined from historic highs in the late 1970s to early 1980s until 2001. After 2004, however, the mortality rate began to rise, reaching mid-1980s levels. Moreover, although the firearm-related mortality rate was higher at the beginning of the study period, firearm-related deaths accounted for only 2% of all injury-related deaths in 1976, compared with close to 5% (127 deaths) in 2016 (authors' estimates).

On average, young African American children had firearm-related mortality rates 3 times as high as young white children, while also experiencing a similar upward trend in these rates over the past decade. Contrary to young white children, African American children were not immune to the broader crime-related violence experienced by the general population during the mid-1980s through early 1990s, which contributed to a spike in firearm-related mortality during that period.[24]

Family Firearm Ownership

Our first aim in this study was to examine how firearm ownership in families with young children changed over the past 4 decades. Figure 2 A and B displays ownership by type of firearm from 1976 to 2016 for white and African American families with young children, respectively. In 1976, half of white families with young children owned a firearm, dropping to a low of 29% in 2002, at which time ownership began to increase. In 2016, 45% of white families with young children owned firearms.

Over time, firearm owners became less likely to own only a rifle or shotgun and more likely to own a pistol or revolver. For example, in 1976, 25% of white families with young children owned a rifle and/or shotgun only, whereas 24% owned a pistol and/or revolver. By 2016, the proportion owning only a rifle or shotgun declined to 12%, whereas the share owning a handgun increased to 32%. Overall, then, despite a modest decline over the past 4 decades in the proportion of white families with young children owning firearms, the types of firearms these families owned were increasingly types that may be more accessible to and operable by young children, such that of those firearm-owning families, 72% had a handgun in the home in 2016 (vs 49% in 1976).

Among African American families with young children, a smaller proportion owned firearms across all years compared with white families, with 38% owning firearms in 1976, declining to 6% by 2016. Similar to white families, the proportion of families who only owned rifles and/or shotguns declined from 23% in 1976 to <1% in 2016. Unlike white families, however, the proportion who owned handguns also declined (from 15% to 6%).

From the 1970s through to the 2010s, the sociodemographic composition of white families with young children who owned firearms changed in ways that would suggest a lower risk of firearm-related mortality. For example, firearm-owning families experienced greater declines than families without firearms in the proportion with less-educated parents and more modest incline in the proportion living in the South (Supplemental Fig 3).

Family Firearm Ownership and Firearm-Related Child Mortality

Next, we turn to the VAR models (Table 1) to examine the multivariate

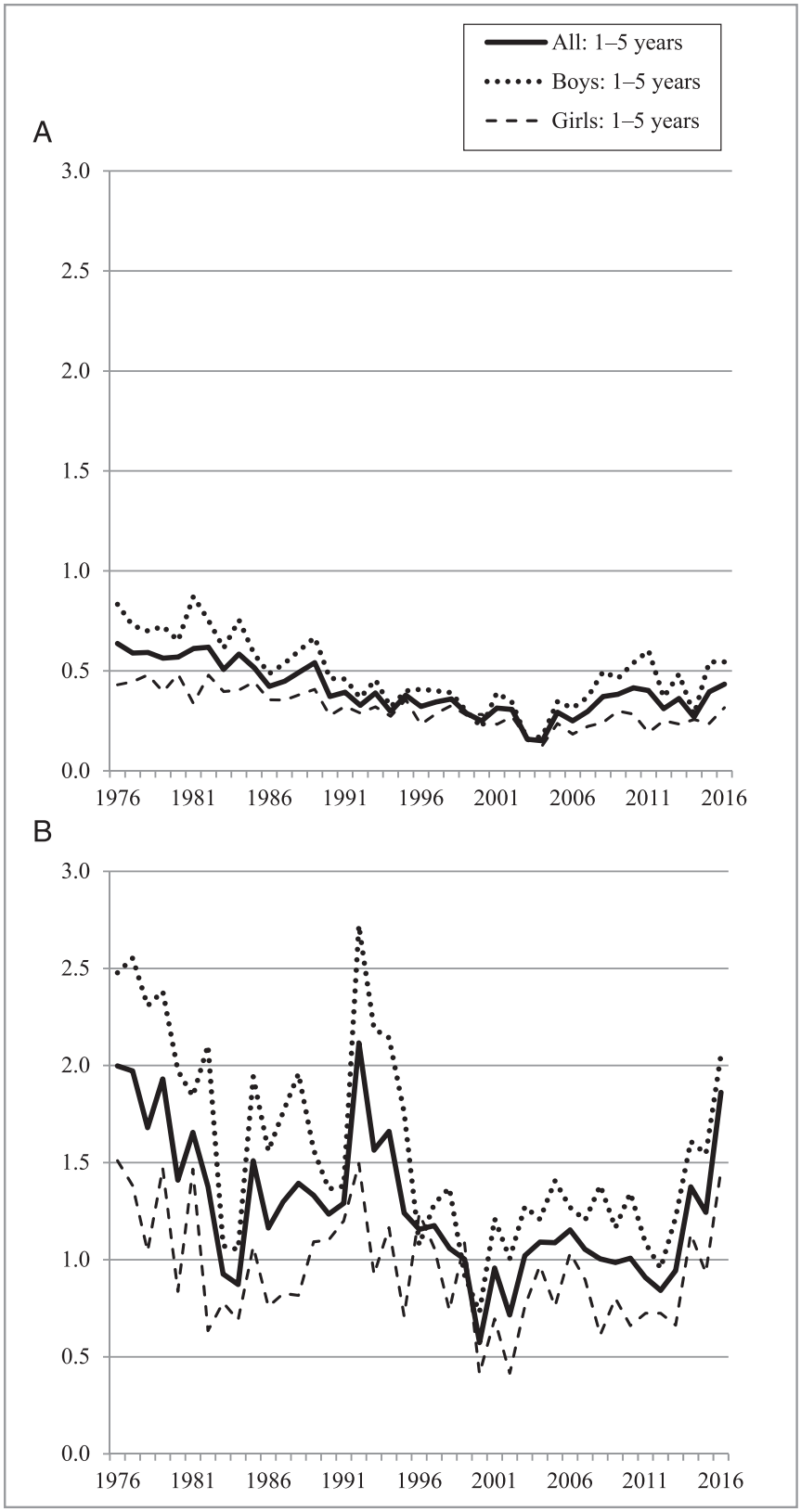

FIGURE 1

A, Firearm-related child mortality rate (per 100 000): White 1- to 5-year-olds. B, Firearm-related child mortality rate (per 100 000): African American 1- to 5-year-olds.

association between firearm ownership and firearm-related mortality among non-Hispanic white children aged 1 to 5 years. Model 1 presents the association between ownership and mortality, with no covariates (except for the lagged mortality rate) included, revealing a significant association. A 1% increase in the proportion of white families with young children who had a firearm in the home was associated with a 0.493% increase in the child mortality rate. The inclusion of a covariate for the non-Hispanic white unemployment rate (a proxy for broader economic context) did not change the association between firearm ownership and mortality (model 2). Model 3 introduced sociodemographic characteristics of firearm-owning families, and (in line with the bivariate findings that suggested that over time, firearm-owning families had characteristics less likely to predict firearm-related fatalities) their inclusion reduced the association slightly, but firearm ownership remained a statistically significant predictor.

Finally, instead of using a general measure of firearm ownership among families with young children, we examined whether the type of firearm was a better predictor of firearm-related mortality (model 4). In line with our expectation that certain firearms are easier for children to operate and access, the proportion of families with a handgun in the home, but not a rifle and/or shotgun only, was positively and significantly associated with child mortality.

Sensitivity Analyses

We found no associations between firearm ownership and the non–firearm-related injury mortality rate or the total mortality rate, nor did the firearm-related mortality rate predict firearm ownership in our main models (results available on request).

FIGURE 2

A, Firearm ownership and type of firearm: White families with young children. B, Firearm ownership and type of firearm: African American families with young children.

DISCUSSION

Our findings reveal that firearm ownership has declined among non-Hispanic white and African American families with young children during the past 4 decades. Among white families, the share of those who reported owning firearms declined from 50% in 1976 to 45% in 2016. African American families experienced a greater decline, from 38% in 1976 to 6% in 2016. Despite the decline in firearm ownership, the proportion of white families with young children who reported having pistols or handguns in their homes increased by close to one-third. As a result, 72% of white firearm-owning families with young children now have a handgun in the home.

This change in the type of firearm ownership observed among white family households was associated with consequences for the firearm-related mortality rate among young white children. Indeed, firearm ownership, generally, was positively associated with firearm-related mortality among 1- to 5-year-old white children, but this correlation was primarily driven by changes in the proportion of families who owned handguns: firearms more often stored unsecured and loaded. These findings suggest that ease of access and use may be an important consideration when examining firearm-related fatality risk among young children. The association between firearm ownership did not attenuate with the inclusion of an indicator of the broader economic context and sociodemographic characteristics of firearm-owning families. This finding is in line with research documenting that the presence of a firearm in the home matters above and beyond other risk factors associated with child injury.[1,8]

Addressing the high numbers of preventable deaths among children caused by firearms is an important public health and policy issue.[25,26] Policymakers have called for and implemented a number of strategies to prevent firearm-related deaths among children.[26] State-level child access prevention (CAP) legislation has been 1 policy approach aimed at restricting children's access to firearms, typically through penalties in response to accessing a firearm in the home of the owner. Importantly, there is strong public support for these laws.[27] Evidence of the efficacy of these laws, however, is unclear. For example, 1 study found that CAP laws

TABLE 1 VAR Models Predicting Firearm-Related Mortality Among White 1- to 5-year-olds (n = 41)

	Coefficient (95% Confidence Interval)			
	Model 1	Model 2	Model 3	Model 4
Firearm-related 1–5 y white mortality rate at $t-1$	0.475** (0.185 to 0.765)	0.427* (0.100 to 0.754)	0.332 (−0.025 to 0.689)	0.311 (−0.054 to 0.676)
	0.148[a]	0.167[a]	0.182[a]	0.186[a]
White family firearm ownership at $t-1$				
Proportion with firearms	0.493* (0.121 to 0.865)	0.491* (0.117 to 0.865)	0.467* (0.088 to 0.847)	—
	0.190[a]	0.191[a]	0.194[a]	—
Type of firearm (ref: no firearm)				
Proportion with rifle and/or shotgun only	—	—	—	0.769 (−0.154 to 1.692)
	—	—	—	0.471[a]
Proportion with pistol and/or handgun (with or without rifle and/or shotgun)	—	—	—	0.426* (0.026 to 0.826)
	—	—	—	0.204[a]
Contextual factors at $t-1$				
White unemployment rate	—	0.005 (−0.011 to 0.021)	0.004 (−0.018 to 0.026)	0.001 (−0.023 to 0.025)
	—	0.008[a]	0.011[a]	0.012[a]
Characteristics of white families who own firearms at $t-1$				
Proportion who live in a rural area	—	—	0.251 (−0.127 to 0.629)	0.272 (−0.114 to 0.658)
	—	—	0.193[a]	0.197[a]
Proportion parents' education without college degree	—	—	−0.290 (−0.649 to 0.069)	−0.252 (−0.628 to 0.124)
	—	—	0.183[a]	0.192[a]
Proportion live in the South	—	—	0.326 (−0.133 to 0.785)	0.239 (−0.282 to 0.760)
	—	—	0.234[a]	0.266[a]
Proportion with incomes in the bottom quartile	—	—	0.101 (−0.162 to 0.364)	0.066 (−0.218 to 0.350)
	—	—	0.134[a]	0.145[a]
Constant	0.018 (−0.154 to 0.190)	0.014 (−0.160 to 0.188)	0.117 (−0.326 to 0.560)	0.072 (−0.393 to 0.537)
	0.088[a]	0.089[a]	0.226[a]	0.237[a]
Trend	−0.001 (−0.003 to 0.001)	−0.001 (−0.003 to 0.001)	−0.004 (−0.008 to −0.000)	−0.002 (−0.008 to 0.004)
	0.001[a]	0.001[a]	0.002[a]	0.003[a]
Model fit				
R^2	0.759	0.761	0.801	0.804
Adjusted R^2	0.739	0.734	0.750	0.745

$t-1$ refers to predicted relationship between variables in previous year with firearm-related mortality rate in current year. Trend term captures change in mortality due to average change over time. Ref, reference; —, not applicable.

[a] SE is shown.

* $P < .05$

** $P < .01$

were associated with safer storage practices but only within a more comprehensive firearm legislative climate.[28] Moreover, another study examining unintentional child firearm fatalities reveals an association between state CAP laws and mortality, but after controlling for state-level firearm ownership, the association is no longer statistically significant (barring 2 states).[3] Such evidence underscores the risk firearms in the home pose, regardless of penalties used to inform or deter unsafe storage practices.

Recent research suggests that parents are comfortable discussing firearm safety with pediatricians.[29,30] In line with these findings, medical practitioners should ask parents about the presence of firearms in their home, discuss the developmental ramifications concerning different types of firearms, and work with parents to find solutions that keep firearms locked and unloaded and ensuring ammunition is locked in a different location (all practices that have been shown to have a protective additive effect on firearm-related injury risk among children).[31]

This study has several limitations. First, we infer that trends at the population level (ie, mortality rates) are associated with trends from population-level estimates (eg, firearm ownership). Potentially, in years in which there are lower rates of handgun ownership, increases in mortality might be driven by more unsafe behaviors correlated with a more selective group of handgun owners. Moreover, we use estimates

of firearm ownership to predict mortality, which results in uncertainty around the true population parameters. The limits of ecological data, therefore, mean our findings should not be interpreted causally.

Second, we did not distinguish between different types of firearm-related mortality. Nevertheless, we believe our measure offers a more holistic approach to the impact of firearms on young child mortality and attempts to avoid the measurement issues associated with identifying whether firearm mortality was intentional versus unintentional, which is particularly problematic when examining young victims.[9]

Third, given the analytical sample size, we were limited in the number of covariates that could be included in the multivariate models. In the same vein, there are likely unmeasured or unobserved covariates that explain the association between firearm ownership and young child firearm-related mortality.

Finally, small cell sizes in the GSS did not allow for a closer examination of the association between firearm ownership and firearm-related African American child mortality. Even so, the violence spike and associated impact on child mortality in the 1980s would not have been explained by rates of firearm ownership in African American families, illustrating stark racial contrasts in contextual violence exposure and the potential relative influence of parents' decisions around firearm ownership and their children's safety.

CONCLUSIONS

In an era in which firearm-related deaths constitute a public health crisis, the rising firearm-related young child mortality rate in the context of declining firearm ownership highlights the importance of understanding the factors that drive firearm-related deaths. We found that although firearm ownership generally has declined among white families with young children, the proportion of families who own handguns has increased. Importantly, handgun ownership had a stronger association with firearm-related fatalities among white 1- to 5-year-olds than firearm ownership, generally, suggesting that changes in the types of firearms in the homes of families may be contributing to the rising firearm-related mortality rate among young children.

ABBREVIATIONS

CAP: child access prevention
GSS: General Social Survey
VAR: vector autoregression

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