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Association of pediatric firearm injury with neighborhood social deprivation in Philadelphia

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ABSTRACT

Background Firearm-related injury is the leading cause of death among children and adolescents. There is a need to clarify the association of neighborhood environment with gun violence affecting children. We evaluated the relative contribution of specific social determinants to observed rates of firearm-related injury in children of different ages.

Methods This was a population-based study of firearm injury in children (age <18 years) that occurred in Philadelphia census tracts (2015–2021). The exposure was neighborhood Social Deprivation Index (SDI) quintile. The outcome was the rate of pediatric firearm injury due to interpersonal violence stratified by age, sex, race, and year. Hierarchical negative binomial regression measured the risk-adjusted association between SDI quintile and pediatric firearm injury rate. The relative contribution of specific components of the SDI to neighborhood risk of pediatric firearm injury was estimated. Effect modification and the role of specific social determinants were evaluated in younger (<15 years old) versus older children.

Results 927 children were injured due to gun violence during the study period. Firearm-injured children were predominantly male (87%), of black race (89%), with a median age of 16 (IQR 15–17). Nearly one-half of all pediatric shootings (47%) occurred in the quintile of highest SDI (Q5). Younger children represented a larger proportion of children shot in neighborhoods within the highest (Q5), compared with the lowest (Q1), SDI quintile (25% vs 5%; p<0.007). After risk adjustment, pediatric firearm-related injury was strongly associated with increasing SDI (Q5 vs Q1; aRR 14; 95% CI 6 to 32). Specific measures of social deprivation (poverty, incomplete schooling, single-parent homes, and rented housing) were associated with significantly greater increases in firearm injury risk for younger, compared with older, children. Component measures of the SDI explained 58% of observed differences between neighborhoods.

Conclusions Neighborhood measures of social deprivation are strongly associated with firearm-related injury in children. Younger children appear to be disproportionately affected by specific adverse social determinants compared with older children. Root cause evaluation is required to clarify the interaction with other factors such as the availability of firearms and interpersonal conflict that place children at risk in neighborhoods where gun violence is common.

Level of evidence Level III - Observational Study

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Adverse social determinants are associated with firearm-related injury in children.
⇒ Less is known of the relative contribution of specific social determinants to risk of firearm injury among children of different ages.

WHAT THIS STUDY ADDS

⇒ In this population-based study of Philadelphia neighborhoods, we found that neighborhood Social Deprivation Index (SDI) is strongly associated with risk of firearm-related injury in children.
⇒ Incremental increases in neighborhood levels of poverty, incomplete schooling, single-parent homes, and rented housing were associated with disproportionately greater increase in risk of firearm injury among younger (<15 years old) compared with older children (15–18 years old).

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study clarifies how stark disparities in social determinants of health impact the risk of firearm-related injury among children in a major US center.
⇒ Granular differences in specific determinants appear to harm younger children most.
⇒ Further research is needed to clarify root causes for these observations at the individual level.
⇒ Policies to support income, families, school retention, and economic development in neighborhoods with high SDI are urgently needed.

INTRODUCTION

In 2020, firearm-related injury became the leading cause of death among children and adolescents in the USA.[1 2] At the same time, firearm-related injuries have been the leading cause of death among black children since 2006.[3] Because firearm homicides disproportionately affect young people, children and youth have borne the brunt of the burgeoning gun violence epidemic in US cities.[4–6] For this reason, there is an urgent need to identify the underlying factors contributing to firearm-related injury among children.

It has long been understood that health outcomes are contingent on social determinants.[7] Such determinants include socioeconomic status, access to education, environmental exposures, and community characteristics, among other factors.[8] Recent

studies have identified associations between social determinants and gun violence in US cities.[9–11] Determinants associated with higher rates of gun violence include neighborhood-level measures of poverty, single-parent households, unemployment, utilization of public assistance, and food insecurity. These measures are correlated with race-based disparities such that neighborhoods with higher proportions of black residents are at greatest risk of harm.[9 12 13]

Less is known of the contribution of social determinants to firearm-related injury in children. Studies of social factors as they relate to pediatric firearm injury have been predominantly single-center analyses, limited by small sample size and unable to explore the role of neighborhood-level measures of deprivation.[14–16] To our knowledge, no studies have evaluated how specific social determinants impact children of different ages. This is an important gap in knowledge since environmental stressors are likely to affect younger children differently than older children.

To better understand the contribution of neighborhood social determinants to firearm-related injury in children, we evaluated the association between Social Deprivation Index (SDI) and pediatric firearm injury in neighborhoods in Philadelphia. We hypothesized that children exposed to greater neighborhood deprivation would be at higher risk of firearm-related injury.

METHODS

Study design

This study was a population-based analysis of firearm injury in children and adolescents (age <18 years) that occurred within census tracts (neighborhoods) in Philadelphia County between January 1, 2015 and December 31, 2021. The study objectives were (1) to measure the association between SDI and pediatric firearm injury at the neighborhood level, and (2) to evaluate the relative contribution of specific measures of social deprivation (SDI components) to the neighborhood-level risk of firearm injury in children of different ages.

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.[17] The project was approved by our Institutional Review Board. All data sources used were publicly available and deidentified; informed consent was waived.

Exposure: neighborhood SDI

The exposure was defined as neighborhood SDI. The SDI is a composite measure of area level deprivation comprised of seven demographic characteristics collected by the American Community Survey.[18 19] Initially developed in 2013,[20] the index was derived using factor analysis and operationalized as a centile ranking ranging from 1 to 100, with larger values indicating worse area level deprivation. Components of the SDI are outlined in the online supplemental table 1[18] and include measures of poverty (poverty rate, non-employment, no household vehicle), education (adults with less than 12 years of schooling), housing (rented housing, crowded housing), and family (single-parent household). The SDI has been used to quantify socioeconomic variation and is associated with adverse health outcomes.[18 20] In our study, Philadelphia census tracts were grouped into quintiles of SDI for the purpose of analysis.

Outcome: firearm injury rate in children

The primary outcome was the neighborhood rate of pediatric firearm injury, reported as firearm injuries per 100,000 child-years. Data for children and adolescents (age <18 years) injured by firearm were obtained from the Philadelphia Police Department's registry of shooting victims.[21] This dataset includes individual level data for all people shot as the result of interpersonal violence since 2015. Only shootings classified by police as criminal in nature are included; therefore, self-inflicted injuries are excluded. Variables captured include time and date, baseline demographic characteristics, documented wounds, indoor (vs outdoor) shooting location, and mortality. Geospatial coordinates were included, allowing for each shooting to be mapped. Race data were included in this study due to known race-based disparities in firearm-related injury. Categories of race are presented in keeping with the manner they were recorded in police records. Asian and unknown race categories were consolidated as they represented 0.6% of firearm-injured children.

Pediatric firearm injuries were mapped and aggregated within Philadelphia census tracts using ArcMap geospatial analysis software. The US Census Bureau provided population estimates for each census tract to allow for the calculation of firearm injury rates.[19] Neighborhood rates of firearm injury were stratified by age (<5, 5–9, 10–14, 15–17), sex, race, and year.

Statistical analysis

To provide context on the study setting, we compared the demographic and social deprivation measures (SDI and SDI components) in Philadelphia neighborhoods to census tracts in the rest of the USA. Univariable analyses were then performed to compare demographic and social deprivations measures across Philadelphia neighborhoods by SDI quintile. Characteristics of pediatric firearm injuries were also compared across SDI quintiles. The Wilcoxon rank-sum and Kruskal-Wallis tests were then used to compare continuous variables, whereas frequencies were compared using the χ^2 or Fisher's exact tests. We then used two analytic approaches to achieve the stated study objectives.

First, a negative binomial model was used to measure the association between SDI quintile and the rate of pediatric firearm injury at the neighborhood level. The model was adjusted by categories of population age, sex, and race, as well as study year. This model was a multilevel mixed model[22] that included a random intercept term to account for repeated observations within the census tracts.

Second, we sought to evaluate the relative contribution of the seven component measures of social deprivation on the neighborhood rate of pediatric firearm injury. To accomplish this, we used hierarchical negative binomial regression models to estimate the risk-adjusted rate ratio (aRR) and 95% confidence interval (95% CI) associated with each individual component of the SDI. For this purpose, SDI components were operationalized into quintiles such that each measure of social deprivation was standardized to its range among Philadelphia neighborhoods. All models were adjusted for categories of population age, sex, and race, as well as study year. Multicollinearity between SDI components was evaluated using the variance inflation factor, with a threshold >4 to indicate collinearity.

Third, we considered that the association of specific measures of social deprivation and firearm injury risk might differ among children of different ages. Specifically, the impact of neighborhood social determinants might affect younger children differently from older children (adolescents approaching young adulthood). For this reason, we tested for effect modification based on age between younger (<15 years old) and older children (≥15 years old). The results of interaction terms and aRRs are reported for each SDI component as a stratified analysis for both younger and older children.

Finally, we used the proportional change in variance (PCV) to measure the proportion of neighborhood variation in pediatric firearm injury that could be explained by each measure of social deprivation. The PCV is estimated using the following equation[23]:

$$PCV = \left(\frac{V_1 - V_2}{V_1}\right) \times 100\%,$$

where V_1 is the neighborhood-level variance in the multilevel model including only demographic characteristics and study year, and V_2 is the neighborhood-level variance in the same model after adding individual SDI components. In this way, the PCV represented the degree to which the observed differences in pediatric firearm between neighborhoods were explained by each social determinant.

Mapping was performed using ESRI ArcMap GIS software (V.10.5, ESRI). Statistical analyses were performed using the SAS software (V.9.4, SAS Institute Inc., Cary, NC). Threshold for statistical significance was $p<0.05$.

RESULTS

Pediatric firearm injury and neighborhood social deprivation

During the 7-year study period, 927 children were injured due to gun violence in 377 Philadelphia census tracts (overall pediatric firearm injury rate, 38 shootings per 100,000 child-years). Firearm-injured children were predominantly male (807 of 927 children; 87%), of black race (826 of 927 children; 89%), with median age of 16 years (IQR 15–17 years). One in five children shot was younger than 15 years of age (184 of 927 children; 20%). Mortality was 15% (136 of 927 children).

Compared with the census tracts in the rest of the USA, neighborhoods in Philadelphia showed significantly higher measures of social deprivation (online supplemental table 2). Specifically, the median SDI for census tracts in Philadelphia was 83 (IQR 60–93) compared with 52 (IQR 27–77) in other US census tracts ($p<0.001$). This disparity was driven by significant differences in all components of the SDI except for crowded housing.

Table 1 compares the demographic and social deprivation measures across quintiles of neighborhood SDI in Philadelphia. The magnitude of disparity across the spectrum of social deprivation between census tracts in Philadelphia was significant (Q5 vs Q1; median, SDI 97 vs 37; $p<0.001$). Compared with the lowest quintile of SDI (Q1), neighborhoods in the highest quintile of SDI (Q5) had fivefold higher rates of poverty, schooling <12 years, and single-parent homes, and nearly fourfold higher rates of non-employment, crowded housing, and no household vehicle. Neighborhoods with highest social deprivation were disproportionately black (Q5 vs Q1; median, 69% vs 6%; $p<0.001$) with more children (Q5 vs Q1; 29% vs 16%; $p<0.001$).

Characteristics of firearm-injured children are compared across SDI quintiles in table 2. Nearly half of all pediatric shootings occurred in the highest quintile of social deprivation (447 of 927 shootings; 48%). Compared with the lowest quintile, children injured in the highest quintile of SDI were significantly more likely to be younger than age 15 (Q5 vs Q1; 110 of 447 vs 1 of 19 children; 25% vs 5%; $p<0.007$). The rate of pediatric firearm injury was significantly higher in neighborhoods with higher social deprivation (figure 1A). Specifically, the unadjusted rate of pediatric firearm injury rose significantly in a dose-response manner in association with higher neighborhood social deprivation (Q5 vs Q1; firearm injury rate, 61 vs 7 per 100,000 child-years).

Hierarchical negative binomial model for pediatric firearm injury

Table 3 shows the results of the hierarchical negative binomial model for pediatric firearm injury. After adjusting for population differences in age, sex, and race, as well as study year, higher neighborhood social deprivation was strongly associated with higher rates of firearm injury in children (Q5

Table 1 Comparison of population demographic and social deprivation measures by SDI quintile

	Philadelphia census tract SDI quintile					
	Lower social deprivation			Higher social deprivation		
	Q1	Q2	Q3	Q4	Q5	
Census tracts (n)	73	76	69	75	84	
SDI, median (IQR)	37 (26–44)	65 (59–70)	81 (79–85)	91 (89–92)	97 (95–99)	
Parameter						**P value**
Demographics, median % (IQR)						
Children (<18 years)	16 (10–20)	17 (13–21)	23 (18–26)	24 (18–28)	29 (24–32)	<0.001
Black population	6 (3–12)	14 (6–37)	45 (16–73)	71 (32–91)	69 (28–88)	<0.001
SDI, median (IQR)	37 (26–44)	65 (59–70)	81 (79–85)	91 (89–92)	97 (95–99)	<0.001
SDI components, median % (IQR)						
Poverty	8 (6–10)	15 (12–20)	23 (19–30)	32 (28–37)	43 (38–52)	<0.001
Schooling <12 years	6 (2–10)	11 (7–14)	16 (13–20)	20 (16–24)	28 (25–37)	<0.001
Non-employment	6 (4–8)	10 (6–15)	14 (10–17)	18 (13–22)	22 (18–27)	<0.001
Single-parent home	9 (6–16)	18 (14–24)	28 (24–35)	35 (31–41)	46 (40–53)	<0.001
Crowded housing	1 (0–2)	1 (1–3)	2 (1–3)	2 (1–4)	4 (2–6)	<0.001
Rented housing	34 (21–47)	40 (28–52)	42 (33–57)	51 (44–60)	59 (52–68)	<0.001
No vehicle	12 (6–26)	19 (13–29)	28 (20–41)	41 (32–49)	49 (44–57)	<0.001

IQR, interquartile range; SDI, Social Deprivation Index.

Table 2 Characteristics of pediatric firearm injuries by SDI quintile

	Philadelphia census tract SDI quintile					
	Lower social deprivation			Higher social deprivation		
	Q1	Q2	Q3	Q4	Q5	
Census tracts (n)	73	76	69	75	84	
SDI, median (IQR)	37 (26–44)	65 (59–70)	81 (79–85)	91 (89–92)	97 (95–99)	
Parameter						**P value**
Child characteristics						
Age (years)						
<5	0 (0)	0 (0)	5 (3.4)	10 (3.7)	18 (4.0)	0.850
5–9	0 (0)	1 (2.4)	4 (2.7)	4 (1.5)	15 (3.4)	0.590
10–14	1 (5.3)	4 (9.5)	16 (11.0)	29 (10.6)	77 (17.2)	0.063
15–17	18 (94.7)	37 (88.1)	121 (82.9)	230 (84.3)	337 (75.4)	0.007
Male sex, n (%)	19 (100)	39 (92.9)	127 (87.0)	234 (85.7)	388 (86.8)	0.338
Race, n (%)						
White	3 (15.8)	8 (19.1)	12 (8.2)	6 (2.2)	66 (14.8)	<0.001
Black	16 (84.2)	34 (81.0)	133 (91.1)	263 (96.3)	380 (85.0)	<0.001
Other	0 (0)	0 (0)	1 (0.7)	4 (1.5)	1 (0.2)	0.316
Shooting characteristics						
Indoor shooting, n (%)	1 (5.3)	0 (0)	6 (4.1)	18 (6.6)	22 (4.9)	0.421
Wound location, n (%)						
Head	2 (10.5)	4 (9.5)	14 (9.6)	30 (11.0)	38 (8.5)	0.826
Torso	5 (26.3)	12 (28.6)	25 (17.1)	47 (17.2)	109 (24.4)	0.079
Extremity	10 (52.6)	15 (35.7)	76 (52.1)	135 (49.5)	185 (41.4)	0.054
Multiple	2 (10.5)	10 (23.8)	29 (19.9)	59 (21.6)	110 (24.6)	0.530
Fatality, n (%)	4 (21.1)	9 (21.4)	25 (17.1)	43 (15.8)	55 (12.3)	0.218
Population firearm injury						
Population, n kids	40,565	57,796	66,766	74,768	105,499	
Firearm-injured children	19	42	146	273	447	
Firearm injury rate (/100,000 child-years)	6.7	10.4	31.2	52.2	60.5	

IQR, interquartile range; SDI, Social Deprivation Index.

vs Q1; aRR 14.1; 95% CI 6.13 to 32.2) (figure 1B). Firearm injury was highest among black children (aRR 3.73; 95% CI 2.86 to 4.86) that were male and aged 15–17. The risk-adjusted rate of pediatric firearm injury rose significantly in 2020 compared with earlier study years (2020 vs 2015; aRR 2.64; 95% CI 1.89 to 3.68).

Association of individual SDI components with pediatric firearm injury

Having identified a significant association between SDI and pediatric firearm injury, we sought to determine the associations of individual components of the SDI with neighborhood risk of firearm injury in children. The variable representing no

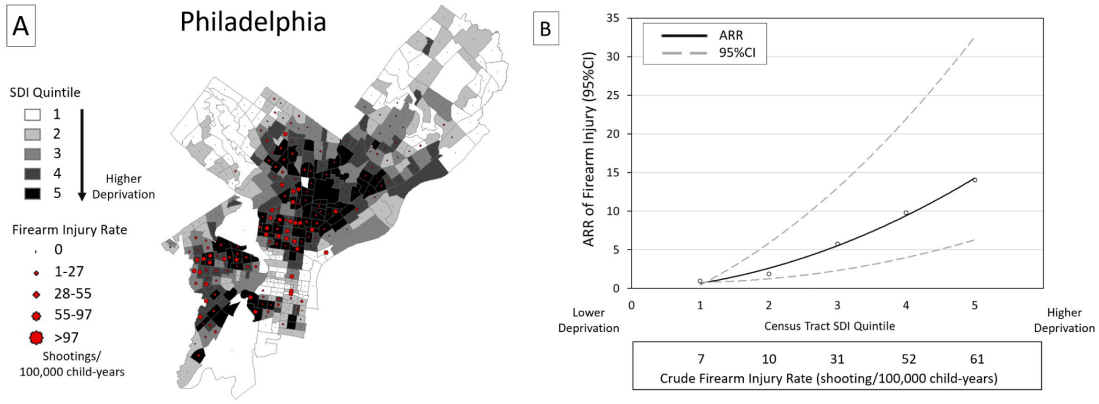

Figure 1 (A) Map of census tracts in Philadelphia. Neighborhood Social Deprivation Index (SDI) quintile is portrayed by grayscale color gradient. Pediatric firearm injury rate is shown by circle sized proportional to the rate. (B) Curve showing the risk-adjusted rate ratio (ARR) of pediatric firearm-related injury as a function of increasing SDI quintile. The corresponding crude rate is shown beneath the curve. 95% CI, 95% confidence interval.

Table 3 Negative binomial model for firearm injury in children

Parameter	Rate ratio	95% CI
SDI quintile		
5	14.1	6.13 to 32.2
4	9.82	4.26 to 22.7
3	5.79	2.49 to 13.4
2	1.88	0.76 to 4.64
1	Reference	NA
Age category (years)		
15–17	Reference	NA
10–14	0.10	0.08 to 0.12
5–9	0.02	0.01 to 0.03
<5	0.02	0.02 to 0.04
Female sex (vs male)	0.16	0.12 to 0.19
Race		
White	Reference	NA
Black	3.73	2.86 to 4.86
Other	0.03	0.01 to 0.10
Year		
2021	2.83	2.03 to 3.93
2020	2.64	1.89 to 3.68
2019	1.51	1.06 to 2.16
2018	1.41	0.98 to 2.02
2017	1.26	0.87 to 1.82
2016	1.30	0.90 to 1.87
2015	Reference	NA

95% CI, 95% confidence interval; NA, not applicable; SDI, Social Deprivation Index.

household vehicle was highly collinear with other measures and so was excluded from multivariable analyses of individual SDI components. Table 4 shows the results of the negative binomial regression models for pediatric firearm injury when considering each measure individually. All components of the SDI, except crowded housing, were significant predictors of pediatric firearm injury.

Comparison of effects of SDI components between younger and older children

Interaction terms between age (younger vs older children) and the measures of poverty ($p<0.001$), incomplete schooling ($p=0.042$), single-parent home ($p<0.001$), and rented housing ($p<0.001$) were significant. Interaction was not present between age and non-employment ($p=0.328$) or crowded housing ($p=0.601$). The association of each SDI component with neighborhood risk of firearm injury stratified for younger and older children is shown in table 4. Neighborhood poverty and rented housing were associated with firearm injury risk to a significantly greater degree among younger children. Increasing neighborhood prevalence of incomplete schooling and single-parent homes were also associated with higher adjusted risk of firearm injury among younger, compared with older children; however, this was not significant owing to overlapping 95% CIs.

Relative contribution of SDI components to pediatric firearm injury

Using the PCV, we measured the relative contribution of each individual measure of social deprivation to the observed rates of pediatric firearm injury at the neighborhood level (online supplemental table 3). Poverty explained the largest proportion of the observed differences in neighborhood pediatric firearm injury (43%). When all components of the SDI were included in the model, measures of social deprivation accounted for 58% of the observed between-neighborhood differences in pediatric firearm injury rate.

DISCUSSION

In this population-based study of Philadelphia census tracts, neighborhood social deprivation was strongly associated with firearm-related injury in children. Children living in neighborhoods with the highest SDI were at 14-fold higher risk of suffering injury due to gun violence. Incremental increases in neighborhood levels of specific social determinants, namely, poverty, incomplete schooling, single-parent homes, and rented housing, were disproportionately associated with higher risk among younger children. Altogether, the social measures comprising the SDI accounted for 58% of the observed between-neighborhood differences in pediatric firearm injury rate.

These findings confirm what trauma providers have observed for decades: that children exposed to adverse social determinants of health in their environment are at significantly greater risk of harm due to gun violence. Although the association between social determinants of health and firearm injury has been clearly demonstrated,[9–11] studies evaluating this relationship in children are mainly limited to single-center studies.[14–16] Tracy *et al* found that among 114 children with firearm-related injuries, metrics reflecting community distress in Chatham County, Georgia, were predictive of pediatric gun violence.[15] In a 20-year review of their trauma registry, Bayouth *et al* found clustering of pediatric firearm-related injury presenting from lower socioeconomic areas of Jacksonville, Florida.[14] Trinidad *et al* found that children presenting with gunshot wounds to Cincinnati

Table 4 Association between SDI components and firearm injury in children

Parameter	All children		Older children (≥15 years old)		Younger children (<15 years old)	
SDI component ***per quintile increase***	**aRR**	**95% CI**	**aRR**	**95%CI**	**aRR**	**95%CI**
Poverty	1.73	1.59 to 1.87	1.16	1.11 to 1.22	1.70	1.46 to 1.98
Schooling <12 years	1.44	1.34 to 1.55	1.39	1.27 to 1.52	1.66	1.43 to 1.92
Non-employed	1.38	1.29 to 1.47	1.51	1.37 to 1.66	1.52	1.30 to 1.78
Single-parent home	1.51	1.40 to 1.64	1.49	1.36 to 1.64	1.64	1.39 to 1.92
Crowding	1.01	0.96 to 1.07	1.01	0.94 to 1.08	1.04	0.94 to 1.15
Rented housing	1.35	1.28 to 1.43	1.18	1.14 to 1.22	1.39	1.23 to 1.56

All models adjusted for age, sex, race, and year.
aRR, adjusted rate ratio; 95% CI, 95% confidence interval; SDI, Social Deprivation Index.

Children's Hospital were significantly more likely to come from neighborhoods with high SDI.[16] As institutional registry-based studies, generalizability of these reports to broader populations was limited. In contrast, we used a population-based study design to capture all shootings involving children in Philadelphia neighborhoods across the spectrum of social deprivation. In doing so, our findings are a true public health evaluation of the association between neighborhood SDI and risk of pediatric firearm-related injury.

A key strength of our study was its evaluation of the role of specific measures of social deprivation in children of different ages. A recent study by Polcari *et al* evaluated the association between social vulnerability index and firearm injury in five US cities.[24] Although this study identified broad associations between themes of social vulnerability and firearm injury among children, it did not evaluate the role of granular social determinants in different age groups. In contrast, we found that children younger than 15 years old were at disproportionately greater risk in neighborhoods with high SDI. Specifically, incremental increases in neighborhood-level poverty, incomplete schooling, single-parent homes, and rented housing were associated with significantly greater increases in risk of firearm injury among younger children compared with their older peers. These findings are important because they indicate that mechanisms may exist through which younger children are disproportionately susceptible in environments where these stressors are heightened. Low-income environments where high poverty and housing instability are pervasive correlate highly with firearm injury.[25] It stands to reason that additional factors such as high prevalence of single-parent homes and incomplete schooling would further exacerbate the potential for younger children to be exposed to gun violence. In addition to income support policies, which have been shown to reduce interpersonal firearm violence,[26 27] programs that support families of young children and promote school retention should be instituted and studied.

Another observation integral to interpreting our results is the stark disparities in social deprivation and risk of gun violence between different populations of people within a single major urban center. Neighborhoods with the highest social deprivation, and the highest rate of firearm injury, were those with predominantly black residents. These findings reflect known structural disparities largely attributable to the historical practice of redlining—a government-based policy through which investment in urban, predominantly African American communities was discouraged during the early 20th century.[28 29] As a result, neighborhoods in Central and West Philadelphia were outlined in red and deemed "Hazardous", with the result that residential racial segregation and disparities of wealth were exacerbated.[30] Today, historically redlined neighborhoods in Philadelphia and other US cities correspond to those with high levels of social deprivation and gun violence.[31 32] Intentional investment by federal and city governments to support economic development and improve the built environment in these neighborhoods is both a viable strategy to reduce gun violence and a moral obligation.

The finding of an increase in risk-adjusted rate of pediatric firearm-related injury during 2020 is consistent with the well-documented rise in gun violence during this period. Beard *et al* documented a significant and sustained increase in shooting incidence in Philadelphia during 2020 that may be attributable to containment policies during the early COVID-19 pandemic.[33] In their analysis of data from the Gun Violence Archive, Cohen *et al* found an increase in risk of firearm-related injury in children younger than 12 years during the first 6 months of the pandemic as compared with the three prior years.[34] Iantorno *et al* found that non-Hispanic black children and those with public insurance were disproportionately affected by this increase in gun violence.[4] These findings suggest that pandemic conditions have further exacerbated existing structural inequities and health disparities.

This study has several important limitations. First, as a retrospective study of census tracts in Philadelphia, the generalizability of our results to different populations across the US is unclear. It was noted that measures of social deprivation were significantly higher in Philadelphia as compared with other US census tracts. For this reason, it is important to emphasize that our observations most likely represent the relationship between neighborhood social deprivation and pediatric firearm-related injury in comparable urban environments.

Second, although the Philadelphia Police Department's registry of shooting victims is prospectively updated and complete, we are not able to know the circumstances surrounding each shooting. Therefore, we are not able to elucidate granular event information that might provide insight into causative factors (eg, domestic violence vs other forms of interpersonal violence).

Third, the location of residence for shooting victims was unknown. Therefore, it is not known whether injured children were shot within their neighborhoods of residence. However, it is known that injury due to gun violence most often occurs close to home,[35] and we have no reason to believe this to be different in Philadelphia (let alone for children). Therefore, we believe our evaluation of adverse neighborhood-level social determinants as environmental exposures that might predispose to pediatric firearm injury to be reasonable.

Fourth, as an area-level measure, we used SDI as an ecologic exposure applied to the neighborhood level. Therefore, it is important not to make causal interpretations at the individual level (ecologic fallacy).[36] For example, we cannot know to what degree adverse social determinants actually contributed to the circumstances of children injured by gun violence in neighborhoods with high SDI. Rather, our findings offer insight into the relationship between environment and risk of firearm injury for populations of children.

Finally, the SDI is a composite measure of social deprivation that was not intended specifically for the study of gun violence. Therefore, it is incomplete with respect to the many potential socioeconomic and environmental factors that may contribute to community risk for firearm-related injury. Acknowledging this key limitation, our findings should be interpreted with a public health lens as reflecting the relationship between specific measures of social deprivation and firearm-related injury in children of different ages.

CONCLUSIONS

In this population-based study of census tracts in Philadelphia, neighborhood social deprivation was strongly associated with risk of firearm-related injury in children. Younger children were disproportionately affected by specific measures of economic disadvantage, single-parent households, and incomplete schooling. Poverty appeared to be the strongest neighborhood-level predictor of pediatric firearm injury. Root cause evaluation is required to clarify the interplay between economic distress and other factors such as the availability of firearms and interpersonal conflict that place children at risk in neighborhoods where gun violence is common.

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Contributors JK: Study design, interpretation, drafting manuscript, revision. MN: Interpretation, critical review, revision. JC: Interpretation, critical review, revision. JS: Interpretation, critical review, revision. EH: Interpretation, critical review, revision. DS: Interpretation, critical review, revision. GR: Interpretation, critical review, revision. JB: Study design, data analysis, interpretation, drafting manuscript, revision, guarantor.

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Ethics approval Johns Hopkins IRB00176618. This study was exempted because this was a retrospective study of deidentified data which is routinely collected and is publicly available. Patient risk was deemed minimal.

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