Differences in Mortality Rates of Gunshot Victims: The Influence of Neighborhood Social Processes

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Abstract
Firearm violence is considered a public health crisis in the United States. Firearm violence spatially concentrates within neighborhoods and is associated with community factors; however, little is understood about the geographic differences in gunshot wound mortality and associated neighborhood social processes. Applying a public health approach through the Haddon’s Matrix, the results demonstrate systematic differences in social and physical features associated with gunshot mortality. These findings have important implications to improve neighborhood physical and social conditions, police transporting gunshot victims, and police-public health partnerships to improve data collection on nonfatal shootings and shots fired.

KEYWORDS: gun homicide, nonfatal shootings, neighborhood social processes, public health, gunshot wound mortality

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Introduction

Firearm violence is considered a public health crisis in the United States. Both fatal and nonfatal urban firearm violence spatially concentrates within neighborhoods (Braga et al., 2009; Cohen & Tita, 1999) and contributes to individual, family, and community trauma (Jacoby et al., 2017; McDonald et al., 2011; Smith & Patton, 2016). Nonfatal firearm shootings result in long-term physical and mental disabilities, such as substance use disorder, post-traumatic stress disorder (DiScala & Sege, 2004; Greenspan & Kellermann, 2002; Howell, 2013; Rich & Grey, 2005) and repeat violent victimization (Carter, 2015; Cunningham et al., 2015). Scholars have long studied fatal firearm violence, however, nonfatal firearm violence has dramatically increased over the last decade (Jena et al., 2014) and typically occurs at rates three times higher than fatal firearm assaults (i.e., homicide) (Hipple & Magee, 2017). For instance, in the US, approximately 34,538 fatal firearm assaults and 85,694 nonfatal firearm assaults occur annually (Kaufman et al., 2021). Despite the prevalence of firearm violence, relatively little is understood about the geographic differences in gunshot wound mortality and associated neighborhood social processes. Therefore, this study extends our current knowledge in three ways: 1) by applying a public health conceptual framework, 2) assessing the proportion of fatal and nonfatal shootings to overall reported firearm discharges (i.e., shots fired), and 3) examining geographic differences and associated neighborhood social processes with gunshot wound mortality.

Public Health Approach

Criminologists, police leaders, and local, state, and national leaders have stated the need for a public health approach to prevent and end firearm violence within many large urban communities in the United States. A public health approach has successfully reduced traffic...
fatalities, work related injuries, and childhood injuries (Hemenway, 2009), by identifying the risk and protective factors to determine the root causes of injuries. The public health approach is largely focused on prevention of injury and involves four stages: (1) understanding the epidemiology, (2) program development, (3) research and evaluation of outcomes, and (4) dissemination of successful interventions (Bulger et al., 2019). Given the dearth of available data on nonfatal shootings at the local and national level (Identifying Reference -1; Identifying Reference – 5) this study focuses on the epidemiology of fatal and nonfatal shootings regarding geographic disparities in gunshot wound mortality and associated neighborhood social processes through a commonly used public health framework.

The Haddon’s Matrix is a public health conceptual framework to injury prevention that identifies the temporal nature of injury, across the pre-event, event, and post-event, and incorporates opportunities for intervention across four domains: the host, vector, social environment, and physical environment. The framework further assesses influencing elements of events (victim, agent, physical and social environment) during different event phases (Runyan, 1998). The matrix has been widely used in the prevention of traffic crashes, for instance, seat belts protect the people in the car (i.e., victim), better headlights, brakes and airbags improve the safety of the vehicle (i.e., agent), and speed bumps, roundabouts, and guardrails improve the safety of the environment (i.e., social and physical environment) (Hemenway, 2009). Given the success in traffic safety specifically, scholars have more recently began to apply the framework to the study of firearm violence (Abaya et al., 2019; Kaufman & Richmond, 2020; Ranney et al., 2017) to better understand the epidemiology, risk, and protective factors of firearm violence across each domain (Richmond & Foman, 2019). For example, the physical and social environment includes

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improving neighborhood lighting, neighborhood development, gunshot monitoring systems (e.g., ShotSpotter), rapid access to trauma care and engagement of the community (Bulger et al., 2019; Richmond & Foman, 2019), however, few studies have utilized data on fatal and nonfatal shootings to examine both the physical and social environment to better understand the epidemiology and differences in gunshot wound mortality across neighborhoods.

Neighborhood-level Social Processes

Decades of research has established the importance of neighborhood social processes on rates of firearm assaults. For instance, neighborhood disadvantage, residential instability, ethnic heterogeneity (i.e., social disorganization theory), neighborhood disorder, lower collective efficacy, and higher Black and Hispanic populations have continuously been associated with higher levels of fatal firearm assault (i.e., homicide) (Cohen & Tita, 1999; Morenoff et al., 2001; Rosenfeld et al., 1999; Sampson et al., 1997). Recent research extended these findings to both fatal and nonfatal shootings at the micro-social level, suggesting street segments with higher levels of disorder and lower levels of collective efficacy are associated with higher rates of fatal and nonfatal shootings (Magee, 2020). However, the considerable measurement and population differences in existing studies account for our limited understanding in associated neighborhood social process and differences in gunshot wound mortality.

Criminologists have traditionally measured physical disorder using systematic social observations (Braga & Bond, 2008; Sampson & Raudenbush, 1999; Uchida et al., 2013) and collective efficacy using five-item Likert-type scale questions (Browning, 2002; Browning et al., 2004; Morenoff et al., 2001; Sampson & Raudenbush, 1999; Sampson et al., 1997), such data collection methods are expensive and time consuming (O’Brien et al., 2015). More recently large
administrative data sets, such as police 911 calls have been used and validated as measures of community social disorder (Boggess & Maskaly, 2014; O'Brien & Sampson, 2015; Weisburd & Green, 1995), as such calls suggest residents are unable to handle disputes themselves and indicates a lack of informal social control that requires police intervention. For instance, in Boston, police 911 calls for public social disorder and shootings predicated increases in violence and homicides the following year (O'Brien & Sampson, 2015).

In addition to police 911 calls, scholars have leveraged administrative datasets such as nonemergency calls for services (i.e., 311 calls), the rate of active voters, and community rain collector barrels to measure community disorder and collective efficacy (Weisburd et al., 2012; Wheeler, 2018). Residents calls to the 311 system have been used to measure both physical disorder (Huebner et al., 2020; Wheeler, 2018) and collective efficacy (Magee, 2020), as a resident’s willingness to call for city services may indicate civic engagement (O'Brien & Sampson, 2015). For instance, Wheeler (2018) demonstrated a positive relationship between 311 calls and overall crime. Similar results from St. Louis suggest higher rates of 311 calls were positively associated with resident reports of gunfire via 911 calls (Huebner et al., 2020). They further note the negative association between concentrated disadvantage and 311 calls, and therefore suggest 311 calls reflect community engagement. This finding aligns with prior research which suggests 311 calls is negatively associated with higher rates of firearm violence (Magee, 2020). These studies are limited in that they each examined different outcomes of violence and firearm violence, and little is still understood on the relationship between 911 calls, 311 calls and differences in fatal and nonfatal shootings outcomes. Given these findings,

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however, higher rates of residents’ engagement with the 911 and 311 systems may lead to differences in connection to trauma care among gunshot wound victims.

Linkage to Critical Care

Timing of critical care from first responders and the transport distance to a trauma center is associated with shooting mortality (Crandall et al., 2013; Crandall et al., 2016; Hatten & Wolff, 2020). In Chicago, assault severity and intent were most associated with mortality and patients shot further away from a trauma center were more likely to die from their gunshot wound (Crandall et al., 2013; Crandall et al., 2016). This is problematic in cities like Chicago, where most shootings occur on the South side of the city but there is a lack of available trauma centers. Furthermore, the closure of trauma centers most often occurs in communities with majority minority residents (Shen et al., 2009) and areas with higher rates of poverty (Hsia et al., 2011). Differences in mortality have also been observed when police and emergency medical services (EMS) transport gunshot wound victims, especially in areas with longer average EMS wait times and greater distance to a trauma center (Crandall et al., 2013; Hatten & Wolff, 2020; Jacoby, Branas, et al., 2020; M. Wandling et al., 2016). In Philadelphia, assault severity predicted mortality, but travel time of first responders and location of trauma centers were also associated with mortality. For instance, for every additional minute it took a first responder, the mortality rate of gunshot wound victims increased by nearly 13 percent, when adjusting for victim demographics, injury severity and distance to trauma center (Hatten & Wolff, 2020).

Other studies display similar results but note that other neighborhood level factors may contribute to gunshot wound mortality. For instance, in Detroit, victims in trauma deserts died at a rate 12% higher than the city-wide rate and victims in trauma oases died at a rate 14% lower.

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than the city-wide average (Circo, 2019). These “trauma deserts” are associated with higher gunshot wound mortality rates; however, many neighborhoods without nearby trauma facilities did not have elevated gunshot wound mortality rates, suggesting other neighborhood-level factors may contribute to gunshot wound survival (Circo, 2019). Research in Philadelphia, found no difference in morality for victims transported by police or EMS but did find that police were more likely to transport victims from neighborhoods with a greater number of fire houses, more Black residents, and higher rates of abandoned homes (Jacoby, Branas, et al., 2020; M. Wandling et al., 2016). These findings suggest the importance of neighborhood level social processes in connecting gunshot wound victims to critical care.

These prior studies have largely overlooked the role of neighborhood social processes in the variation in gunshot wound mortality within an urban environment. Therefore, this study fills this gap in the literature by utilizing Haddon’s Matrix to study the epidemiology of fatal and nonfatal shootings to understand differences in gunshot wound mortality and associated physical and social process across neighborhoods. As the social processes of a neighborhood may influence how gunshot wound victims are connected to critical care.

**Methods**

The study takes place in Indianapolis, Indiana. Indianapolis spans 361 square miles, and as of 2016 had an estimated population of 855,164 people (Bureau, 2016). This study is a cross-sectional ecological analysis of census-level data that examines differences in fatal and nonfatal shooting incidents (n=1,593) and associated neighborhood social processes in Indianapolis, Indiana between January 1, 2014 - December 31, 2016. Among cities in the United States with populations over 200,000, Indianapolis was ranked the tenth most violent city in 2015, with a

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violent crime rate of 1,288 per 100,000 and a homicide rate of 17 per 100,000 (Investigation, 2016). There are approximately 120 fatal and 400 nonfatal shooting each year, producing one victim of firearm violence each day and a rate of 48 per 100,000 population.

Data Sources

Data were obtained from the Indianapolis Metropolitan Police Department (IMPD), the Indianapolis Mayor’s Action Center (MAC), the City of Indianapolis, and the U.S. Census Bureau. Fatal and nonfatal shooting incidents were measured using data from IMPD. IMPD collects data on all fatal (i.e., homicide) shootings through the homicide records management database. All criminal fatal shootings where the cause of death was due to a firearm are included in the study. Nonfatal shooting incidents were collected through the Nonfatal Shooting Review database, which is generated using information from both police incident reports and internal documents from IMPD (Hipple & Magee, 2017). Records include incident location, incident date, and victim demographics. Only incident date and location were included in this study. A nonfatal shooting was defined as a criminal assault in which a projectile weapon with a powder discharge caused a penetrating assault injury (Beaman et al., 2000). All self-inflicted, accidental, and police-involved shootings were excluded from this study. Computer aided dispatch calls for 911 service data were obtained from IMPD and used to measure firearm discharges “shots fired” police runs and social disorder. IMPD provided the date, location, and call type of each event. Resident calls for public service (e.g., 311 calls) were obtained from the Indianapolis Mayor’s Action Center (MAC) and abandoned home data were obtained from the City of Indianapolis open data portal (http://data.indy.gov). Other neighborhood-level measures of neighborhood
disadvantage, residential mobility, and ethnic composition were available from the U.S. Census Bureau.

Unit of Analysis and Geocoding

The unit of analysis is the 2010 census tract boundaries and is operationalized as the neighborhood. All data measures were geocoded, the process of assigning X and Y coordinates to individual addresses through ArcGIS (version 10.4.1). Records were automatically matched with a 90 percent minimum candidate and match score. Unknown addresses and addresses where an exact location could not be determined (e.g., 3567 Harding – unknown if Drive, Court, or Street) were dropped from the analysis. Of the 1,593 fatal and nonfatal shooting incidents, 1,529 were successfully geocoded with a 95 percent match rate. There were three fatal shooting incidents and 61 nonfatal shooting incidents with unknown or undetermined locations. These unknown nonfatal shooting incident locations most often indicate the victim was unwilling to give a location of the shooting, likely due to lack of cooperation with police or were unable to give a specific location due to injury severity (Board, 2016; Hipple et al., 2019). Geocoded records were spatially joined, and the number of fatal and nonfatal shooting incidents were aggregated to the corresponding census tract.

Outcome Measures: To understand the variation in mortality of gunshot wounds across census tracts, the fatal and nonfatal shooting rate was calculated as the number of fatal or nonfatal shootings over the total number of 911 “shots fired” runs. This proportion examines the likelihood of gunshot wound mortality on the reported number of firearm discharges.

Independent Measures
Neighborhood characteristics:

Following prior studies, *social disorder* is comprised of data on calls from IMPD 911 calls for service. The number of calls for narcotics, public intoxication, disturbances, and loud noise complaints were combined into an index measure (Boggess & Maskaly, 2014; Sherman & Weisburd, 1995; Weisburd & Green, 1995). *311 calls for city service* were drawn from the MAC, which is an office within the Mayor’s Office of Indianapolis and serves as a central repository where citizens submit requests for city services. The calls were requests made by residents regarding the public space surrounding their home and neighborhood and included calls for abandoned vehicles, high weeds or grass, debris and illegal dumping, and graffiti. The MAC (i.e., 311 calls) offers a unique data source of resident’s assessments of issues within their neighborhood (Magee, 2020; O’Brien et al., 2015). *Reported firearm discharge* was measured as the rate of “shots fired” calls. Two binary measures were included in each multivariate model to control for an emergency department and a firehouse being located within that census tract. Firehouses were included in the models as EMS units typically deploy from firehouses (Jacoby, Branas, et al., 2020).

Neighborhood-level measures were calculated as population rates per 100,000. Each measure was broken into quartiles, then categorized into a dichotomous variable, with the three lower quartiles indicating lower levels and the upper quartile indicating higher levels (Magee, 2020; Magee et al., 2020; Steelesmith et al., 2019). The number of abandoned homes was divided into quartiles, then categorized as a binary measure, with the three lower quartiles indicating lower levels and the upper quartile indicating higher levels.

Neighborhood Social disorganization Measures:

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Neighborhood Disadvantage: Neighborhood disadvantage is a composite index measure (Corsaro & McGarrell; Sampson et al., 1997) created using principal components analysis on three socioeconomic measures from the U.S. Census Bureau; percent unemployed, percent living in poverty, and percent female-headed household. The standardized communality loadings in the principal component were similar across all three census measures (e.g., >0.59) and explains 75 percent of the co-variance in these three measures with an alpha value of 0.80. Higher values indicate higher levels of neighborhood disadvantage.

Residential mobility is a composite index variable created using three U.S. Census Bureau measures; percentage of owner-occupied residents, the percentages of individuals that have lived in the same house for the last year, and the percentage who have moved in the last year. Principal components analysis was conducted, and each measure loaded on the same factor with loadings greater than 0.75 and alpha value of 0.80. Higher values indicate higher levels of residential mobility.

Ethnic heterogeneity is a composite index measure of two U.S. Census Bureau measures; the percentage of Hispanic residents and the percentage of individuals who are foreign born. Both measures loaded on the same factor during principal components analysis with scores greater than 0.70 and an alpha value of 0.82. Higher values indicate higher levels of ethnic heterogeneity. Lastly, the percentage of Black residents was obtained from the U.S. Census Bureau to account for the racial composition of each census tract.

Analysis

Descriptive statistics for neighborhood social processes and fatal and nonfatal shooting rates are calculated for each census tract. The population rate per 100,000 population was calculated as:

the number of fatal or nonfatal shooting incidents over the total population within a census tract. To display the variation between fatal and nonfatal shootings across census tracts the rate ratio was calculated by taking the fatal firearm shooting rate divided by the nonfatal shooting rate. To assess the bivariate relationship between neighborhood measures a Pearson’s correlation was conducted for continuous variables. Next, the rate of gunshot wound mortality compared to reported firearm discharges were broken into quintiles, then divided into three mutually exclusive categories by census tract: (1) with a higher likelihood of fatal shootings, (2) with a higher likelihood of nonfatal shootings, (3) overlapped with likelihood of experiencing both fatal and nonfatal shootings. This was done to examine the likelihood of experiencing a fatal or nonfatal shooting compared to the number of firearm discharges within census tracts and describe neighborhood social processes for each of the groups.

To assess how neighborhood social processes are associated with fatal and nonfatal shootings two multivariate models were conducted. A zero-inflated negative binomial regression model was run on the fatal shooting rate since nearly half of census tracts reported zero fatal shootings. The total population was used to estimate the excess zeros in the model (Karmakar et al., 2021; Knittel et al., 2019). A negative binomial regression was used to model nonfatal shooting outcomes due to the skewness and overdispersion in the nonfatal shooting rate (Kivisto et al., 2019; Magee, Fortenberry, et al., 2021). Fatal and nonfatal shooting rates were modeled as a function of community social process across each model and the incident rate ratios (IRR) were estimated for each community measure. Lastly, to assess the model fit a Bayesian information criterion (BIC) was conducted (Schwarz, 1978).

**Results**

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### Descriptive Statistics

There were 364 fatal shootings and 1,165 nonfatal shootings, for a total of 1,529 shooting incidents between 2014 and 2016. The average rate of reported firearm discharges across census tracts is 3023.3 per 100,000 population (Table 1). Nonfatal shootings were more prevalent than fatal shootings; with a nonfatal shooting rate nearly three times that of a fatal rate (192.5 v 58.7 per 100,000 population, respectively). At the census tract level, 111 (52%) and 174 (82%) census tracts reported fatal and nonfatal shootings, with an average of 1.68 fatal shootings and 5.48 nonfatal shootings per census tract. Fatal/nonfatal rate ratios by census tracts showed 89 census tracts have a greater risk for nonfatal shootings (mean of; 10.5 nonfatal shootings and 3.4 fatal shootings per census tracts) and nine census tracts had higher risk of fatal shootings (mean of; 3 fatal shootings and 1.9 nonfatal shootings). An additional nine census tracts had no difference in risk of fatal versus nonfatal shootings. These census tracts averaged 2 fatal and 2 nonfatal shooting incidents. Figure 1 displays the geographic patterns of gunshot wound mortality. Fatal shootings are more spatially concentrated within specific census tracts compared to nonfatal shootings which occur across most census tracts. Some overlap in higher rates of fatal and nonfatal shootings is observed within the center of the city, however patterns begin to diverge further out from the downtown center.

Bivariate correlations were conducted to test the relationships between neighborhood social processes to determine if there were any potential issues with multicollinearity. The results displayed in Table 2 demonstrate there was significant correlation between 311 calls (-0.58, p < 0.05), abandoned homes (0.49, p < 0.05), concentrated disadvantage (0.606, p < 0.05) and social disorder. As an additional test of multicollinearity, each of these measures was run through

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ordinary least squares (OLS) regression models. The collinearity diagnostics test did not indicate any problematically high levels of multicollinearity with variance inflation factors <= 3.01 for all measures (Fisher & Mason, 1981).

Social Processes and Top Quartiles of Gunshot Wound Mortality

The rate of gunshot wound mortality compared to reported firearm discharges was broken into quintiles, in the top quintiles (i.e., highest rates) of census tracts reporting fatal shootings, average rates of fatal shootings were higher than fatal shootings within the top quintile of census tracts reporting nonfatal shootings (133.5/100,000 population v. 58.4/100,000; p < 0.05).

Nonfatal shooting rates (413.6/100,000 v. 192.3/100,000; p < 0.05) and rates of firearm discharges were higher (3,902/100,000 v. 3,843.5/100,000; p > 0.05) in the top quintile of census tracts reporting nonfatal shootings, compared to the top quintile of fatal shootings (Table 3). Levels of concentrated disadvantage (3.49 v. 3.09; p < 0.05) and ethnic heterogeneity (3.21 v. 2.79; p < 0.05) were higher in the top quintile of census tracts reporting nonfatal shootings, compared to those reporting fatal shootings. There were 11 census tracts that overlapped as the highest quintiles for both fatal and nonfatal shootings with higher rates of both fatal (236.5/100,000; p < 0.05) and nonfatal shootings (644.3/100,000; p < 0.05), compared to the nonoverlapped highest quintiles of fatal and nonfatal shootings. These census tracts had higher mean rates of 311 calls for city services (18,978.4 vs. 10,683.9 and 14,151.0 per 100,000, p < 0.05 respectively), compared to top quintiles census tracts for fatal and nonfatal shootings (Table 2). In the overlapped census tracts, levels of residential mobility were higher (3.07 v. 2.51; p < 0.05) and levels of ethnic heterogeneity were lower (2.41 v. 3.21; p < 0.05) compared to top quintile census tracts for nonfatal shootings.

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Incident Rate Ratios

Two multivariate models were examined (Table 4): one examining the fatal shooting rate per number of firearm discharges by census tract (Model A) and one examining the nonfatal shooting rate by census tract (Model B). For Model A, census tracts with a larger number of abandoned homes (IRR: 1.34, 95% CI: 1.04, 1.70) was associated with increased mortality of firearm discharges, compared to census tracts with lower levels of abandoned homes. Census tracts with higher levels of concentrated disadvantage (IRR: 0.66, 95% CI: 0.57, 0.76), residential mobility (IRR: 0.84, 95% CI: 0.72, 0.88), and racial/ethnic heterogeneity (IRR: 0.80, 95% CI: 0.72, 0.88) was negatively correlated with higher firearm mortality. Social disorder, resident 311 calls for service, the percentage of Black residents, and an emergency department or firehouse within the census tract did not reach the level of statistical significance.

For Model B, census tracts with higher levels of 311 calls for city services (IRR: 1.42, 95% CI: 1.07, 1.87) was associated with higher proportions of nonfatal firearm injuries, compared to census tracts with fewer calls for service. Census tracts with higher levels of concentrated disadvantage (IRR: 1.26, 95% CI: 1.04, 1.52) and higher proportions of Black residents (IRR: 2.49, 95% CI: 1.63, 3.79) were associated with higher rates of nonfatal shootings, compared to census tracts with lower concentrated disadvantage and fewer residents identifying as Black. Social disorder, abandoned homes, residential mobility, ethnic heterogeneity, and an emergency department or firehouse within the census tract did not reach the level of statistical significance.

Discussion

This study utilized a public health approach to examine the epidemiology of fatal and nonfatal shootings and neighborhood differences in mortality rates using key elements of the Haddon’s Framework. This is the author’s manuscript of the article published in final edited form as:

matrix that are not well understood regarding gunshot wound mortality. Results indicate three important findings: 1) systematic differences in spatial patterns in gunshot wound mortality across census tracts, 2) diverse neighborhood social processes associated with gunshot wound mortality, and 3) the need for better data collection on nonfatal shootings and overall firearm discharges. A better understanding of disparities in gunshot wound mortality across neighborhoods most impacted by firearm violence can help determine tailored prevention efforts.

Results indicate specific census tracts are more likely to experience nonfatal shootings, others were more likely to experience fatal shootings, and only five percent of census tracts overlapped as the highest quintile of both fatal and nonfatal shootings. These findings support prior work which suggests some overlap between fatal and nonfatal hotspots, but fatal and nonfatal hotspots primarily have separate patterns (Hipple et al., 2020). Additionally, neighborhoods with higher rates of reported firearm discharges experienced more nonfatal shootings, compared to fatal shootings, and represent nearly 40 percent of all nonfatal shooting incidents within the city. These findings also demonstrate systematic differences in neighborhood social processes associated with gunshot wound mortality, but confirm decades of research indicating the importance of neighborhood social processes related with firearm violence (Magee, 2020; Sampson et al., 1997). Fatal shootings was positively associated with the number of abandoned homes in a census tract and negatively associated with concentrated disadvantage, residential mobility, and ethnic heterogeneity, whereas nonfatal shootings was positively associated with resident 311 calls for city services, a higher percentage of residents who identify as Black, and higher levels of concentrated disadvantage in proportion to total reported firearm discharges. These findings both confirm and extend prior research in several ways. First, fatal shootings

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occurring in census tracts with more abandoned homes may indicate fewer residents to call 911 and connect shooting victims to trauma care or a lack of necessary trauma resources, as police in Philadelphia were more likely to transport victims from neighborhoods with higher rates of abandoned homes (Jacoby, Branas, et al., 2020). Second, residents are more likely to be a nonfatal shooting victim in census tracts with higher concentrated disadvantage relative to the total number of firearm discharges than a fatal shooting victim. This finding is counterintuitive to prior research on homicides which suggests firearm violence is concentrated in disadvantaged communities, however aligns with more recent research that demonstrates fatal shooting hot spots were not occurring in the poorest communities compared to nonfatal hotspots (Sadler et al., 2021). These findings suggest residents in communities with higher concentrated disadvantage are more likely to suffer a nonfatal shooting which may be due to the intentionality and circumstance of the shooter. For example, a suspect in a domestic violence situation may have greater control over the weapon versus a suspect shooting from a moving vehicle during a drive-by (Beaman et al., 2000; Hipple & Magee, 2017), which would result in more nonfatal shootings. Incident motive or circumstance were not included in this study but is a clear direction for future research.

Third, findings indicate census tracts with higher rates of 311 calls and higher proportions of residents identifying as Black experience higher rates of nonfatal shootings but not fatal shootings. Three alternative and not mutually exclusive hypotheses may explain the linkages of census tract 311 calls and gunshot wound mortality: 1) resident engagement or collective efficacy, 2) physical disorder, or 3) overall neighborhood distress, as 311 calls have previously measured resident civic engagement, collective efficacy, neighborhood distress, and

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neighborhood physical disorder (Li et al., 2020; Magee, 2020; O’Brien & Sampson, 2015; Wheeler, 2018). For instance, 311 calls may indicate more civic engagement or collective efficacy within census tracts with higher rates of nonfatal shootings and therefore a greater likelihood of residents calling 911 to connect gunshot victims with the appropriate trauma care, therefore improving survival. This finding is consistent with Huebner and colleagues who found 311 calls were positively associated with residents calling 911 for gunfire (Huebner et al., 2020). In the context of the overall findings from this study, 311 calls are more likely to indicate physical disorder given the results also display higher levels of concentrated disadvantage and higher percentage of Black residents associated with nonfatal shootings. These findings are more consistent with prior research which suggest firearm violence occurs in economically disadvantaged, predominately Black communities, that are less likely to trust the police, or call the police for firearm discharges (Huebner et al., 2020; Kirk & Papachristos, 2011; Sampson & Bartusch, 1998) and other governmental agencies (e.g., such as 311) but extend these findings specifically to nonfatal shootings in proportion to total reported firearm discharges.

These findings further speak to the social processes of neighborhoods that have higher rates of nonfatal shootings and may experience higher levels of hopelessness among residents, overall neighborhood distress and more indiscriminate gun fire leading to less serious gunshot wound injuries. This notion confirms prior research that demonstrates higher 311 calls indicate neighborhood distress and residents within communities with higher levels of disorder often feel hopelessness as resources and city investments are not occurring within their neighborhood (Li et al., 2020; Mair et al., 2012). Many communities with higher rates of firearm violence today have experienced deep-rooted structural inequalities for decades and are many of the same

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communities that experienced historic red-lining practices and a lack of investment in neighborhoods (Jacoby et al., 2018), such as trauma centers (Hsia et al., 2011; Shen et al., 2009). Additionally, residents within high firearm violence communities often become desensitized to the high prevalence of gun fire as it often becomes normalized and routine in daily life and may impact the decision to call 911 (Gaylord-Harden et al., 2016). Although this study is unable to determine residents’ motivations for calling 311 or 911 in the context of gunshot wound mortality, residents are calling for services and this resident engagement, even in conjunction with higher levels of physical disorder, and neighborhood distress may be the difference between living and dying. Future research should further examine the relationship between 311 calls and gunshot wound mortality.

These findings highlight critical pre-incident, incident, and post-incident implications based on the Haddon’s matrix. Pre-incident improvement and investment in communities with higher rates of both fatal and nonfatal shootings may prevent and decrease future firearm violence. For instance, removing as many as five abandoned buildings within communities can reduce firearm violence by 11 percent (Jay et al., 2019). Similarly, other studies demonstrate community greening projects decrease community violence and specifically gun assaults (Branas et al., 2011; Pizarro et al., 2020). Beyond demolishing abandoned buildings, cities should utilize the 311 data to identify communities with the highest needs and prioritize investments in the physical and social conditions. As improving the physical condition may also improve the community involvement and limit the feeling of hopelessness that residents who live in high firearm violence communities often experience. Cities should also invest and implement acoustic gunfire detection systems (e.g., ShotSpotter) to quickly identify and locate where firearms are

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being discharged, therefore, facilitating a more rapid response by first responders. Such technology has improved data collection of firearm discharges (Huebner et al., 2020), improved response time to the incident scene (Carr & Doleac, 2016), and expediated the transport time of firearm assault victims to a trauma center, therefore increasing the likelihood of victim survival (Goldenberg et al., 2019). Transport of trauma victims from the scene to a trauma center by either police or EMS has improved mortality rates of gunshot wound victims and may improve gunshot wound mortality in census tracts more likely to experience fatal shootings (Band et al., 2014; M. W. Wandling et al., 2016).

In the Matrix’s incident or post-incident phase, implementing new policies that allow police to transport trauma victims to the hospital versus waiting for EMS to improve gunshot wound mortality. For instance, in Philadelphia, Pennsylvania police transport trauma victims to the hospital, through a ‘scoop and run’ policy and are more likely to transport gunshot victims in neighborhoods with more vacant housing and in neighborhoods with a higher proportion of Black residents, as previously noted (Jacoby, Branas, et al., 2020). Additional benefits of the Philadelphia program include opportunities for positive interactions between police and victims. As police can render medical attention and an officer providing aid to the victim negates the appearance that police are simply “waiting for EMS” and not helping the victim, as is often observed by bystanders (Jacoby, Branas, et al., 2020). Although such a program may not be possible in other cities due to different police policies and procedures (Jacoby, Reeping, et al., 2020) principals of the program could be integrated into everyday policing, such as police applying critical care while waiting for EMS. As an example, the San Antonio Police...
Department formed a tactical medic program that allows officers to provide prehospital medical care on trauma victims before EMS arrives (Smith et al., 2013).

As the first step in a public health approach and across all stages of the Haddon’s Matrix, there is a need for better data collection on nonfatal shootings and shots fired at both the local and federal level. Nonfatal shootings represent three-fourths of all firearm violence within Indianapolis but has largely been left out of our current understanding of community firearm violence due to a lack of reliable data. Police data on fatal shootings are often more reliable and the data collection process for nonfatal shootings has proven time consuming (Hipple et al., 2017). There is some evidence that integrated data between police, public health, and the healthcare systems is the best avenue to improve data on nonfatal shootings (Kaufman et al., 2019; Magee, Ranney, et al., 2021; Post et al., 2019), however more research is needed. Lastly, firearm violence impacts the health of the entire community (Jacoby et al., 2017; McDonald et al., 2011; Smith & Patton, 2016), as nonfatal shooting victims often return to the same neighborhoods which suffer from poverty due to a lack of economic development and available jobs (Irvin-Erickson et al., 2016), lack access to health care services, and where retaliation is often likely (Huebner et al., 2016). Future research should examine and address the long-term health implications of nonfatal shooting victims and the broader impact on the community, as this study and prior research suggests fatal and nonfatal firearm shootings and associated social processes are distinct.

Limitations

There are several limitations that should be considered. First, this is an ecological study and differences at an individual level cannot be evaluated, however, ecological studies allow

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researchers to examine which neighborhoods are most at risk (Zeoli et al., 2019). Second, this study examined one large metropolitan jurisdiction with high rates of firearm violence; however, results may not be generalizable to other cities. Third, a number of measures are operationalized using police data which are known to be problematic from a reporting standpoint and biased from a community standpoint, as not all communities call the police at similar rates (Black, 1970; Kirk & Papachristos, 2011), however, this study utilized a unique dataset on fatal and nonfatal shooting incidents that is not available in all cities. These results are also limited by resident’s ability and willingness to call the Mayor’s Action Center and 911 dispatch, though, prior research suggests residents do utilize cities 311 data systems (O'Brien & Sampson, 2015). Fourth, prior research has indicated differences in fatal and nonfatal shooting mortality on victim age, injury severity, victim cooperation, shooting motive, and weapon caliber (Braga & Cook, 2018; Grommon & Rydberg, 2014; Hipple & Magee, 2017), which are potential confounders that were not accounted for in this study due to unavailability of the data during this study time. This limitation again speaks to the need for better data collection on nonfatal shootings, as well as standardized data collection across cities (Wardell, 2020). Future research should examine individual and neighborhood-level social processes in a multilevel model framework to account for all confounders. Furthermore, the presence of a trauma center or firehouse within a census tract was not statistically significant in gunshot wound lethality, however, future studies should measure more precise distances to trauma centers, as well as EMS response times. Lastly, physical disorder was only measured through levels of abandoned homes. Future research should examine more precise measures of the built environmental to further explore differences in fatal and nonfatal shootings as well as associated spatial risk factors. For instance, risk terrain modeling (RTM), which is used to predict future events at the micro level. Research utilizing This is the author’s manuscript of the article published in final edited form as:

RTM has demonstrated micro areas that include both blighted properties and convenience stores are associated with homicides (Valasik et al., 2019).

**Conclusion**

This study utilized a public health approach to examine the epidemiology of fatal and nonfatal shootings and neighborhood differences in mortality rates through the Haddon’s matrix framework. Results demonstrate the importance of the neighborhood social environment regarding gunshot wound mortality. These findings have important implications of placed based initiatives, such as police transport of gunshot wound victims and police-public health partnerships to improve data collection on nonfatal shootings, shots fired incidents, and mortality rates of shooting incidents. It is imperative to understand when and where both fatal and nonfatal shootings are occurring to enhance police and trauma response, as well as improve neighborhood physical and social conditions to decrease gunshot wound mortality rates and increase the overall health of the community.
References


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Table 1 – Descriptive statistics of fatal and nonfatal shooting incidents by census tracts, Indianapolis, Indiana, 2014 – 2016

<table>
<thead>
<tr>
<th>Measures</th>
<th>All Census Tracts (n=212)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal firearm shootings (mean, IQR)</td>
<td>1.68 (0, 1, 3)</td>
</tr>
<tr>
<td>Nonfatal firearm shootings (mean, IQR)</td>
<td>5.48 (1, 3, 7.5)</td>
</tr>
<tr>
<td>Shots Fired calls (mean, IQR)</td>
<td>93.4 (32, 74, 141)</td>
</tr>
<tr>
<td>Fatal shooting rate per 100,000 population</td>
<td>58.7 (0, 16.9, 70.2)</td>
</tr>
<tr>
<td>Nonfatal shooting rate per 100,000 population</td>
<td>192.5 (27.9, 84.3, 239.8)</td>
</tr>
<tr>
<td>Shots fired call rate per 100,000 population</td>
<td>3023.3 (765.0, 1943.4, 4073.8)</td>
</tr>
<tr>
<td>Fatal shooting rate per 100,000 shots fired calls</td>
<td>1380.1 (0, 741.1, 2476.8)</td>
</tr>
<tr>
<td>Nonfatal shooting rate per 100,000 shots fired calls</td>
<td>4872.5 (2552.8, 4545.5, 7184.5)</td>
</tr>
</tbody>
</table>

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Table 2 – Neighborhood Measures Descriptive Statistics and Bivariate Correlations

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calls for social disorder</td>
<td>1036.7</td>
<td>697.2</td>
<td></td>
<td></td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>311 calls</td>
<td>278.1</td>
<td>234.4</td>
<td>-0.584</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abandoned homes</td>
<td>15.3</td>
<td>23.3</td>
<td>0.491</td>
<td>-0.680</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentrated disadvantage</td>
<td>3.03</td>
<td>1.01</td>
<td>0.606</td>
<td>-0.551</td>
<td>0.618</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential mobility</td>
<td>2.96</td>
<td>0.98</td>
<td>-0.299</td>
<td>0.104</td>
<td>-0.142</td>
<td>-0.481</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnic heterogeneity</td>
<td>3.01</td>
<td>0.99</td>
<td>0.231</td>
<td>0.078</td>
<td>-0.105</td>
<td>0.212</td>
<td>-0.316</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Percent Black residents</td>
<td>0.31</td>
<td>0.26</td>
<td>0.226</td>
<td>-0.264</td>
<td>0.449</td>
<td>0.533</td>
<td>-0.292</td>
<td>-0.055</td>
<td>1.00</td>
</tr>
</tbody>
</table>

All Census Tracts (n=212) | Bolded values indicate p < 0.05
Table 3 – Descriptive statistics of Neighborhood-Level Social Processes by top quintile census tract of gunshot wound mortality, Indianapolis, Indiana, 2014-2016

<table>
<thead>
<tr>
<th>Measures</th>
<th>Higher Likelihood of Fatal Shooting Mean (IQR)</th>
<th>Higher Likelihood of Nonfatal Firearm Shooting Mean (IQR)</th>
<th>Highest risk for Fatal and Nonfatal Shooting Mean (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrated disadvantage</td>
<td>3.09 (2.42, 2.92, 3.98)</td>
<td>3.49 (2.73, 3.51, 4.12)</td>
<td>3.52 (3.14, 3.63, 4.63)</td>
</tr>
<tr>
<td>Residential mobility</td>
<td>2.74 (1.85, 2.87, 3.36)</td>
<td>2.51 (2.05, 2.55, 3.21)</td>
<td>3.07 (2.59, 3.22, 3.71)</td>
</tr>
<tr>
<td>Ethnic heterogeneity</td>
<td>2.79 (2.18, 2.64, 3.10)</td>
<td>3.21 (2.29, 3.04, 3.91)</td>
<td>2.41 (1.93, 2.14, 2.96)</td>
</tr>
<tr>
<td>% Black individuals</td>
<td>0.42 (0.22, 0.37, 0.64)</td>
<td>0.39 (0.19, 0.36, 0.59)</td>
<td>0.58 (0.12, 0.74, 0.91)</td>
</tr>
<tr>
<td>Reported firearm discharges per 100,000 population</td>
<td>3843.5 (1029.6, 2630.7, 5781.2)</td>
<td>3902.0 (1042.9, 2883.5, 5643.7)</td>
<td>5795.4 (1342.4, 5414.6, 9937.5)</td>
</tr>
<tr>
<td>Social disorder call rate per 100,000 population</td>
<td>36038.9 (12087.4, 31448.4, 54688.2)</td>
<td>39008.4 (19277.7, 26029.9, 58233.0)</td>
<td>45159.4 (27767.6, 33055.5, 67685.9)</td>
</tr>
<tr>
<td>311 call rates per 100,000 population</td>
<td>10683.9 (1362.8, 7520.2, 17419.7)</td>
<td>14151.0 (4031.8, 6967.0, 25991.5)</td>
<td>18978.4 (10630.2, 16732.7, 28584.4)</td>
</tr>
<tr>
<td>Abandoned Homes</td>
<td>21.0 (1, 5, 35)</td>
<td>22.8 (2, 6, 36)</td>
<td>35.3 (3, 39, 62)</td>
</tr>
<tr>
<td>Rate ratio</td>
<td>0.89 (0.53, 0.76, 1.00)</td>
<td>0.09 (0, 0.08, 0.17)</td>
<td>0.38 (0.33, 0.33, 0.42)</td>
</tr>
<tr>
<td>Fatal shooting rate per 100,000 population</td>
<td>133.5 (42.8, 91.9, 195.3)</td>
<td>58.4 (0.00, 30.9, 76.7)</td>
<td>236.5 (36.7, 214.8, 455.2)</td>
</tr>
<tr>
<td>Nonfatal shooting rate per 100,000 population</td>
<td>192.3 (3.8, 133.1, 348.7)</td>
<td>413.6 (83.4, 259.7, 589.2)</td>
<td>644.3 (110.3, 515.7, 1181.4)</td>
</tr>
</tbody>
</table>

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Table 4 – Incident rate ratios of Fatal and Nonfatal Shooting Incidents by Neighborhood Social Processes, Indianapolis, Indiana, 2014 – 2016*

<table>
<thead>
<tr>
<th>Measures</th>
<th>Model A</th>
<th>Model B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal Firearm Injury/Shots Fired</td>
<td>Nonfatal Firearm Injury/Shots Fired</td>
</tr>
<tr>
<td></td>
<td>IRR (95% CI)</td>
<td>IRR (95% CI)</td>
</tr>
<tr>
<td>Calls for social disorder</td>
<td>0.98 (0.81, 1.20)</td>
<td>0.92 (0.76, 1.13)</td>
</tr>
<tr>
<td>311 calls</td>
<td>0.99 (0.81, 1.22)</td>
<td>1.42 (1.07, 1.87)</td>
</tr>
<tr>
<td>Abandoned homes</td>
<td><strong>1.34 (1.04, 1.70)</strong></td>
<td>0.85 (0.64, 1.12)</td>
</tr>
<tr>
<td>Concentrated disadvantage</td>
<td><strong>0.66 (0.57, 0.76)</strong></td>
<td><strong>1.26 (1.04, 1.52)</strong></td>
</tr>
<tr>
<td>Residential mobility</td>
<td><strong>0.84 (0.72, 0.88)</strong></td>
<td>0.91 (0.78, 1.06)</td>
</tr>
<tr>
<td>Ethnic heterogeneity</td>
<td><strong>0.80 (0.72, 0.88)</strong></td>
<td>1.02 (0.93, 1.11)</td>
</tr>
<tr>
<td>% Black residents</td>
<td>1.33 (0.83, 2.12)</td>
<td><strong>2.49 (1.63, 3.79)</strong></td>
</tr>
<tr>
<td>Emergency Department</td>
<td>0.82 (0.48, 1.41)</td>
<td>1.24 (0.68, 2.24)</td>
</tr>
<tr>
<td>Fire Houses</td>
<td>0.92 (0.75, 1.14)</td>
<td>1.26 (0.97, 1.63)</td>
</tr>
<tr>
<td>AIC</td>
<td>2204.7</td>
<td>3841.6</td>
</tr>
<tr>
<td>BIC</td>
<td>2248.3</td>
<td>3878.5</td>
</tr>
</tbody>
</table>

| IRR – Incident rate ratios | Bolded values indicate p <0.05 | AIC = Akaike information criterion; BIC = Bayesian information criterion. |

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Figure 1 – Fatal and Nonfatal Firearm Gunshot Wound Mortality*, Indianapolis, Indiana, 2014 – 2016

*Mortality was calculated by the # fatal & nonfatal shooting incidents/# reported firearm discharges

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