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Geospatial Analysis Of Violent Crime And Premature Mortality From Chd

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Geospatial analysis of violent crime and premature mortality from CHD

A thesis submitted by
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Abstract

Background: Cardiovascular disease (CVD) is the leading cause of death in the United States and many of these deaths are preventable. Studies have shown that neighborhood-level characteristics may contribute to health outcomes, but no study has yet examined whether neighborhood crime contributes to early mortality from CVD.

Objective: We examined geographic trends in the association between neighborhood crime rates and premature mortality from coronary heart disease (CHD) using New Haven, CT USA as a model city.

Methods: Neighborhoods in New Haven were established by existing census tracts. CHD deaths were identified from the Connecticut Master Death Files and violent crime rates were calculated from the FBI Uniform Crime Reports. We conducted a global ordinary least squares (OLS) analysis and a geographically weighted regression (GWR) analysis to model average years of potential life lost (YPLL) by census tract.

Results: Out of 687 CHD deaths in the city of New Haven from 2005-2010, 319, or 46.4%, are considered premature. The OLS model accounted for 30.8% and the GWR model accounted for 48.6% of the variability in premature deaths from CHD. An increase of 10 violent crimes per 1,000 residents was associated with an average of 2.3 additional years of life lost (p=0.043), while holding other neighborhood factors constant. Moreover, the GWR model predicted a 7-fold disparity in premature CHD mortality across census tracts, ranging from 1.73 YPLL to 12.38 YPLL.

Conclusion: Our findings suggest that neighborhood violent crime rates may contribute to premature death from CHD. Modeling based on geographic variation is a powerful tool to enhance resolution of previously unidentified environmental factors contributing to preventable death from cardiovascular disease.

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Introduction

Heart disease is the leading cause of death in the United States (based on 2011 data), and increasing cardiovascular health is a focus area of the Healthy People 2020 (HP2020) initiatives [1]. In addition, over 200,000 deaths from heart disease and stroke are considered to be preventable, and 60% of these deaths are occurring in people less than 65 years old [2]. Although the number of preventable deaths have been declining in those between the ages of 65-74, this same progress has not been seen for deaths that are occurring more prematurely [2]. The absolute number of preventable deaths and absence of impact on those less than 65 years old suggests that an unidentified or inadequately addressed factor is contributing to this issue.

It has been recognized that there are important geographic disparities in health outcomes, and research has shown that neighborhood-level factors are associated with these outcomes independent of individual-level factors [3-6]. Studies have found associations between neighborhood-level characteristics, like poverty, segregation, residential instability, and unemployment, and many chronic diseases including cardiovascular disease [7-9], obesity [5, 10], diabetes [11], and cancer [12]. Exposure to neighborhood violence may impact health through biological mechanisms from a chronic stress response[13] or through modifications to health behaviors [14]. Studies that have looked specifically at neighborhood violence and heart disease provide evidence that more violent neighborhoods have a greater burden of coronary heart disease (CHD) [13, 15, 16], but to our knowledge no study has examined this association with the focus on premature mortality from CHD.

The city of New Haven, Connecticut USA is a highly diverse city that exhibits the geographic trends of poverty, segregation, and residential instability in health outcomes. Through a Community Health Needs Assessment, it was observed that mortality from CHD was much lower in high income neighborhoods, while the difference between middle and low income neighborhoods was not as substantial. However, differences between middle and low income neighborhoods were observed when comparing overall rates of premature deaths [17]. Violence is another major concern for New Haven, with certain areas of the city having violent crime rates that are ten times higher than the statewide average [17]. This city can therefore serve as a model for examining geographic associations between these two variables.

The purpose of this study was to model the extent to which the geography of violent crime is associated with premature death from CHD in New Haven. The first objective was to map violent crime rates and premature CHD mortality by census tracts to get a finer visual picture of the data. The second objective was to determine whether exposure to neighborhood violence has an impact on cardiovascular disease health, resulting in younger ages at death, independent of other neighborhood-level variables. Examining this association with the focus on premature death may provide further insights on how to reduce preventable deaths that are occurring in younger populations.

Methods

Study Site

The study was conducted in the city of New Haven, Connecticut. Based on the 2010 US Census, New Haven has a total population of 129,779 residents. For the purposes of this study, the 31 existing census tracts were used to represent neighborhoods within New Haven. The average violent crime rate from 2005-2012 was 14.9±1.4 crimes per 1,000 residents. 80.5% of the population had graduated from high school, and 31.4% held a bachelor's degree or higher. The median household income was $38,963 and 19.6% of families lived below the poverty line. 31.8% of the population was non-Hispanic white, 33.4% was non-Hispanic black, 27.4% was Hispanic, and 7.4% was another race/ethnicity. Substantial variation was observed for all variables between the different neighborhoods.

From the Community Health Needs Assessment, the age-adjusted mortality rate (AAMR) from CHD was 115 deaths per 100,000 residents for the total city [17]. For high, middle, and low income neighborhoods, the AAMRs were 70, 118, and 104 deaths per 100,000 residents respectively. The prevalence of heart disease/heart attack in high, middle, and low income neighborhoods was 2.2%, 12.0% and 8.9% respectively.

Data

Independent variables: Our exposure of interest was measured as a yearly violent crime rate per 1,000 residents. Violent crimes are defined as aggravated assault, murder, forcible rape, and robbery (Appendix I). Data for violent crimes came from the Uniform Crime Reports for 2005-2012, and the numbers of crimes committed were

aggregated by census tract. A yearly violent crime rate was found using the 2010 Census population size in each tract. Data for the social and economic covariates came from the American Community Survey (ACS) for 2006-2010.

Dependent variable: The extent of premature mortality from CHD was measured by assessing years of potential life lost (YPLL). Death data were obtained from the Connecticut Master Death files for 2005-2010. We identified CHD deaths using the ICD-10 codes of I11 and I20-I25. Through this method, 711 deaths were identified, and 687 were geocoded to census tracts within New Haven (exclusions: 9 lacked house numbers, 1 unable to find a match, and 14 not located within New Haven). We calculated YPLL by subtracting the age at death from gender-specific 2010 life expectancies for the US population (80.57yrs for women and 75.6yrs for men) [18]. Average YPLL were then calculated for each census tract.

Statistical Analyses

We first conducted global ordinary least squares (OLS) analyses to determine the optimal model to be used in the geographically weighted regression (GWR) analysis. OLS regression models with different combinations of variables were compared using adjusted R^2 values and the Akaike information criterion (AIC). Variance Inflation Factors (VIFs) were examined to ensure that multicollinearity would not be an issue when proceeding to the GWR analysis. The multivariate model included the covariates: percent whose income in the past 12 months is below the poverty level, percent vacant housing units, and percent non-Hispanic white. The Koenker statistic was examined to assess whether the relationship between exposure and outcome being modeled was consistent across the study area.

The model identified in the OLS regression analysis was used in the GWR analysis. Spatial weights were included for the calibration of the model based on the number of CHD deaths in each census tract so that more reliable mortality data had greater influence in the model. In order to account for variation in census tract sizes, an adaptive Gaussian kernel was specified, and the bandwidths were determined by minimizing the AIC [19].

For GWR analyses it is desirable to include as few covariates as possible into the model due to issues of multicollinearity [9, 20]. For this reason, we divided potential covariates into three categories, with one variable from each category included in the final models. The covariates that were considered were divided into the following groups: socioeconomic disadvantage (percent with a bachelor's degree or higher, percent unemployed, and percent whose

income in the past 12 months is below the poverty level), residential instability (percent in the same residence one year ago, percent vacant housing units, and percent owner-occupied housing), and race/ethnic composition (percent non-Hispanic white, percent non-Hispanic black, and percent Hispanic).

Ad Hoc Analyses

We assessed potential effect modification by examining interaction terms between the different model covariates to be included in the OLS model.

All analyses were conducted using SAS 9.2 and ArcGIS 10.2. Maps were constructed in ArcGIS 10.2.

Results

There were a total of 15,424 violent crimes committed within the city of New Haven from 2005-2012. The majority of violent crimes were aggravated assault (49.8%), followed by robbery (45.9%). Only 1.0% of violent crimes committed were murder and 3.3% were forcible rape. There were an average of 960.8 (±102.4) aggravated assaults, 884.9 (±87.7) robberies, 19.1 (±6.9) murders, and 63.3 (±16.7) forcible rapes committed each year.

Out of 687 CHD deaths in the city of New Haven from 2005-2010, 319, or 46.4%, are considered premature (occurring before the 2010 US gender-specific adjustments for life expectancy). 54.9% of these premature deaths occurred at ages less than 65 and 45.1% occurred at ages 65 and above. There were significant differences in the proportion of premature deaths between gender (χ^2=18.1, p<.0001) and race/ethnic groups (χ^2=93.6, p<.0001). A total of 38.0% of CHD deaths among women and 54.2% of CHD deaths among men occurred prematurely during this time period. For CHD deaths stratified by each race/ethnic group, 31.1% occurred prematurely among non-Hispanic white residents, 67.8% among non-Hispanic black residents, 72.3% among Hispanic residents, and 62.5% among residents of other race/ethnicities.

Table 1 presents the descriptive statistics for the 31 census tracts that were used to divide the city of New Haven into neighborhoods. These descriptive statistics present the variables that were included in the final models and provide the variability in these neighborhood-level characteristics. Table 2 provides the Spearman's rank correlation coefficients to show the univariate correlations between the neighborhood-level variables and the outcome of premature death as

expressed by YPLL. Violent crime rates, socioeconomic disadvantage, and residential instability were positively correlated with YPLL, while race/ethnic composition was negatively correlated with YPLL. Increases in violent crimes rates, percent living in poverty, and percent vacant housing units were associated with increases in premature CHD mortality. An increase in the percent of non-Hispanic white residents in a neighborhood was associated with a decrease in premature CHD mortality.

Table 2 Neighborhood-level variables in New Haven census tracts

Tract	AAMR[a]	Percent Premature[b]	Average YPLL[c]	Violent Crime[d]	Socioeconomic Disadvantage[e]	Residential Instability[f]	Race/ethnic Composition[g]
1401	624.9	85.7	14.1	32.0	15.1	19.6	46.9
1402	834.3	16.1	1.4	29.8	77.1	5.8	15.0
1403	679.8	72.7	18.6	26.7	39.1	20.2	12.7
1404	304.7	57.1	13.6	17.7	33.5	10.5	18.0
1405	937.9	70.6	10.8	22.3	27.4	16.3	7.2
1406	927.7	39.5	6.0	20.2	36.8	24.6	8.5
1407	3416.5	45.0	6.3	24.5	31.6	4.9	27.4
1408	645.8	34.5	7.0	21.7	19.7	17.7	6.4
1409	688.9	73.7	15.0	22.5	14.1	12.1	17.9
1410	410.8	37.5	7.3	2.9	1.2	7.9	68.4
1411	630.8	37.5	5.2	1.4	2.7	7.8	57.8
1412	744.1	50.0	8.3	14.2	16.9	12.3	23.7
1413	472.3	47.6	10.3	9.4	33.9	15.0	37.3
1414	554.6	55.6	5.4	12.2	13.5	7.0	25.5
1415	608.2	74.3	12.1	25.3	19.5	19.8	5.1
1416	634.5	71.4	11.2	23.7	25.0	19.9	9.5
1418	464.2	40.0	9.5	7.7	12.1	11.5	43.0
1419	290.7	50.0	4.5	4.5	0.2	4.0	77.6
1420	492.5	40.0	4.8	5.3	2.2	12.5	61.2
1421	559.8	80.0	17.9	22.6	26.5	24.6	25.4
1422	703.8	54.5	5.3	27.3	11.5	10.6	88.8
1423	744.8	29.2	4.5	19.6	26.6	9.8	13.7
1424	550.2	57.1	6.4	23.8	37.2	24.8	8.9
1425	580.8	44.0	7.1	15.2	26.5	10.1	19.0
1426.01	389.6	64.7	11.2	10.8	17.0	10.2	17.8
1426.03	1038.8	35.6	4.2	7.8	15.3	12.4	45.9
1426.04	1013.8	42.9	4.5	4.5	19.3	7.7	28.1
1427	550.7	48.0	7.3	8.9	16.0	16.4	35.3
1428	415.9	30.3	4.3	1.9	3.1	10.2	83.8
3614.01	551.4	40.0	7.5	9.2	14.6	10.1	58.9
3614.02	1550.9	0.0	0.0	6.0	0.0	33.3	59.8

[a]AAMR- age-adjusted mortality rates calculated using direct standardization and the US 2010 reference population
[b]Percent premature- percent of deaths occurring at ages younger than the gender-specific US 2010 life expectancies
[c]YPLL- average years of potential life lost to gender-specific US 2010 life expectancies
[d]Violent crime- violent crime rates per 1,000 residents
[e]Socioeconomic disadvantage- percent whose income in the past 12 months is below the poverty line
[f]Residential instability- percent vacant housing units
[g]Race/ethnic composition- percent non-Hispanic white

Table 2 Descriptive statistics for outcome and exposure variables and correlation coefficients

Variable[a]	Mean	Min	Max	SD	ρ[b]
YPLL	8.1	0	18.6	4.5	-
Violent crime	15.5	1.4	32.0	9.2	0.44*
Socioeconomic disadvantage	20.5	0	77.1	15.6	0.31
Residential instability	13.9	4.0	33.3	6.9	0.39*
Race/ethnic composition	34.0	5.1	88.8	24.7	-0.40*

[a]**F** or definitions refer to footnote a of Table 1.
[b]Spearman's rank correlation coefficient comparing dependence between variable and YPLL.
*Significant at the $p < 0.05$ level (two-tailed)

Figure 1a displays a choropleth map of violent crime rates divided into quintiles. The data range from census tracts with a yearly average of less than 6.01 crimes committed per 1,000 residents to census tracts with a yearly average of greater than 23.8 crimes committed per 1,000 residents. At the extremes, the city ranges from a census tract with 1.44 violent crimes per 1,000 residents to a census tract with 32 violent crimes per 1,000 residents, over a 22-fold increase. Violent crime rates appear highest within the central region of the city and are lower along the eastern and western borders.

Figure 1b displays a choropleth map of premature CHD mortality, expressed as average YPLL, divided into quintiles. The data range from census tracts with less than an average of 4.55 YPLL to census tracts with greater than an average of 11.25 YPLL. At the extremes, the city ranges from a census tract with no premature CHD deaths to a census tract with an average of 18.6 YPLL. This map identifies census tracts with the greatest burden of premature CHD mortality. Based on this mapping, the western region of the city is identified as experiencing greater premature mortality than the eastern region, with a possible cluster of high YPLL running down census tracts in the center of the city. When viewed together, overlap between areas with high premature mortality and high violent crime are evident, providing rational for continuing into a regression analysis to examine the association between these variables while controlling for other covariates.

Figure 1 Choropleth maps of violent crime rates (a) and premature CHD mortality (b) by census tract in New Haven, CT.
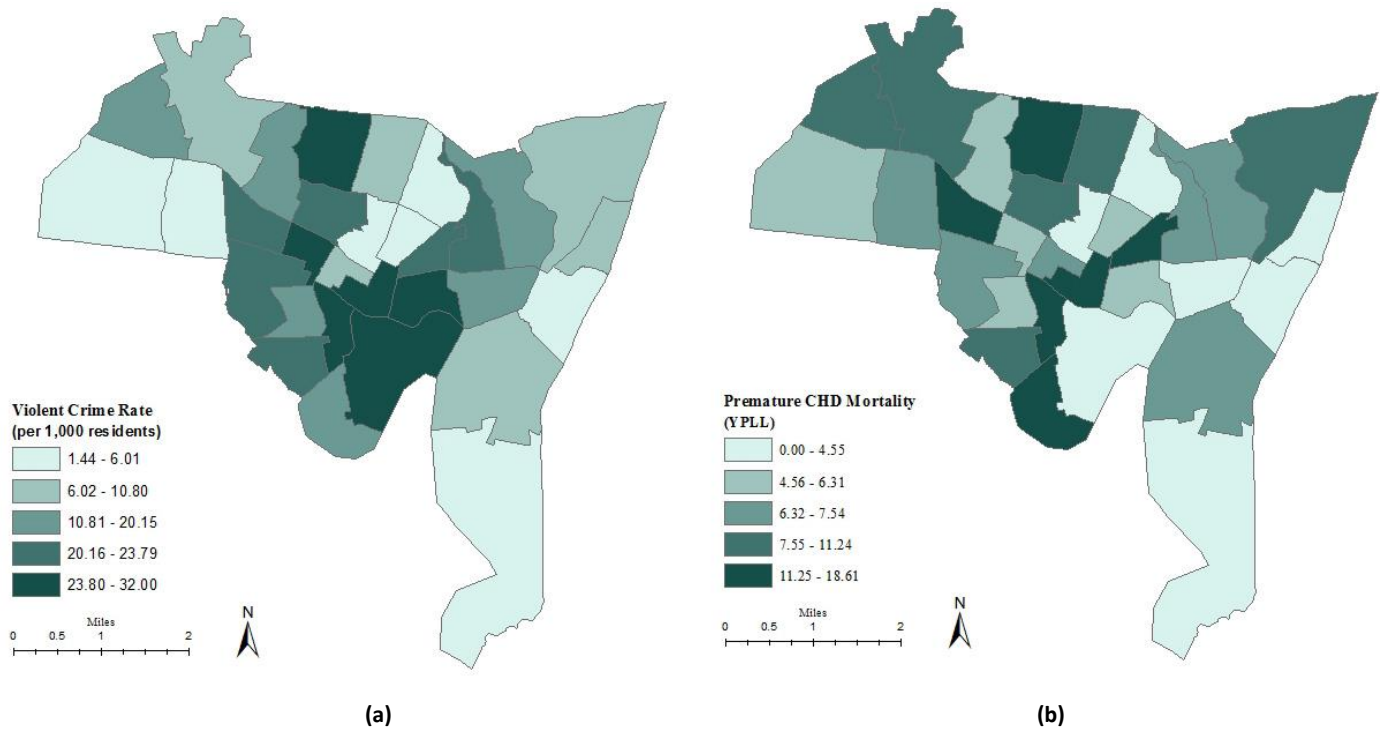

(a)

(b)

Table 3 shows the results from the global OLS regression model. This model accounted for 30.8% of the variation in premature CHD deaths. Violent crime was positively correlated with premature CHD mortality. An increase of 10 violent crimes per 1,000 residents was associated with an increase of 2.3 YPLL (p=0.043) when controlling for the effects of socioeconomic disadvantage, residential instability, and race/ethnic composition.

The socioeconomic disadvantage and race/ethnic composition indicators were negatively correlated with premature CHD mortality while residential instability was positively correlated with premature CHD mortality in the multivariate model. Increases in percent living in poverty and percent non-Hispanic white were associated with decreases YPLL, while the increases in percent vacant housing units were associated with increases in YPLL. The VIFs for the independent variables in the model were low, indicating that these predictors were not highly correlated or redundant measures of one another. The Koenker statistic (BP=10.4, p=0.035) indicated that the relationship modeled was not consistent across the study area, providing rationale for moving to a GWR analysis.

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Table 3 Global OLS Regression Analysis

| Variable[a]	Regression coefficient	*p value*	VIF
Violent Crime	0.23	0.043*	1.94
Socioeconomic Disadvantage	-11.82	0.109	2.32
Residential Instability	1.91	0.871	1.20
Race/ethnic composition	-6.92	0.106	1.96

[a]For definitions refer to footnote a of Table 1.
*Significant at the p<0.05 level (two-tailed)

The GWR model accounted for 48.6% of the variation in premature CHD deaths. Figure 2 displays the maps of GWR violent crime coefficients and significance levels. When we allow for geographic variation, we can see that the magnitude of the association between violent crime and premature CHD mortality varies throughout the study area, with the strongest association seen in the southern area of the city. In the northwest corner of the city, an increase of 10 violent crimes per 1,000 residents was associated with an increase of 1.73-1.93 YPLL, holding socioeconomic disadvantage, residential instability, and race/ethnic composition constant. In the southeast region, an increase of 10 violent crimes per 1,000 residents was associated with an increase of 2.40-2.51 YPLL, holding socioeconomic disadvantage, residential instability, and race/ethnic composition constant. Statistical significance was seen in areas where the magnitude of the association was higher (Figure 2b).

When the map that displays the GWR violent crime coefficients (Figure 2a) is compared to the map of violent crime rates (Figure 1a) it can be seen that there is some overlap between areas with the highest crime rates and areas with the strongest association between crime and CHD. This may suggest that there is some type of dose-response relationship or threshold effect where a certain level of crime is needed in order for it to have a significant impact on premature mortality.

Figure 2 Choropleth maps of violent crime rate parameter estimates (a) and significance levels (b) by census tract for the GWR of YPLL.

(a)   (b)
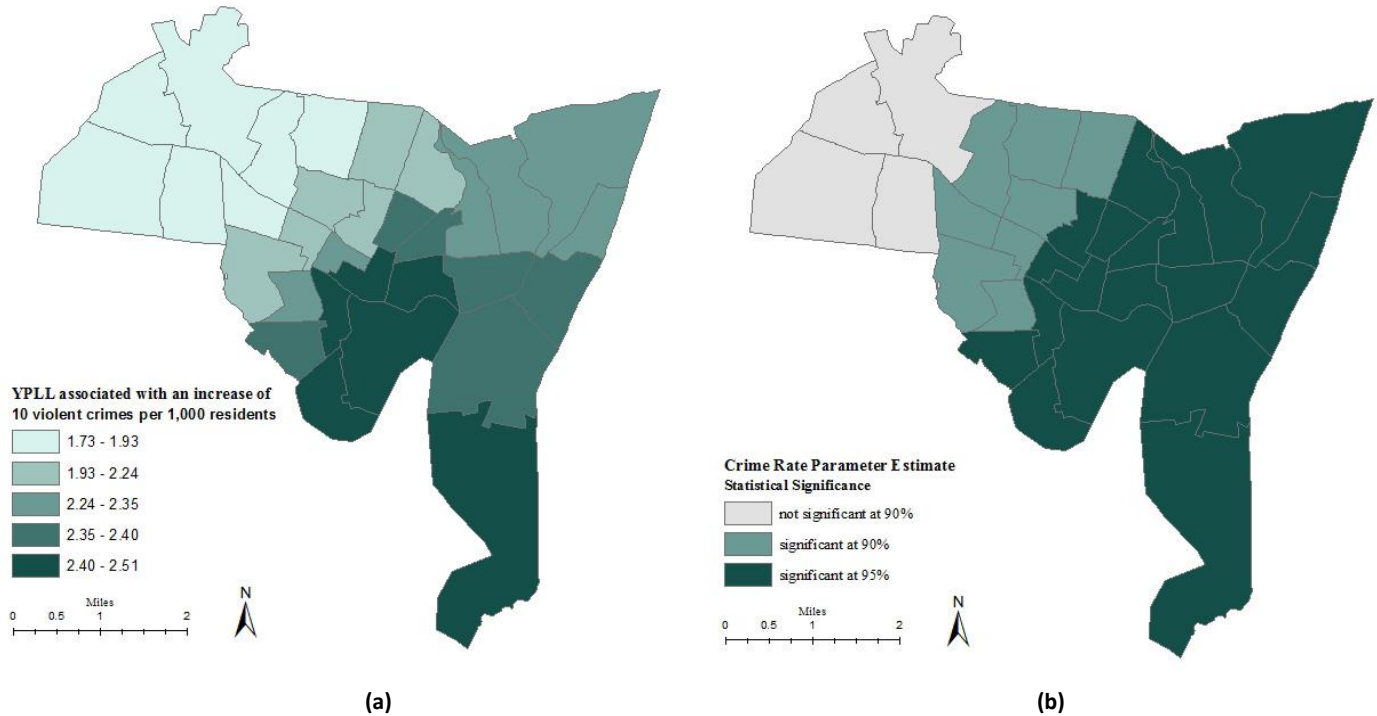
Ad hoc analyses

Table 4 displays the results of the OLS regression model for the *ad hoc* analysis. When examining the different interactions, we were looking for a term that would cause the regression coefficient for socioeconomic disadvantage to switch back to the positive direction as it had been in the univariate associations. This was observed for the interaction between violent crime and socioeconomic disadvantage. When this term was included in the model, violent crime had a more significant effect on premature CHD mortality. An increase of 10 crimes per 1,000 residents was associated with an increase of 3.4 YPLL (p=0.016). Race/ethnic composition remained negatively correlated with YPLL, but residential instability and socioeconomic disadvantage were positively correlated with YPLL when the interaction term was included. A GWR analysis was not able to be conducted using this model due to multicollinearity issues between the interaction term and the socioeconomic disadvantage indicator.

Although the interaction term between crime and socioeconomic disadvantage was not statistically significant (p=0.170), this model was important for accounting for the changes seen in the correlation between socioeconomic disadvantage and YPLL. This may also provide insights into the geographic trends seen in Figure 2. Effect modification by

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socioeconomic status could result in certain areas having a stronger association between crime and premature CHD mortality than other areas. The regions that display the stronger associations are some of the lower income neighborhoods in the city [17].

Table 4 OLS results from *ad hoc* analyses of testing for effect modification.

Variable[a]	Regression coefficient	*p value*	VIF
Violent Crime	0.34	0.016*	2.87
Socioeconomic Disadvantage	9.05	0.584	12.69
Residential Instability	2.13	0.854	1.21
Race/ethnic composition	-4.18	0.362	2.41
Crime*SES	-0.81	0.170	13.21

[a]For definitions refer to footnote a of Table 1. Crime*SES- interaction term between socioeconomic disadvantage indicator and violent crime rates.
*Significant at the p<0.05 level (two-tailed)

Figure 3 displays the map of predicted premature CHD mortality based on the GWR model for violent crime. The spatial relationships (as displayed in Figure 2) are applied to the known values of the independent variables to estimate YPLL for each census tract. For example, even though the southern-most neighborhood has one of the highest magnitudes of association between crime and YPLL, it has a low predicted premature CHD mortality because there is still a relatively low crime rate in this neighborhood. From this model we would expect the burden of premature mortality to be highest within the central region of the city. These census tracts are expected to have an average of 9.61-12.38 YPLL. In comparison, the southeast region of the city is predicted to have average YPLL ranging from 1.73 to 6.53. At the extremes, the disparity in premature CHD mortality is represented by a 7-fold increase comparing the census tract with 1.73 YPLL to the census tract with 12.38 YPLL. Notably, 39.5% of CHD deaths occurred in those less than 65 years old in the predicted highest risk regions in Figure 3, versus 15.7% in the predicted lowest risk regions (χ^2=24.1, p<.001). There was not a significant difference in the proportion of CHD deaths occurring between the ages of 65-74 when comparing these two regions (24.4% for the highest risk regions versus 19.3% for the lowest risk regions, χ^2=1.2, p=0.272).

Figure 3 displays how this model can be used to predict which regions have the greatest burden of premature CHD mortality based on neighborhood characteristics of violence, socioeconomic disadvantage, residential instability,

and race/ethnic composition. When compared to Figure 1b, it can be seen that this model underestimates premature

CHD mortality compared to what was actually observed, but shows similar geographic trends and disparities.

Figure 3 Choropleth map of predicted YPLL from the GWR model.
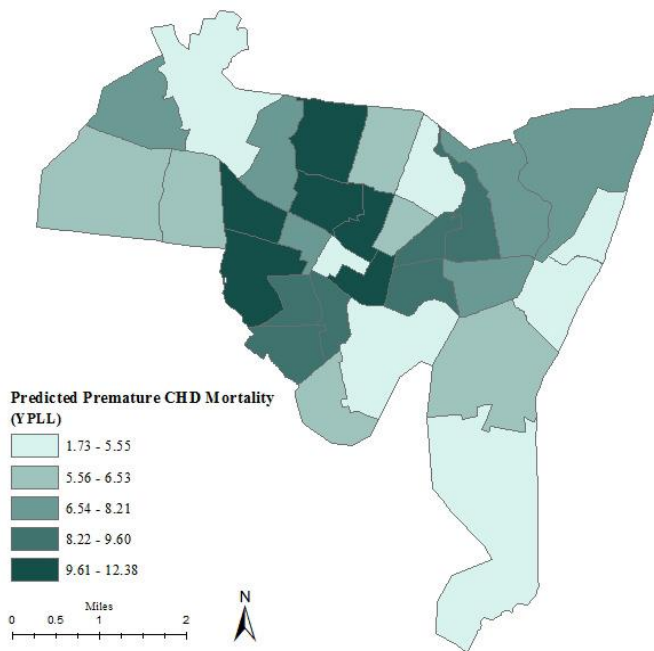
Discussion

Here we examined the potential association of violent crime and premature death from coronary heart disease

using the city of New Haven, CT USA. The geographical modeling demonstrated significant disparities exist in premature

CHD mortality within a diverse city, with a 7-fold difference in average years of potential life lost across census tracts.

The GWR model accounted for 48.6% of the variability in observed YPLL, and the results suggest that the association

between crime and premature mortality is significant even when neighborhood characteristics like socioeconomic

disadvantage, residential instability, and racial/ethnic composition are controlled. Moreover, the findings provide

preliminary evidence that violent crime is potentially a strong factor influencing premature death below the age of 65, a

range of preventable death proven difficult to reduce by targeting traditional risk factors [2].

The geographical modeling approach demonstrates the resolution possible at even the city-level for examining the association between violence and CHD. When this association was examined for geospatial patterns, the magnitude was observed to vary throughout the study region and was strongest within the southern area of the city. This trend is possibly related to a dose-response or threshold effect based on rates of violent crime or from effect modification by socioeconomic status [21]. The geographic variation may also be explained by perceptions of crime and safety. Research has shown that greater perceived neighborhood safety is associated with decreased likelihood of chronic diseases including hypertension and obesity [22, 23]. Research also suggests that fear of crime increases with greater perceived street traffic by strangers [24]. In this study, the strongest associations between crime and CHD were seen in the downtown area and along major highways, where there is an influx of pedestrian and street traffic by non-residents. Residents in these neighborhoods may have a greater fear of crime, which could have a stronger impact on heart disease compared to areas where residents are not as concerned about violence.

Few studies have looked specifically at neighborhood violence and heart disease, but the literature does support that more violent neighborhoods would have a greater burden of CVD. In one study, spikes in burglary rates were observed to be associated with elevated C-reactive protein in men, which is a marker of inflammation that leads to CVD [15]. Psychosocial hazards, including violent crime, have been shown to be associated with self-reported CVD independent of individual-level risk factors [13]. Odds of incident CHD have also been shown to be higher in women from more violent neighborhoods compared to neighborhoods with lower crime rates [16]. This study supports these findings and provides additional evidence that violence is associated with increased burden from CHD in terms of premature mortality. This finding is important since we have not seen as much progress in reducing the number preventable heart disease deaths that are occurring at younger ages [2]. When it comes to CVD burden, much of the attention is on individual-level risk factors like diet, smoking, and body mass [25]. Shifting our focus and efforts to these neighborhood characteristics like violence may result in greater gains than we have experienced as of yet.

Two major mechanisms could explain the association between crime and heart disease. It is suggested that neighborhood violence could lead to chronic stress, which has been shown to have detrimental impacts on health. Evidence suggests that perceived stress may be associated with incidence and mortality from CHD in certain vulnerable populations [21, 26]. A physiological stress response can lead to the disregulation of the autonomic nervous system or

the hypothalamic-pituitary-adrenal axis, which can cause increases in cardiovascular disease risk factors, such as high blood pressure and inflammation [4, 13, 27]. In addition to this biological mechanism, neighborhood violence could influence this outcome through unhealthy behaviors like smoking, lower physical activity, drug use, and poor diet [3, 13, 14, 28]. The perceived threat to life may make individuals more likely to engage in risky activities that would ultimately harm their health later in life [14].

This study adds to the literature by including a geospatial component to our understanding of violent crime and the potential influence on premature death. Since these relationships and associations are based on geographic characteristics, it is important to take into account the principle of spatial autocorrelation. This principle states that observations that are closer together in space are more similar than observations that are further apart [29]. This is particularly important when working with crime data, where crimes that occur on the border of multiple census tracts are assigned to only one tract. A growing body of literature on spatial analyses relevant to violent crime have mainly used two methods to account for spatial autocorrelation, GWR and Bayesian hierarchical modeling [20, 30-32]. These models have been shown to give better fits of the data than traditional regression models, and they allow the observed relationship to vary with space [32]. When comparing these two approaches, studies have shown that both methods are valuable for examining geographic relationships, but GWR may be preferred for practical implementation [20]. The GWR analysis is weighted based on neighboring regions, allowing crime rates to have a more continuous influence rather than a pure container model, like the global OLS model [33].

We are using variables that are aggregated at the neighborhood-level, and therefore cannot make claims about associations that exist at the individual-level. Neighborhoods with higher violent crime rates were associated with greater premature mortality from CHD, but through this study we cannot conclude that individuals who live in neighborhoods with high violent crime have a greater risk of dying early from heart disease. These models include neighborhood-level characteristics and not individual-level behaviors like smoking or diet. However, as discussed above, these behaviors may lie within the causal pathway of this association and would not be included for this reason. It remains that our models may not fully control for all possible confounders or that our covariate indicators do not fully capture the relationships we are trying to control. Even with these limitations, the ecological study design is useful for providing etiological evidence for population and geographic-level health outcomes [11].

The power of this analysis was that we could gain insight at the city-level that is relevant for health departments and police departments alike. The GWR analysis has been effectively implemented in numerous cities within the United States to examine a variety of associations. In Houston, TX, it was used to examine the association between alcohol outlet locations and incidence of violence [20]. In New York, NY, this method was used to examine disparities in access to parks [33], and in Philadelphia, PA, GWR was used to examine relationships between population density and median home value [19]. That said, the number of CHD deaths and violent crimes experienced during this time frame and the number of census tracts in New Haven limit the ability to stratify the analysis by factors like gender or race/ethnicity, and even age. The limited number of census tracts also resulted in associations that exhibited a graduated trend rather than localized hotspots that can be seen in studies that look at larger cities or nations [9, 20]. Since the data come from New Haven alone, we are treating the city as though it is isolated. The census tracts on the borders of the city are realistically influenced by crime rates in the surrounding towns, so the estimates for census tracts in the center of the city are likely to be more reliable. Even with these considerations, the city-level analysis is beneficial for practical implementation since health and police departments are organized at this level.

This study provides a model to examine geographic associations between crime and premature mortality in urban environments that uses data routinely obtained at local or state health departments. It demonstrates how neighborhood-level variables, including residential instability or race/ethnic composition, can be geographically weighted to provide resolution as a potential pattern in premature death. In the case of violent crime, these results can guide where public heath interventions are most needed and which regions are particularly susceptible to the damaging effects of violent crime. Future directions would be to look at a larger geographic area to obtain a more substantial sample size that would allow us to conduct stratified analyses. There are significant disparities in the burden of CHD by gender and race/ethnicity, and it would be desirable to examine whether this association is different among these subgroups. Future studies are needed to examine the influence of perceptions of crime and safety since this may be a more relevant measure for understanding why crime is associated with heart disease. It may also be useful to create a neighborhood socioeconomic disadvantage index [34] to more fully capture and control for these potential confounders.

Conclusion

CHD deaths that are occurring at younger ages represent a greater loss of human potential and are more likely to be preventable than deaths that are occurring at ages above average life expectancies [2]. Neighborhood-level characteristics are important determinants for heart disease and evidence suggests that more violent areas have a greater burden of premature CHD morality.

References

1. *2020 Topics & Objectives- Objectives A-Z*. HealthyPeople.Gov 2013 [cited 2013 June 28]; Available from: www.healthypeople.gov/2020/topicsobjectives2020/default.aspx.
2. *Preventable Deaths from Heart Disease & Stroke*, in *CDC Vital Signs*2013, Centers for Disease Control and Prevention: Atlanta, GA.
3. Diez Roux, A.V. and C. Mair, *Neighborhoods and health.* Annals of the New York Academy of Sciences, 2010. **1186**(1): p. 125-145.
4. Daniel, M., S. Moore, and Y. Kestens, *Framing the biosocial pathways underlying associations between place and cardiometabolic disease.* Health & Place, 2008. **14**(2): p. 117-132.
5. Glass, T.A., M.D. Rasmussen, and B.S. Schwartz, *Neighborhoods and obesity in older adults: the Baltimore Memory Study.* Am J Prev Med, 2006. **31**(6): p. 455-63.
6. James, W.L. and R.E. Cossman, *Using Maps to Monitor At-Risk Geographic Areas of Heart Disease: Tracking Access to Prescription Medication and Mortality Rates.* Journal of Maps, 2010. **6**(1): p. 478-487.
7. Chaix, B., M. Rosvall, and J. Merlo, *Assessment of the magnitude of geographical variations and socioeconomic contextual effects on ischaemic heart disease mortality: a multilevel survival analysis of a large Swedish cohort.* J Epidemiol Community Health, 2007. **61**(4): p. 349-55.
8. Borrell, L.N., et al., *Neighbourhood characteristics and mortality in the Atherosclerosis Risk in Communities Study.* Int J Epidemiol, 2004. **33**(2): p. 398-407.
9. Gebreab, S.Y. and A.V. Diez Roux, *Exploring racial disparities in CHD mortality between blacks and whites across the United States: a geographically weighted regression approach.* Health Place, 2012. **18**(5): p. 1006-14.
10. Naimi, A.I., et al., *Associations between Area-Level Unemployment, Body Mass Index, and Risk Factors for Cardiovascular Disease in an Urban Area.* International Journal of Environmental Research and Public Health, 2009(6): p. 3082-3096.
11. Green, C., et al., *Geographic analysis of diabetes prevalence in an urban area.* Soc Sci Med, 2003. **57**(3): p. 551-60.
12. Freedman, V.A., I.B. Grafova, and J. Rogowski, *Neighborhoods and chronic disease onset in later life.* Am J Public Health, 2011. **101**(1): p. 79-86.
13. Augustin, T., et al., *Neighborhood psychosocial hazards and cardiovascular disease: the Baltimore Memory Study.* Am J Public Health, 2008. **98**(9): p. 1664-70.
14. Ellen, I.G., T. Mijanovich, and K.-N. Dillman, *Neighborhood Effects on Health: Exploring the Links and Assessing the Evidence.* Journal of Urban Affairs, 2001. **23**(3-4): p. 391-408.
15. Browning, C.R., K.A. Cagney, and J. Iveniuk, *Neighborhood stressors and cardiovascular health: Crime and C-reactive protein in Dallas, USA.* Social Science & Medicine, 2012. **75**(7): p. 1271-1279.
16. Sundquist, K., et al., *Neighborhood violent crime and unemployment increase the risk of coronary heart disease: a multilevel study in an urban setting.* Soc Sci Med, 2006. **62**(8): p. 2061-71.
17. Abraham, M., et al., *Greater New Haven Community Index 2013*, 2013: New Haven, CT: DataHaven.
18. *Health, United States, 2012: With Special Feature on Emergency Care* 2013, National Center for Health Statistics: Hyattsville, MD.
19. Mennis, J., *Mapping the Results of Geographically Weighted Regression.* The Cartographic Journal, 2006. **43**(2): p. 171-179.
20. Waller, L., et al., *Quantifying geographic variations in associations between alcohol distribution and violence: a comparison of geographically weighted regression and spatially varying coefficient models.* Stochastic Environmental Research and Risk Assessment, 2007. **21**(5): p. 573-588.
21. Redmond, N., et al., *Perceived Stress Is Associated With Incident Coronary Heart Disease and All-Cause Mortality in Low- but Not High-Income Participants in the Reasons for Geographic And Racial Differences in Stroke Study.* Journal of the American Heart Association, 2013. **2**(6).
22. Mujahid, M.S., et al., *Neighborhood Characteristics and Hypertension.* Epidemiology, 2008. **19**(4): p. 590-598 10.1097/EDE.0b013e3181772cb2.

23. Fish, J.S., et al., *Association of perceived neighborhood safety with [corrected] body mass index.* American journal of public health, 2010. **100**(11): p. 2296-2303.

24. Hunter, A. and T.L. Baumer, *Street Traffic, Social Integration, and Fear of Crime*.* Sociological Inquiry, 1982. **52**(2): p. 122-131.

25. Collaborators, U.S.B.o.D., *The state of us health, 1990-2010: Burden of diseases, injuries, and risk factors.* JAMA, 2013. **310**(6): p. 591-606.

26. Iso, H., et al., *Perceived mental stress and mortality from cardiovascular disease among Japanese men and women: the Japan Collaborative Cohort Study for Evaluation of Cancer Risk Sponsored by Monbusho (JACC Study).* Circulation, 2002. **106**(10): p. 1229-36.

27. Wright, R.J. and S.F. Steinbach, *Violence: An Unrecognized Environmental Exposure that May Contribute to Greater Asthma Morbidity in High Risk Inner-City Populations.* Environmental Health Perspectives, 2001. **109**(10): p. 1085-1089.

28. Johnson, S.L., et al., *Neighborhood violence and its association with mothers' health: assessing the relative importance of perceived safety and exposure to violence.* J Urban Health, 2009. **86**(4): p. 538-50.

29. Edelman, L.S., *Using geographic information systems in injury research.* J Nurs Scholarsh, 2007. **39**(4): p. 306-11.

30. Cunradi, C.B., et al., *Alcohol outlets, neighborhood characteristics, and intimate partner violence: ecological analysis of a California city.* J Urban Health, 2011. **88**(2): p. 191-200.

31. Zhu, L., D.M. Gorman, and S. Horel, *Hierarchical Bayesian spatial models for alcohol availability, drug "hot spots" and violent crime.* Int J Health Geogr, 2006. **5**: p. 54.

32. Zhu, L., D.M. Gorman, and S. Horel, *Alcohol outlet density and violence: a geospatial analysis.* Alcohol Alcohol, 2004. **39**(4): p. 369-75.

33. Maroko, A., et al., *The complexities of measuring access to parks and physical activity sites in New York City: a quantitative and qualitative approach.* International Journal of Health Geographics, 2009. **8**(1): p. 34.

34. Franklin, F.A., et al., *Alcohol outlets and violent crime in washington d.C.* West J Emerg Med, 2010. **11**(3): p. 283-90.

35. *Violent Crime*, in *Uniform Crime Report, Crime in the United States, 2009*, U.D.o. Justice, Editor 2010, Federal Bureau of Investigation.

Appendix I: FBI Uniform Crime Reporting Definitions [35]

The FBI's Uniform Crime Reporting (UCR) Program uses the following definitions for classifying violent crimes:

I.   Murder: "The willful (nonnegligent) killing of one human being by another. The classification of this offense is based solely on police investigation as opposed to the determination of a court, medical examiner, coroner, jury, or other judicial body. The UCR Program does not include the following situations in this offense classification: deaths caused by negligence, suicide, or accident; justifiable homicides; and attempts to murder or assaults to murder, which are scored as aggravated assaults."

II. Aggravated Assault: "An unlawful attack by one person upon another for the purpose of inflicting severe or aggravated bodily injury. The UCR Program further specifies that this type of assault is usually accompanied by the use of a weapon or by other means likely to produce death or great bodily harm. Attempted aggravated assault that involves the display of- or threat to use- a gun, knife, or other weapon is included in this crime category because serious personal injury would likely result if the assault were completed. When aggravated assault and larceny-theft occur together, the offense falls under the category of robbery."

III. Forcible Rape: "The carnal knowledge of a female forcibly and against her will. Attempts or assaults to commit rape by force or threat of force are also included; however, statutory rape (without force) and other sex offenses are excluded."

IV. Robbery: "The taking or attempting to take anything of value from the care, custody, or control of a person or persons by force or threat of force or violence and/or by putting the victim in fear."