Analyzing Vulnerability of Low-Income Population to Extreme Heat in New York City, 2013

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PREFACE:
WHY STUDY NEIGHBORHOODS AND HEALTH OUTCOMES

Historically, many cities suffered from severe epidemic diseases, including tuberculosis and cholera, especially in the late 19th and early 20th centuries. The famous work by John Snow in 1854 on the London Cholera epidemic demonstrates that the design of public infrastructure, such as sanitation, sewage system, reliable transportation mode, and fresh air with open space, significantly impacted on individual health conditions and life expectancy. Until 20 years ago, public health research primarily focused on examining individual behavioral, psychological, and biological characteristics. According to Heiman and Artiga (2015), the interest in health promotion in this period lies in mortality and morbidity, health care expenditure, and functional limitations. These include discrete factors such as food choice, health care system, economic sustainability, and education that produce individual health outcomes.

However, in recent years, researchers have begun to realize that the health issues are often driven by a behavioral choice, which depends on the physical and social composition of the built environment. For instance, the lack of walkability restricts people's access to a healthy mode of travel, which in turn could lead to a higher rate of obesity, ultimately resulting in a reduced life expectancy. This approach changed the research direction from an individual to a neighborhood-based context, and the importance when identifying health-related issues of a community is in addressing the geographical context. Furthermore, a measurement of neighborhood health effect that consists of multiple attributes of each neighborhood was constructed including geospatial analysis and assessment of community needs in sustainable ways (Roux and Mair, 2010). The scope of the collaboration between health and planning department then started to expand beyond developing health care programs and delivery system reforms.

In July 2014, Dr. Melody Goodman of New York University told the audience at Dana-Farber Cancer Institute during the Pipelines into Biostatistics Annual Symposium, "Your ZIP code is a better predictor of your health than your genetic code." She pointed to Delmar Boulevard in St. Louis, Missouri, as an example that physically divided the city into a wealthy neighborhood in the south and the poor in the north. She described that the people who live in the north tend to have more heart disease and cancer than those from the affluent neighborhood. Moreover, the underinvested neighborhood in the north has been less likely to have college degrees and more likely to have chronic mental diseases.

The reason for the striking disparity is that health is beyond defeating disease and more about physical, mental, and social well-being (Dannenberg and Frumkin, 2011). A healthy life also involves social well-being that is also affected by one's surroundings. According to Pierre Bourdieu (1986), social capital is the aggregate of actual or potential resources linked to the possessions of a secure network. Social determinants of health consist of the structural condition of a supporting system, requiring social engagement and integration in the communities. Socially interactive neighborhood system, for instance, in a physical environment that has positive elements of constructing social capital, such as green spaces, might encourage active mingling. On the contrary, unsafe and dilapidated surroundings may cause social withdrawal, resulting in a greater chance of depression (Evans, 2006).

The fact that the consequences are especially significant to socially and economically vulnerable population is critical to understanding the relationship between health and place. The purpose of this project is to emphasize the interconnectedness between the built environment and public health in general and to expand the understanding of neighborhood characteristics and population health on a local scale.

INTRODUCTION

In January 2002, the temperature of New South Wales in Australia soared to 43°C (109°F), which was 8°C higher than the average temperature in the region during summer. The extreme weather killed almost 1,200 animals, including livestock and wild birds. During the past decades, there were many reports on cities like New South Wales where people encountered severe environmental problems, such as cyclones, hurricanes, earthquake, or tsunami. Moreover, the impact of the weather events often seemed more significant in large cities, not only because of a growing number of a population due to urbanization but also because the scale of infrastructure and built environment in large cities has become more extensive. One domestic example is Hurricane Katrina in 2005, which is one of the most catastrophic incidents in the United States' history. When Katrina hit Louisiana, almost 2,000 people died in the hurricane and flood that followed, and the property damage was estimated at $81 billion.

Needless to say, the extreme weather events not only impose upon the impacted cities the costs of physical and socio-economic restoration but also have an impact on the health of the population. For example, an allergy season that lasts longer than average due to a rising temperature increases the risk of vector-borne diseases (McGill, 2017). Moreover, weather events like the Louisiana disaster exacerbate any existing problems for vulnerable populations in the city, such as those with pre-existing medical problems, according to McGill. In other words, the impact of extreme weather events in large cities is not just socially and economically destructive but also has the potential to harm public health in those places. Therefore, it is crucial to address the vulnerability of urban populations to environmental problems and be prepared to minimize the foreseeable consequences.

LITERATURE REVIEW

EXTREME HEAT AND LARGE CITIES IN THE U.S.

According to the Centers for Disease Control and Prevention (CDC), an extreme heat event or a 'heat wave' refers to a period of abnormally hot and uncomfortably humid weather that typically lasts two or more days. Extreme heat events are unusual and make people suffer from heat-related illness, also known as "heat stress". When people are heat-stressed, their body is not able to cool down properly, and the body experiencing a very high temperature may suffer from a damage to the brain or vital organs. The most serious illness is heat stroke, which can result in death attributed to exposure to excessive heat. In other words, heat can actually be one of the underlying and contributing causes of death.

According to Morbidity and Mortality Weekly Report (2012), the number of heat related deaths in the U.S. has been increasing since 1999. One of the recent peaks was during 2006 North American Heat Wave. At least 225 heat-related deaths in the U.S. and Canada were reported in a month between July to August (Butler, 2011). Meanwhile, at least 24 died in New York City during the heat wave, which account for 10 percent of the total death at the time (Pérez-Peña, 2006). The number of deaths in the City is exceptional due to the "Urban Heat Island" effect, the reason urban areas are more susceptible to extreme heat. The United States Environmental Protection Agency (EPA) explains that the absolute temperature is generally higher in urban areas compared to rural areas due to the change of landscape. Developments in urban areas are mostly comprised of less green and/or open space, and more impermeable surface. High temperature in the urban areas not only increases energy consumption, but also elevates emissions of air pollutants and greenhouse gases, which makes urban areas even hotter. Another example of the urban heat island effect is

1995 Heat Wave in Chicago. According to a CDC report, 465 heat-related deaths occurred in only a few days. From 1999 to 2010, a total of 7,415 people died of heat-related deaths in Chicago, an average of about 618 deaths a year. There might be synthetic circumstances associated with the astounding number of the heat-related deaths, but the heat island effect has exacerbated the situation.

Until recent years, the health impact of extreme heat events received less attention from public compared to other environmental problems. Klinenberg (2002) explained details in three aspects: social, practical, and political. First, people tend to pay less attention to intangible cases. Even after exposed to the danger of catastrophic natural disaster, they forget about its severity and seriousness unless they were directly affected by it. Furthermore, heat waves do not damage large properties, and major victims of extreme heat events are normally marginalized individuals, such as elderly, poor, and isolated population who are easily undiscovered when dead from heat.

Second, determining heat-related death requires substantial environmental evidence (Madrigano et al., 2015). At the time of death, the body temperature should be 105+°F, and the condition of the corpse should be decomposed without other cause. Therefore, the numbers of heat-related mortality vary among different researchers and the various numbers might bring different but meaningful consequences to policymakers when prioritizing policies and programs.

Third, the health impact of extreme heat was often neglected by politicians and the press. In Chicago, for instance, the city officials did not release a heat emergency warning until the last days, and emergency centers were not properly utilized. The politicians also did not want to publicize the fact that the extreme heat event excessively led so many people in the city to death in order to avoid the blame. Therefore, the significance of the heat impact on population health was often neglected, difficult to be addressed, and intentionally denied until recent years.

ADDRESSING THE VULNERABILITY TO EXTREME HEAT

An essential question in the context of addressing the impact of extreme heat is defining vulnerable population groups. CDC identifies that some people such as seniors (aged 65+), outdoor workers, infant and children, athletes are more at risk of having heat-related illnesses than others, and low-income households are also one of them. Low-income population suffers from significantly higher economic, physical, and structural damage than other population, thus considered more vulnerable to natural disasters (Akter, 2013). Silva & Kawasaki (2018) also demonstrated a similar link between poverty and natural disasters by analyzing household surveys in Sri Lanka. They found that the environmental impact on economically vulnerable groups is statistically higher than the others after the disaster occurred. There are three reasons low-income households are more vulnerable than other socio-economic population groups to extreme heat.

BUILT ENVIRONMENT

First, there is long-term disinvestment in the physical condition of low-income housing and neighborhood. Their housing stock is usually old and generally constructed with lower quality materials, including less thermal efficiency and low quality of building envelope and structural appliance. Moreover, low-income households in urban areas usually live in high-rise buildings that have a higher heat island effect. The high-rise buildings observe more sunlight from the multiple layers of the buildings, and the layers often block wind that can cool the neighborhood. An increased urban temperature, due to the urban heat island effect, requires large energy consumption of buildings for cooling, but low-income households are less likely to have an air conditioning system in their house despite the fact that the air conditioning is the most effective way to reduce the risk of heat-related illness (Santamouris & Kolokotsa, 2015; White-Newsome et al., 2012).

An indirect impact of energy consumption in the neighborhood, such as waste heat from industry, also contributes to the urban heat island effect in the neighborhood (Li & Zhao, 2012). Low-incomes tend to live closer to industrial sites than other population groups where the use of fossil fuel and economy activities intensify the heat island effect. Another physical environment that causes vulnerability to heat is the lack of green space and vegetation in the low-income neighborhood. Greeneries and vegetation can mitigate extreme heat through evapotranspiration and shading effect. However, there is environmental inequity among the neighborhoods with different socio-economic population groups. Green space ability is substantively lower in low-income neighborhoods, and the green spaces tend to be poorly maintained. (Wolch, et al., 2014; Astell-Burt, 2014). Therefore, the physical characteristics of their built environment made low-incomes more vulnerable to extreme heat events.

ENERGY POVERTY

According to Santamouris (2015), energy poverty is used to describe a situation of a household not able to satisfy socially and materially the required levels of energy services in their homes. Low-income households suffer from energy burden, which can be simply and logically explained by an allocation of their budget (Hernández, 2013). Landlords do not pay for the utilities, and there is little investment in efficiency upgrades. During the heat waves, the low-income population cannot keep their home adequately cool because they have to decide between utility-related expenses and food. They are more likely to sweat it out, and the behavioral choice can trigger respiratory illnesses.

PRE-EXISTING HEALTH PROBLEMS, KNOWLEDGE AND PERCEPTION TO HEAT STRESS

Not to mention that low-income households have difficulties in cooling their homes due to energy burden, they are also more likely to have pre-existing health problems (Hatvani-Kovacs et al., 2016). People who already have health problems are the most vulnerable to extreme heat events. Furthermore, Hatvani-Kovacs et al. (2016) also found out that not only housing characteristics but perception related to heat stress and knowledge of heat mitigation are also crucial in order to reduce the health impact of extreme heat. In other words, low-income households who frequently have pre-existing health problems without enough knowledge of heat adaptation and mitigation are prone to heat-related illness.

LOW-INCOME HOUSEHOLDS AND EXTREME HEAT IN NEW YORK CITY

NYC Environmental Justice Alliance (2018) used New York City Heat Vulnerability Index (HVI) to identify the most vulnerable neighborhoods in the city to extreme heat. HVI consists of environmental metrics, poverty rates, and race demographics that are strong indicators of health risk. According to the NYC Climate Justice Agenda (2018), predominantly high poverty areas (low-income neighborhoods) conformed with the list of the most heat-vulnerable communities. Hunts Point in the Bronx, for instance, is one of the low-income neighborhoods in NYC. Residents in Hunts Point are usually people of color with an average median income of $22,000, and about 20-35 percent of them are considered to be living below the city's poverty line (Calma, 2018). They are unlikely to afford an air conditioner or to pay for the extra electricity to power it. The residents live alongside a heavy industrial site, the largest wholesale produce market in NYC, with more than ten waste transfer stations concentrated with high truck traffic. Unfortunately, Hunts Point ranked in one of the highest heat vulnerable communities, and it confirms that HVI geographically matches to low-income neighborhoods in the City.

As the number of worldwide heat events keeps increasing since the late 20th century, extreme heat is now globally considered one of the most dangerous weather impacts. The impact of extreme heat in urban areas is exceptionally more severe than rural areas, and the low-income population is explicitly more vulnerable to extreme heat than other income groups. Their neighborhoods tend to have higher economic, physical, and structural damage than the others in general, thus easily exposed to natural disasters. Furthermore, the prevailing health problems of the low-income population makes them much more vulnerable to heat-related health risk.

According to Akter (2013), nonetheless, vulnerability is different from resilience. High vulnerability does not necessarily mean low resilience, because some similarly vulnerable groups have performed a greater ability to overcome the disastrous events than others. What is more important is to identify what causes the vulnerability of the specific population, and how they can be prepared and be resilient against the future heat waves. In the local context, research has been conducted on the characteristics of New York City neighborhoods and heat impact on population health crisis, but these studies have mainly assessed senior citizen's mortality and their neighborhood risk factors (Rosenthal, 2010; Rosenthal & Kinney, 2014). While these studies primarily focused on the specific age group, their findings still demonstrate that the economic features of the subjects, such as widespread poverty, poor housing conditions, and low rates of access to air-conditioning, are some of the major determinants of their vulnerability.

Therefore, this research aims to delve into the neighborhood-scale vulnerability of economically deprived population, the entire group particularly with extremely low-income, who has manifested symptoms of weakness to heat in New York City. Looking at the variables that affect the heat-related health risks of the low-income residents might help in understanding their heat stress, and finding mechanisms for improving the level of the population health. By examining the links between their neighborhood characteristics and heat-related imminent death, I would like to explore the dynamics of the vulnerability of the low-income class, and fill the gap in the context in which a profound understanding on the neighborhood scale is absent.

METHODOLOGY

The paper constructs empirical research using quantitative data that examines sets of numeric variables to test out the following research hypotheses:

- Low-income population are more vulnerable to extreme heat than other income groups in New York City;
- Neighborhood scale indicators, such as their socio-economic condition, health risk characteristics, strategies of heat impact mitigation and community resources, would explain their vulnerability (Figure 1).

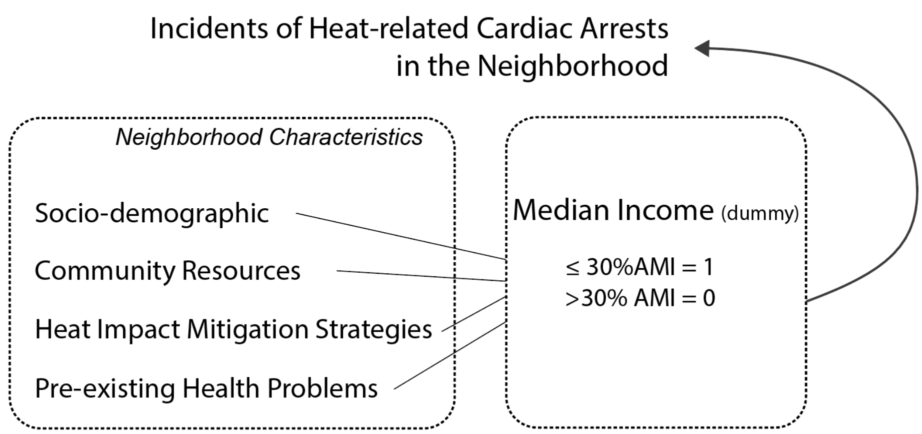

Figure 1. Diagram of the testing hypothesis

SPATIAL UNIT OF ANALYSIS

The geographic unit selected in the study for analyzing the population is ZIP Code Tabulation Areas (ZCTAs), which is an area defined by the Bureau of Census representing the generalized area of U.S. Postal Services (USPS) five-digit ZIP Code services. The Census Bureau presents statistical data by ZCTAs from surveys and censuses by aggregating census blocks with the same ZIP Code. Studies on the relationship between built environment and health outcomes often use ZCTAs as the spatial unit of analysis (Krieger et al., 2002). The study collects the characteristics of socio-economics, built environment, resources, and health risk factors for each ZCTA in New York City.

DEFINING VARIABLES AFFECTING HEAT-RELATED VULNERABILITY

DEPENDENT VARIABLE

Excessive Health Crisis of Low-Income Households during 2013 Heat Wave

The study examines the incidents of cardiac arrests of low-income residents during one of the longest heat waves in the New York City history to assess severe health crisis of the population due to extreme heat. When the outdoor temperature exceeds 80°F or higher, the risk of heat exhaustion and life-threatening heat stroke may lead a person to experience cardiac arrest. Cardiac arrest, the abrupt loss of heart function, is a fatal health issue which could indicate imminent death as American Heart Association defined. The study defines the degree of an excessive heat-related health crisis as the difference between the number of cardiac arrest emergencies during a heat wave and the number of those during the same duration of the time before the heat wave.

According to National Weather Service New York, the historical data of the heat waves are collected from Central Park to best represent the climate of the City (Appendix I). 2013 Heat Wave, from July 14th to July 20th, is selected for analysis as one of the most recent and the longest heat waves in the New York City's historical data. The study examines the data of Emergency Medical Services calls data for cardiac arrests during the appointed periods in 2013, which was collected and provided by the NYC Office of Emergency Management (OEM). Incidents canceled, duplicated, unfounded, treated or condition corrected on site were removed from the consideration in order that the rest would adequately indicate the patients' imminent death. After obtaining the individual data, the numbers of the emergency calls during the heat wave and the earlier week are aggregated to the separate counts by each ZCTA for use.

Defined by the U.S. Department of Housing and Urban Development (HUD), the median income for the regional area each year is specified by different family size (see Table 1). For example, if a family consists of two people and they earned $60,000 in New York City in 2013, they have achieved above 80 percent and below 100 percent of the Area Median Income (AMI). Since the research is interested in the neighborhood scale socio-demographic data, and the family size of the deceased population is difficult to identify, the "low-income neighborhoods" in this study are defined as the ZCTAs with an average income of below or at $18,900 measured in 2013, which is 30 % of the New York City's AMI.

Table 1. Average of below $18,900 (30% AMI) is considered low-income in this study

Median Income	2013 Income Limit Category	1 Person	2 Person	3 Person	4 Person	5 Person
$63,000	**Extremely Low (30%)**	$18,050	$20,600	$23,200	$25,750	$27,850
	Very Low (50%)	$30,100	$34,400	$38,700	$42,950	$46,400
	Low (80%)	$48,100	$55,000	$61,850	$68,700	$74,200

US dollars in 2013

Source: 2013 New York, NY AMI, U.S. Department of Housing and Urban Development (HUD)

INDEPENDENT VARIABLES

The study will examine a range of indicators that might influence the risk of imminent deaths during the heat waves. A list of the various elements that give neighborhoods their distinct environmental characteristics are selected from Neighborhood Character Assessment Tool defined by City Environmental Quality Review (2014), and the combination of the indicators are modified to assess the low-income neighborhoods' population health impact. The explanatory variables in this study are categorized into four main groups: socio-demographic conditions, mitigation strategies for heat impact on health, community resources, and health risk characteristics (Figure 2).

Socio-demographic Characteristics

- *Median Income*
- *Age under 14 and 65+*
- *Education level*
- *Race*
- *Household type (living alone)*

Community Resources

- *Number of Community Facilities (Cooling Center)*
- *Number of Health Facilities*
- *Number of Public Library (Cooling Center)*

Heat Impact Mitigation Strategies

- *Percent vegetation cover (Tree canopy)*
- *AC access in home*
- *Number of Parks and Open Spaces*

Health Risk Characteristics

- *Percent Adult Obese*
- *Percent Adult with Chronic Heart Disease*

Figure 2. Summary of indicators and explanatory variables

Socio-demographic Characteristics

Demographics and socio-economic characteristics are one of the indicators in this study. Obtained from American Census Survey (ACS) 1-year estimates for the ZCTAs in the United States, this is a premier information for detailed social, economic, housing, and demographic characteristics summarized for each geographic area. The collection of questionnaires is sent to a sample of households, and the estimates are obtained from the survey. Indicators included in this study to illustrate the neighborhood conditions are income, age, race, education level, and household type which could indicate the risk of social isolation if living alone. The single-year estimates are selected to precisely reflect the currency in the year of 2013.

Mitigation Strategies for Heat Impact on Health

Some of the features of the residential built environment might alleviate the urban heat island impact in the neighborhood. For example, spatial contiguity of high-rise buildings comprised of less green, open space, and impermeable surface is a critical determinant of the heat island effect. On the contrary, a large amount of green space attracts people and encourages outdoor activities, also reduces summer temperatures because areas with more vegetative cover have more shading and evapotranspiration than areas with built surfaces (Rosenzweig, 2015). Number of parks and open spaces in the areas is included in the analysis provided by the NYC Department of City Planning (DCP). Furthermore, obtained from the Built Environment and Health Project (BEH) at Columbia University, the percentage of tree canopy coverage is used to indicate the amount of area shaded by greeneries. BEH generated the spatial data to examine the impact of the built environment, including land use, public transit, and physical activity, and other aspects of health. A higher tree canopy coverage represents a greater percentage of area shaded by greeneries.

Presence of Air Conditioning at home is also considered one of the independent variables indicating the most effective heat mitigation strategy. Conducted by NYC Department of Health and Mental Hygiene (DOHMH), the Air Conditioning data is a part of the New York City Community Health Survey (CHS), which is a telephone survey data of health topics in NYC for a better understanding of health and risk behavioral indicators of New Yorkers.

Community Resources

The existence of social facilities and community centers is one of the critical factors indicating community preparedness of low-income residents to extreme heat. The amenities for the residents operate not only as socializing places but as cooling centers during the heat waves. New York City opens air-conditioned facilities to offer people relief from the extreme heat when the weather is dangerously hot and humid. According to NYC Emergency Management, the libraries and community facilities are one of the sites where cooling centers are located. Therefore, provided by the Department of City Planning, numbers of community centers, health facilities, and public libraries in each ZCTA are included in this study.

Health Risk Characteristics

According to the CDC, some chronic medical problems are the catalysts of heat-related illness while extreme heat can be dangerous for anyone. For instance, individuals with heart disease and poor blood circulation are more at risk. Moreover, obese people (BMI $\geq$ 30) are also in danger as their body tend to retain more heat than others. Therefore, prevalent heart disease and obesity are considered risk characteristics, describing the general level of health conditions of the neighborhoods in this study. Source of the measure of the chronic disease related to unhealthy behaviors is the Behavioral Risk Factor Surveillance System (BRFSS), provided by the CDC. These estimates for small areas are collected to identify health problems and to implement effective and targeted health prevention initiatives.

STATISTICAL ANALYSIS

The study applies a cross-sectional study to examine the vulnerability of low-income neighborhoods to heat-related health risk. Multiple linear regression analysis and Pearson's correlation test are mainly used to assess the relationship between the excessive heat impact on the population health and their neighborhood scale vulnerable characteristics. The methodological approach of this study follows the previous studies on extreme heat in New York City (Rosenthal, 2010; Rosenthal et al., 2014). Descriptive statistics illustrate the essential features of the population and extreme days during the study year. Moreover, various diagnostic tests are performed to examine the model fit; for example, multicollinearity of the variables is tested in order to rule out similar factors in the regression model, and autocorrelations test is performed to confirm the measurement of the geographically adjacent data is independent of each other. Level of $p<0.10$ is considered variables significant when testing the relationship, while the level of alpha=0 .05 is used in the power test to ensure a statistical power of the model.

RESULTS

DESCRIPTIVE STATISTICS

Low-Income ZCTAs

In 2013, 22 Zip Code Tabulation Areas obtained below or equal to 30% AMI, which is $18,900 (USD adjusted to the same year), out of 181 ZCTAs. The low-income neighborhoods are mostly located in the Bronx, except that 5 of those are in Brooklyn, and 4 are in the edges of Manhattan. The spatial distribution of the low-income neighborhoods in New York City is depicted in Figure 3.

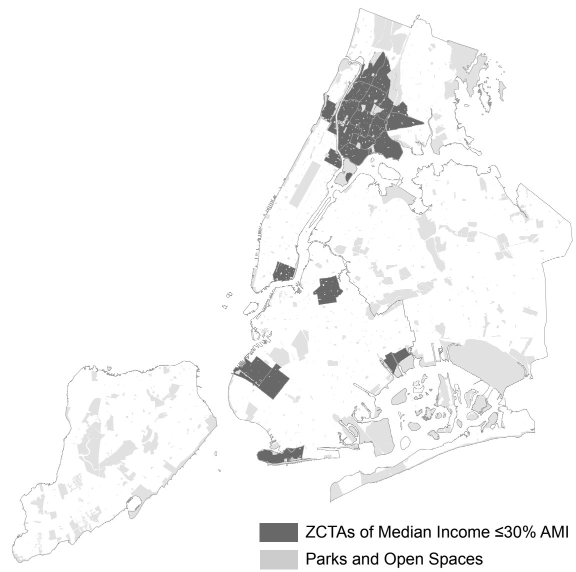

Figure 3. Location of the low-income ZCTAs in NYC

<List of the low-income ZCTAs>

- Manhattan: 10002, 10032,10035, 10039
- Bronx: 10451, 10452, 10453, 10454, 10455, 10456, 10457, 10458, 10459, 10460, 10468, 10472, 10474
- Brooklyn: 11206, 11219, 11220, 11224, 11239

SOCIO-DEMOGRAPHIC CHARACTERISTICS

Household type

According to the American Census Survey, the average of 32.21% of the total households in New York City was reported as single-households, and the average of 60.3% (median 63.1%) households lived with a family in 2013. Median is 29.9% while the distribution ranges from 8.7%

to 64.5% among the ZCTAs in the City. In the meantime, there were 10.42% (median 9.9%) single households over the age of 65 in NYC, and only 0.59% (median 0.5%) of the seniors over 65 years old lived together in average.

Compared to the City, people in the low-income ZCTAs tended more to live together as 63.55% (median 66.3%) of them lived with a family, and the average of 30.94% (median 29.75%) lived alone (range from 16.7% to 50.1%). There were 11.31% (median 9.85%) of single-living seniors over 65 years-old in the low-income ZCTAs, which is slightly more than the City's average. Only 0.5% (median 0.45%) of seniors in the low-income neighborhoods lived together in 2013, almost similar to the City's profile (Figure 4). All the figures in this chapter display the comparisons of the trimmed means (percentages or counts) of the neighborhood characteristics, the calculation of the average after discarding samples in the 10% of a probability at the high and low end, in order to reflect their statistical distribution. Mean, median, and trimmed mean of all the indicators and variables are attached in Appendix IV.

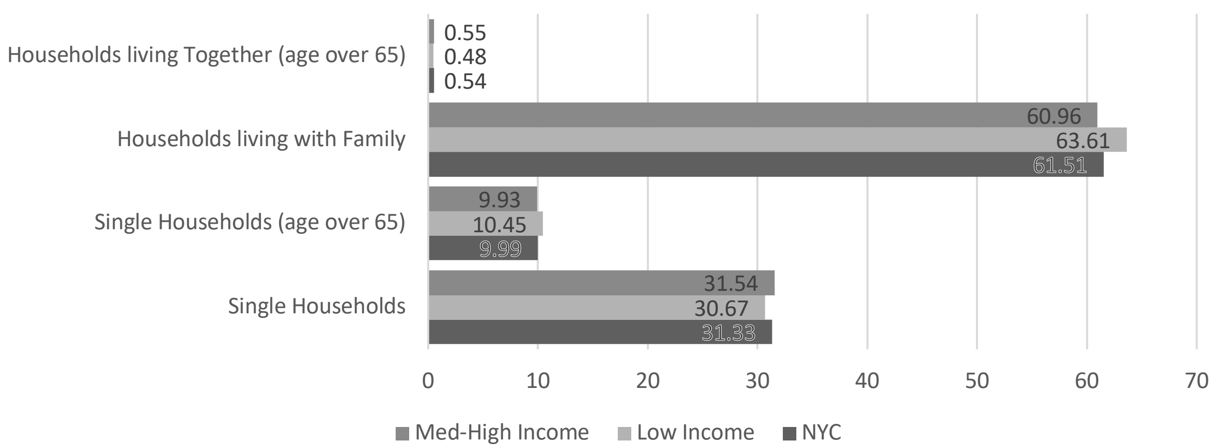

Figure 4. Comparison of Household Types (Trimmed-mean: %)

Age and Race

In New York City, age over 65 consists average of 13.7% of the total population (median 12.5%), and 10.75% was under age 14 (median 11.3%) in 2013. There are 11.22% of seniors (median 9.20%) in the low-income communities while the average of 14.37% (median 15.20%) of the total population is under age 14. As presented in Figure 5, there is less population of age over 65 and more of age under 14 in the low-income ZCTAs than the City and the med-high income neighborhoods.

Meanwhile, most of the low-income ZCTAs in New York City consist of people of color. There are 11.96% of non-Hispanic White, 25.23% of non-Hispanic Black, 7.39% of non-Hispanic Asian, and 53.86% of Hispanic in the areas while NYC consists of 25.39% of Hispanic, 38.29% of White, 20.11% of Black, 13.39% of Asian. In the med-high income ZCTAs, on the other hand, there are 41.94% of White, 19.41% of Black, 14.22% of Asian and 2.99% of other races on the contrary. Figure 6 illustrates the significant disparities of race among the neighborhoods with different income levels.

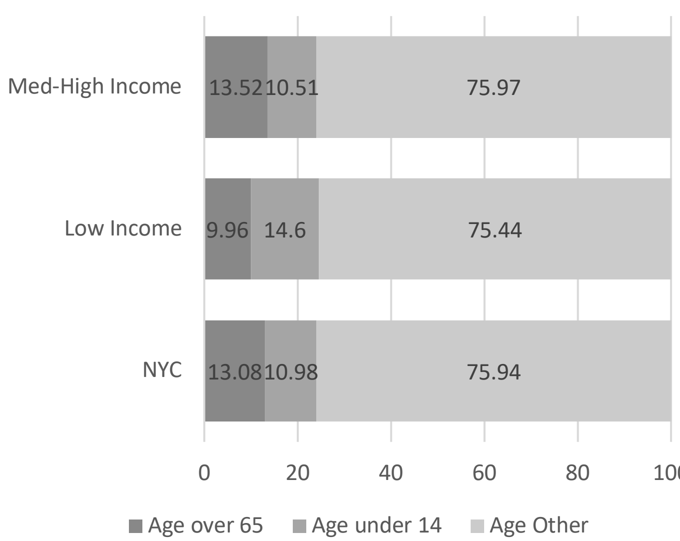

Figure 5. Comparison of Age (Trimmed-mean: %)

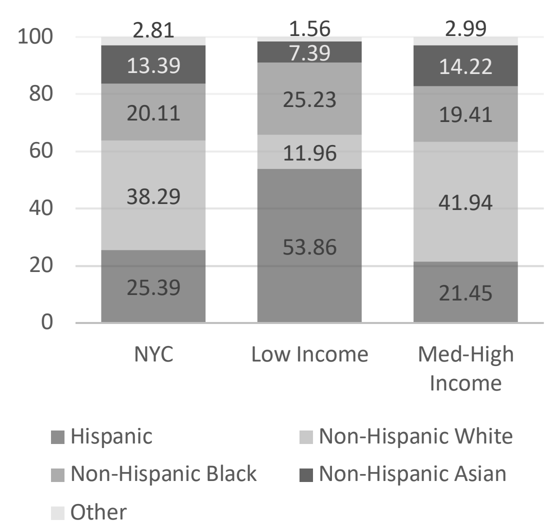

Figure 6. Comparison of Race (Trimmed-mean: %)

Education level

Compared to the City and the med-high income ZCTAs, a large proportion of the residents over 25 years-old in the low-income neighborhoods achieved lower levels of education (Figure 7). In New York City, 14.12% have some college education without a degree while 39.7% have bachelor's degree or higher. 45.18% of the New Yorkers did not achieve a high school degree at average. However, only 18% of the residents in the low-income ZCTAs have a bachelor's degree while 66.35% of them attended less than high school. On the contrary, 42.7% of the people in the med- to high-income neighborhoods graduated with bachelor or higher degrees. 43.39% do not have high school degrees but this is less than the City's average, and the % is almost 20% smaller than the average of the low-income communities.

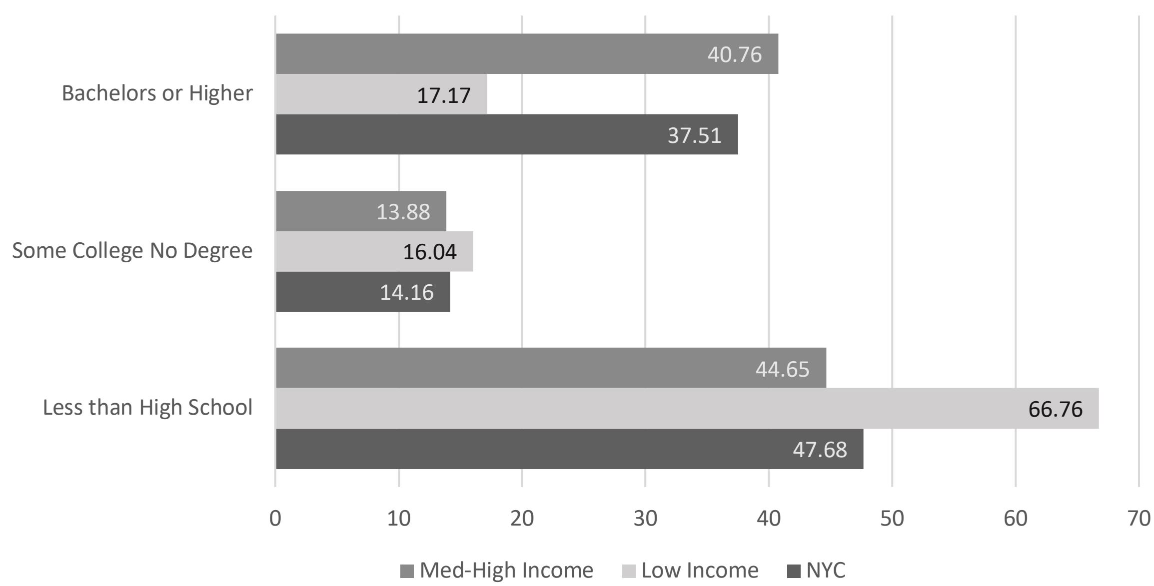

Figure 7. Comparison of Education Attainment (Trimmed-mean: %)

COMMUNITY RESOURCES

According to the NYC Department of City Planning, there is a total of 453 community centers in New York City, an average of 2.5 per each. Among those, 327 are located in the med-high income ZCTAs, an average of 2.06 for each, whereas low-income neighborhoods have an average of 5.73 community facilities per each area, 126 in total. There are roughly three more community facilities per area in the low-income ZCTAs than the med-high. In the meantime, the average number of health facilities in the low-income communities is 0.68, which is 0.23 higher than the City's average and 0.26 higher than the med-high income areas. In total, there are 15 health facilities in the low-income ZCTAs out of 82 locations in the City. Public libraries are almost equally distributed across the ZCTAs as shown in Figure 8.

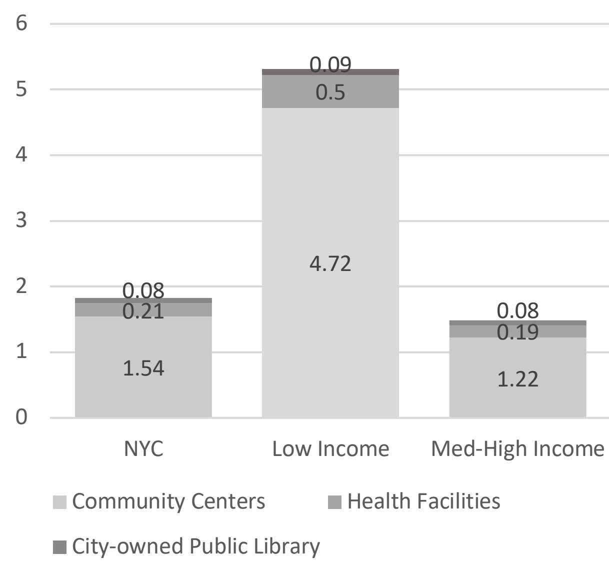

Figure 8. Count of Community Facilities (Trimmed-mean)

HEAT IMPACT MITIGATION STRATEGIES

Tree Canopy, Public Parks and Community Gardens, Air Conditioning Access at Home

In New York City, 18.66% of each ZCTA is covered by tree canopy on average. However, 16.56% of the low-income neighborhoods is shaded by trees, which is lower than the average of the City and the med-high income communities. The average of 18.95% in the med- to high-income ZCTAs is tree-covered (Figure 9). In the meantime, there are more numbers of public parks and community gardens in the low-income neighborhoods, with an average of 6.45 community gardens and 12.05 public parks in each area. The average of the number of community gardens in each ZCTA is 2.41, and that of public parks is 6.86 (Figure 10). Both low-income and med-high income neighborhoods have fewer percentages of senior adults reporting proper Air Conditioning (AC) access at home than those of under the age of 65 (Figure 11). In NYC, 87.58% of adults reported AC at home while only 82% of the seniors reported so. Likewise, %s of seniors who reported AC at home (75.17%) is much lower than the %s of the adults (83.47%) reported in the low-income ZCTAs, but the difference is more significant than the other groups.

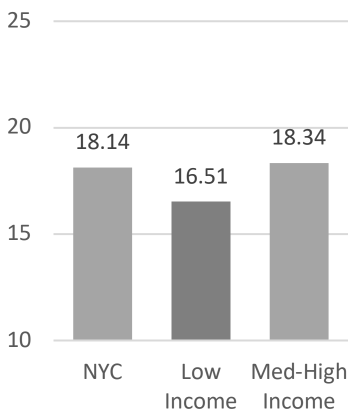

Figure 9. Comparison of Tree Canopy (Trimmed-mean: %)

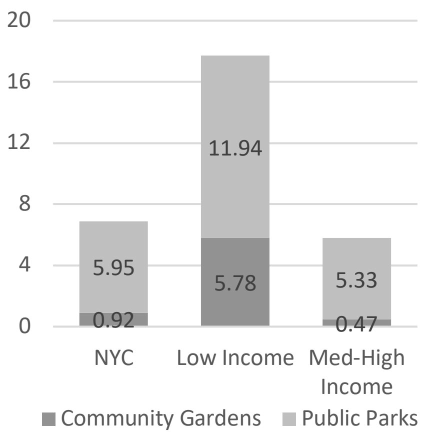

Figure 10. Comparison of Parks and Gardens (Trimmed-mean: Count)

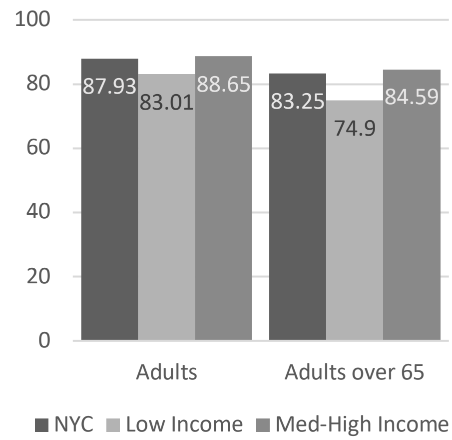

Figure 11. Comparison of Adults Reporting AC at home (Trimmed-mean: %)

Obesity and Chronic Heart Disease

According to the Behavioral Risk Factor Surveillance System's report, adults in the low-income neighborhoods have more prevalent health issues than the others in the rest of the City (Figure 12). In general, average 23.89% of the adults in New York City are considered obese (BMI ≥ 30). While 22.53% of the adults in the med-high income neighborhoods have obesity issues, 33.03% of the low-income adults are obese. Those in the low-income neighborhoods also reported more chronic heart disease than the average of the med-high income or the City. 16.35% of the low-income adults between 35 and 64 years-old reported heart disease while 72.9% of the adults over 65 years-old reported the same health issue. The proportion is almost 15% higher than the average of the City or the med-high income communities.

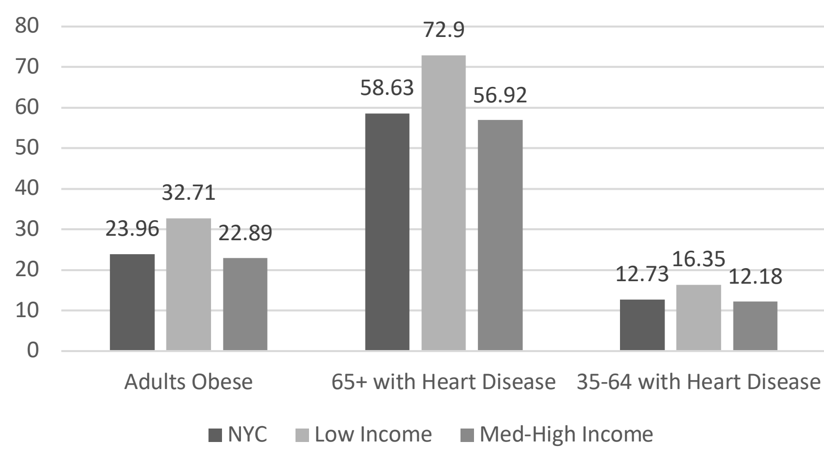

Figure 12. Comparison of Health Characteristics (%)

CALLS BY SEASON

Total 5,329 calls in regards to the cardiac arrest emergencies were reported within the 181 ZCTAs of New York City from June 1 to August 31. In other words, there was an average of 29.44 calls per neighborhoods (median 26) during the Summer in 2013. In the meantime, 972 out of the total occurred during the heat wave, from July 14 to 20, while 350 were reported during the same duration of normal hot days before the heat wave (June 23 to 30). In average, there were three or more calls per ZCTA during the heat wave than the usual hot days. Distribution of the emergencies is depicted in Figure 13.

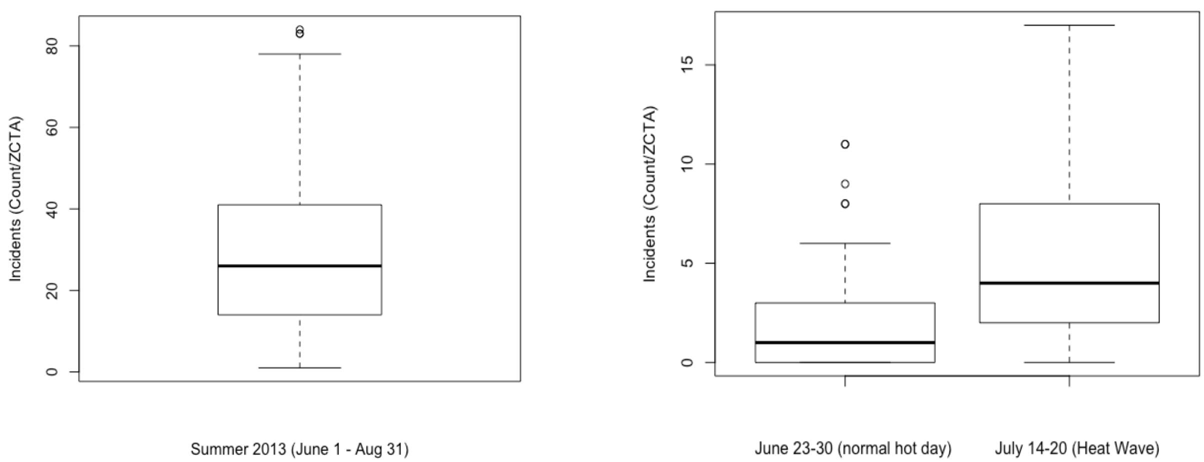

Figure 13. Distribution of the Cardiac Arrest Emergency Calls by Season

- Normal Hot Days (June 23-30): average 1.93 (median 1)
- Heat Wave (July 14-20): average 5.37 (median 4)

The Excessive Cardiac Arrests related to Extreme Heat

The degree of the excessive heat-related health risk is calculated by subtraction of the counts during the normal hot days from the Heat wave. The same duration is used for analysis in order to find out the heat effect in each ZCTA. In 2013, the difference ranged from -4 to 16 at the mean of 3.44 and median of 3, and 143 ZCTAs (73%) had more calls (difference>0) during the heat wave than the normal hot days. Perceiving more imminent deaths during the heat wave conform to the other studies that also found the excessive health risks during heat waves (Hoshiko et al.,2010; Rosenthal et al., 2014). The distribution of the number of heat-related emergencies is described in Figure 14.

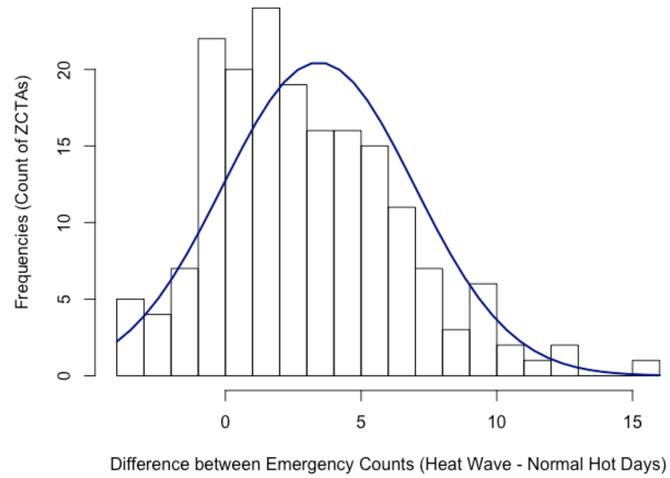

Figure 14. Distribution of Heat-Related Cardiac Arrests (Counts/ZCTA)

CALLS BY INCOME

The number of cardiac arrest incidents related to extreme heat varies by different median income of the ZCTAs. As shown in Table 2, there were 1.11 more calls on average reported within the low-income neighborhoods than the rest during the regular hot days. In the meantime, an average of 8.36 emergencies in the low-income ZCTAs were reported, which is 168% more than the average of the med-high income neighborhoods. These findings reaffirm the relationship between low socio-economic status and the condition associated with cardiovascular-related deaths (Reinier et al., 2011).

	All	Low-income	Average/ZCTA	Med-High Income	Average/ZCTA
Number Of ZCTAs	181	22		159	
Summer (Total)	5329	997	45.32	4332	27.25
2013 Heat Wave	972	184	8.36	788	4.96
June 23 to 30, 2013	350	64	2.91	286	1.80

Table 2. Emergency Calls by Income, 2013

Degree of Heat Vulnerability and Income

As seen in Figure 15, distribution of the difference, or the level of heat effect on the severe health risk, demonstrates that the neighborhoods of median income below 30% AMI ($18,900) in 2013 are more vulnerable to extreme heat than the other neighborhoods in NYC. Out of the 22 ZCTAs, 20 had more emergency calls during the heat wave while one of the rests had equal numbers of incidents between the heat wave and the usual hot days. The average heat effect on the count of emergencies is 5.45 (black dotted line in Figure 15) while the median is 5. On the other side, med-high income neighborhoods have an average difference of 3.44 (gray dotted line) with a median of 3. The relationship is also consistent with the result of binary OLS linear regression test between the level of heat effect and median income (Figure 16). With other conditions being constant, 1,000 dollars increment of a ZCTA's median income (USD in 2013 value) would explain a decrease of -0.028 heat-related cardiac emergencies at 95% confidence level. Although the model explains only 3% of the variation in the heat-related emergencies with the variation of income, the association between low-income and the vulnerability to extreme heat is consistent with the other heat-related research (Rosenthal et al., 2014).

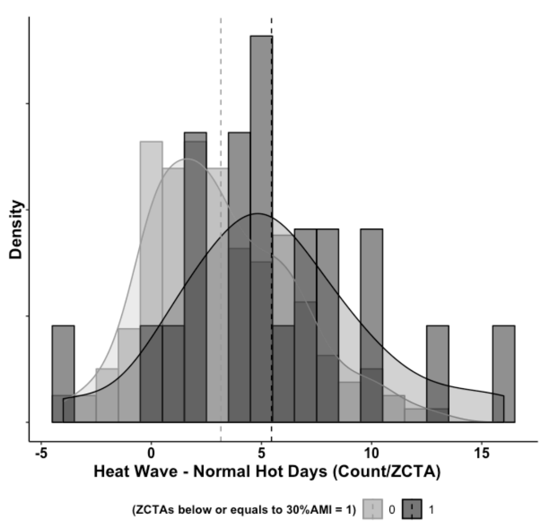

Figure 15. Distribution of Cardiac Arrests by Income, 2013

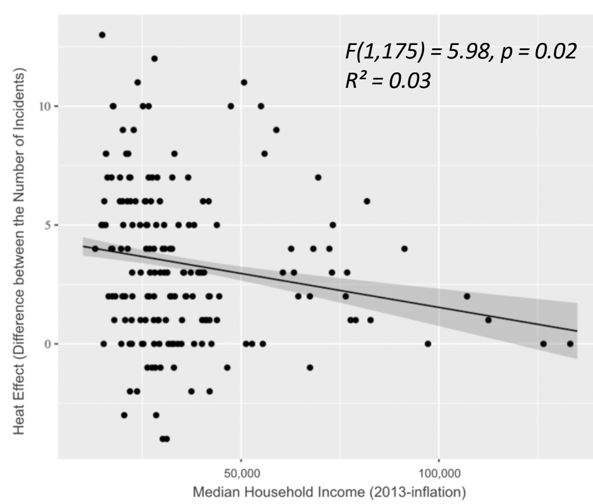

Figure 16. Bivariate OLS Linear Regression between Income and Heat-related Cardiac Arrests

While the descriptive statistics with means and standard deviations of all variables included in the tests are summarized in Appendix III, Figure 17 portrays the spatial distribution of the heat-related cardiac arrests in New York City.

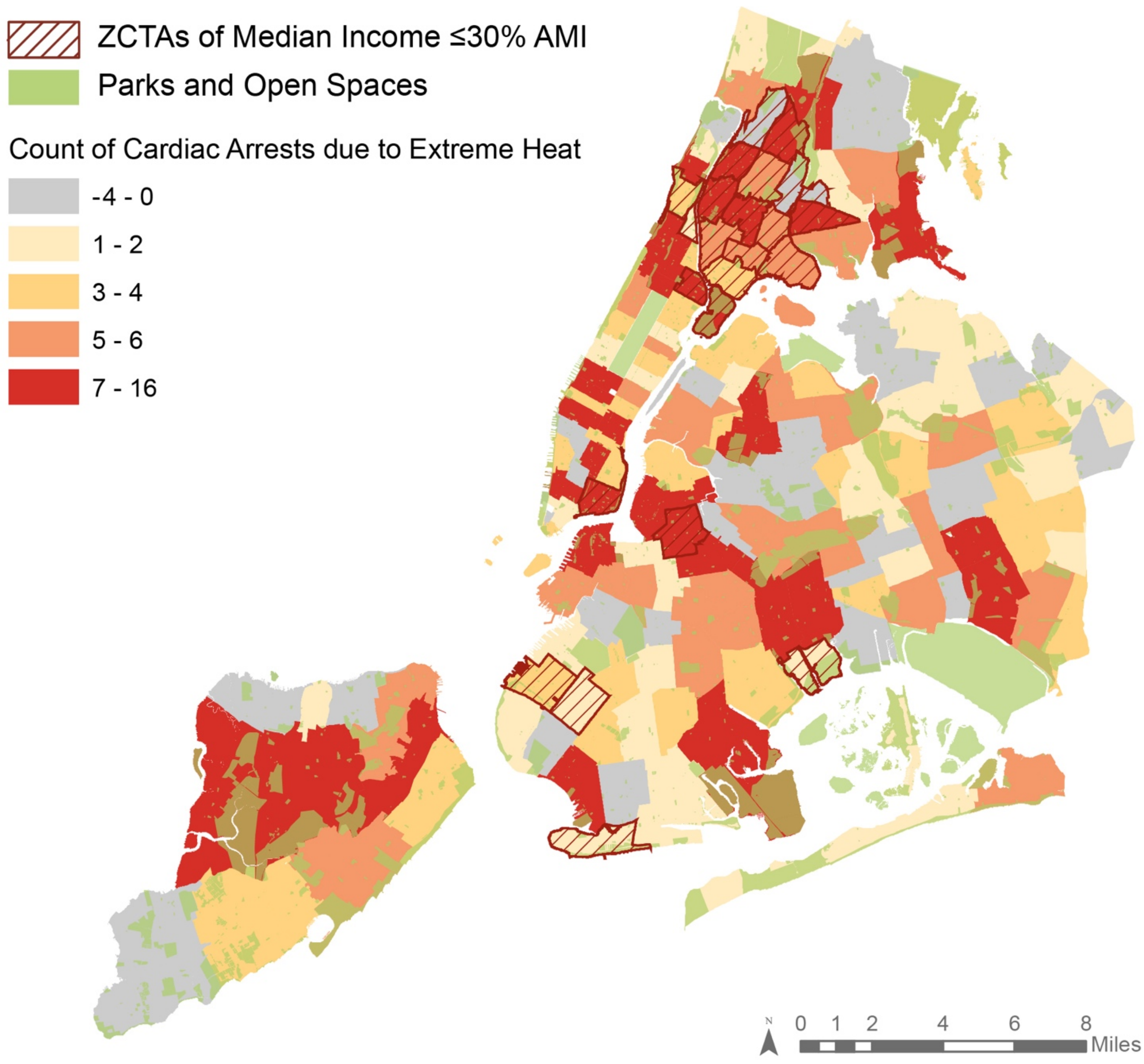

Figure 17. Spatial Distribution of Heat-related Cardiac Arrest Calls and Low-Income ZCTAs

STATISTICAL MODEL

Selection of the Independent Variables

Before assessing the relationship between the explanatory factors and the degree of heat-related emergencies, Pearson's correlation test is used to select the most relevant variables for the use in the multivariate linear regression model. As summarized in Table 3, significant positive correlations (p-value < 0.05) are found between the heat-related health risk and neighborhood-level socio-demographic characteristics such as percentages of single-living, and the population of color. In addition, numbers of community centers, parks and community gardens, health facilities have the strongest positive associations with the heat vulnerability. On the contrary, the percentages of living with family, White and Asian population, and having an Air Conditioning access at home are negatively associated with the neighborhood population's imminent deaths due to extreme heat (p-value < 0.1).

Interaction terms are made with a dummy variable and applied to the selected factors in the model to see how the variation of the neighborhood characteristics among the low-income ZCTAs are associated with the degree of the heat-related cardiac arrests in comparison of the other economic groups. The variable is marked with 1 if the average median income of the ZCTA is under or equals to 30% AMI, otherwise 0.

Selection of the independent variables in the multivariate regression model is fitted iteratively in a stepwise fashion. Started with all candidate variables that have a p-value < 0.10 in the Pearson's correlation test result, those indicate great multicollinearity from the VIF test are eliminated from the model. While avoiding extreme collinearity and searching for statistical significance at $p < 0.10$, the study seeks to identify essential criteria in the model that would explain the vulnerability of low-income neighborhoods during the heat wave. For example, the percentage of single households and percentage of age over 65 in ZCTA are removed from the regression model due to high multicollinearity even though they have p-values below 0.10 in the Pearson's test. Instead, the percentage of single households age over 65 is included to substitute the two variables and to reflect the characteristics in the model.

Table 3. Pearson's correlation test with Difference between Number of Cardiac Arrests, 2013

Pearson's correlation test						
N	**Neighborhood-level characteristics**	**r**	**p**	**Sig.**	**95 percent CI**	
181	Median Household Income	-0.169	0.023	**	(-0.307	-0.024)
181	Household type Single Household Age over 65	-0.016	0.827		(-0.162	0.130)
181	Household type Living Together Age over 65	-0.090	0.230		(-0.232	0.057)
181	Household type Single Household	0.149	0.045	*	(0.003	0.289)
181	Household type Family	-0.141	0.058	.	(-0.281	0.005)
181	Age under14	0.042	0.574		(-0.104	0.187)
181	Age 65plus	-0.143	0.054	.	(-0.283	0.003)
181	Age Other	0.122	0.101		(-0.024	0.263)
181	Race Non-Hispanic White	-0.196	0.008	**	(-0.333	-0.052)
181	Race Non-Hispanic Black	0.185	0.013	*	(0.040	0.322)
181	Race Non-Hispanic Asian	-0.190	0.010	*	(-0.326	-0.045)
181	Race Hispanic (all races)	0.176	0.018	*	(0.031	0.314)
181	Race Other	-0.035	0.640		(-0.180	0.111)
181	Edu less High School	0.096	0.197		(-0.050	0.239)
181	Edu Some College No Degree	0.027	0.714		(-0.119	0.173)
181	Edu BA or Higher	-0.088	0.237		(-0.231	0.058)
181	Community Centers	0.334	0.000	***	(0.198	0.458)
181	Community Gardens	0.311	0.000	***	(0.173	0.437)
181	Public Parks	0.453	0.000	***	(0.328	0.561)
181	Health Facility	0.310	0.000	***	(0.172	0.436)
181	Public Library	0.064	0.392		(-0.083	0.208)
176	Adults Reporting AC at Home	-0.131	0.084	.	(-0.273	0.018)
87	65+ Reporting AC at Home	-0.094	0.387		(-0.299	0.119)
170	Adult Obese	0.010	0.897		(-0.141	0.160)
176	Heart Disease Age 65 plus	0.102	0.179		(-0.047	0.246)
176	Heart Disease Age 35 to 64	0.099	0.193		(-0.050	0.243)
176	Tree Canopy	-0.101	0.181		(-0.245	0.047)

*Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1*
Data Sources: <Appendix II>

Multivariate Regression Model Equation

*Cardiac Arrest Incidents due to Extreme Heat = intercept + a *(Low Income) + b* Single Household Age over 65 + c* Family + d*Race Hispanic + e*Race Non-Hispanic Black + f*Race Non-Hispanic Asian + g*Community Centers+ h*Public Parks + i* Health Facilities + j*(Single Household Age over 65)*(Low Income) + k* Family*(Low Income) + l* Race Hispanic*(Low Income) + m*Race Non-Hispanic Black*(Low Income) + n*Race Non-Hispanic Asian*(Low Income) + o* Community Centers*(Low Income) + p* Public Parks*(Low Income) + q* Health Facilities*(Low Income) + error*

Indicator variable (Low Income): value of 1 if the median income is less than 30% AMI ($18,900), otherwise 0

Table 4. Result of Multivariate Linear Regression Model

Dependent Variable: Difference between cardiac arrest emergencies during Heat Wave and normal hot days in 2013 (Count)
Dummy (indicator variable): value of 1 if the median income is less than 30% AMI ($18,900), otherwise 0
⊗ coefficients corresponding with the same alphabets in the model equation

Multivariate Linear Regression Model with the difference between number of incidents, 2013							
Neighborhood-level Characteristics	⊗	Coefficients	Std. Err	95% CI	t-value	Pr(>|t|)	Sig.
(Intercept)		2.657	1.357	(-0.02, 5.34)	1.958	0.052	.
(Dummy)	*a*	0.753	0.683	(-0.60, 2.10)	1.103	0.27171	
Percent Single Household Age over 65	*b*	0.091	0.066	(-0.04, 0.22)	1.381	0.16929	
Percent Household type Family	*c*	-0.045	0.017	(-0.08, -0.01)	-2.699	0.00771	**
Percent Hispanic (all races)	*d*	0.007	0.018	(-0.03, 0.04)	0.392	0.6955	
Percent Non-Hispanic Black	*e*	0.026	0.012	(0.00, 0.05)	2.119	0.03566	*
Percent Non-Hispanic Asian	*f*	0.000	0.022	(-0.04, 0.04)	0.007	0.9941	
Number of Community Centers	*g*	-0.054	0.068	(-0.19, 0.08)	-0.793	0.42901	
Number of Public Parks	*h*	0.229	0.045	(0.14, 0.32)	5.088	1.01E-06	***
Number of Health Facilities	*i*	0.390	0.267	(-0.14, 0.92)	1.459	0.14653	
Percent Single Household Age over 65 * (Dummy)	*j*	-0.709	0.194	(-1.09, -0.33)	-3.654	0.00035	***
Percent Household type Family * (Dummy)	*k*	0.041	0.058	(-0.07, 0.16)	0.697	0.48684	
Percent Hispanic * (Dummy)	*l*	-0.005	0.054	(-0.11, 0.10)	-0.100	0.92036	
Percent Non-Hispanic Black * (Dummy)	*m*	0.297	0.127	(0.05, 0.55)	2.331	0.02102	*
Percent Non-Hispanic Asian * (Dummy)	*n*	0.167	0.104	(-0.04, 0.37)	1.610	0.10948	
Number of Community Centers * (Dummy)	*o*	0.355	0.180	(-0.00, 0.71)	1.967	0.05092	.
Number of Public Parks * (Dummy)	*p*	-0.265	0.133	(-0.53, -0.00)	-1.999	0.04736	*
Number of Health Facilities * (Dummy)	*q*	-0.834	0.918	(-2.65, 0.98)	-0.908	0.36548	

*Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1*
N:177 Zip Code Tabulation Areas (missing values. omitted)
Type: OLS linear regression
$F(17,159) = 6.19$, $p = 0.00$
$R^2 = 0.40$
Adj. $R^2 = 0.33$

Residuals:

Min	1Q	Median	3Q	Max
-6.193	-1.467	-0.135	1.658	7.527

Interpretation of the Results

Percentage of family households has a significantly negative association with the incidents of cardiac arrests by extreme heat in the moderate-income neighborhoods ($p<0.01$). The one-percentage-point increase of family households can explain the decrease of 0.045 cardiac emergency calls due to extreme heat. The relationship in the low-income neighborhoods is statistically insignificant. On the other hand, an increase of single households over age 65 has a strong negative relationship with the number of cardiac arrests due to extreme heat in the low-income neighborhoods. One percentage-point increase of single senior households in the low-income neighborhoods would explain 0.71 decrease of the heat effect on the medical emergencies, compared to the med-high income neighborhoods with 99% confidence.

The percentage of non-Hispanic Black has a positive correlation with incidents of heat-related cardiac arrests in the New York City neighborhoods ($p<0.05$). When other variables being equal, adding one-percentage-point of the Black population would increase the number of heat-related cardiac arrests by 0.026 in the med-high income neighborhoods while one-percentage-point increase of Black population in the low-income neighborhood would have 0.33 more cardiac arrests. In other words, the effect of Black on the cardiac emergencies is higher by 0.30 under the low-income condition, compared to moderate income.

Number of community centers is also positively related to the heat-related cardiac arrests occurred in the low-income neighborhoods. 0.36 more cardiac arrests are reported when there is another community center in the neighborhood ($p<0.10$). The association between the number of community centers and heat emergencies is found in the med-high income neighborhoods is statistically insignificant with 90% confidence. In the meantime, having another public park in the neighborhood drops the number of cardiac arrests by 0.27 in the low-income areas, compared to med-high income. The number of public parks has a different association with the heat-related cardiac arrests in the different income neighborhoods. A decrease of 0.036 cardiac arrests is related in the low-income neighborhoods when there is one more public park ($p<0.05$), but having one more public park is related to 0.23 more heat-related emergencies under moderate income condition ($p<0.001$). Overall, the model describes 40% of the variation of the heat effect on the cardiac arrest emergencies in 2013 with the explanatory variables (adjusted: 33%).

Power of the linear regression test is also examined with the sample and an effect size of f^2, calculated from the R^2 as Cohen (1988) defined, in order to determine the probability of detecting a true effect when it exists. Given the sample size of N = 177 and the effect size of f^2 = 0.49, there is a 99.9% probability of getting a statistical power with the level of alpha = 0 .05.

Model Fit

Various diagnostic tests were applied in order to identify if the model describes the data well. The p-value for the F-test below the significance level of 0.05 indicates that the sample data provide sufficient evidence to conclude the overall addition of the variables improves the fit of the model significantly. The model assumptions for linear regression were evaluated as well. Table 5 is the test results showing that the relationship between the explanatory variables and the dependent variable in the model is roughly linear, normally distributed, light tailed with low outliers with 95% confidence. Moreover, the results from the Link Function test and Heteroscedasticity test indicate that the distribution of the dependent variable is continuous and the residuals are not heteroscedastic but constant across the range of the independent variables at 95% confidence level.

	Value	p-value	Decision
Global Stat	2.275	0.685	Assumptions acceptable.
Skewness	0.274	0.601	Assumptions acceptable.
Kurtosis	0.030	0.863	Assumptions acceptable.
Link Function	0.017	0.897	Assumptions acceptable.
Heteroscedasticity	1.954	0.162	Assumptions acceptable.

Table 5. Assessment of the Linear Model Assumptions (level of significance= 0.05)

Residuals plots also visualize the model fit (Figure 18). By comparing the actual residuals to ideal distribution, the Normal Q-Q plot indicates that the basic assumption of normality is roughly met in this case. Residual vs. Fitted plot and Scale-Location plot depict the difference between observed residuals of the dependent variable and model-predicted residuals. They confirm the assumption of linearity and homoscedasticity as the distribution of the difference is normal without showing a significant pattern. Residuals vs. Leverage plot displays the Cook's Distance statistic to show if great influencers exist in the model that could mislead the relationship. There is no significant influencer in the model as none of the observations is over the Cook's Distance 1.

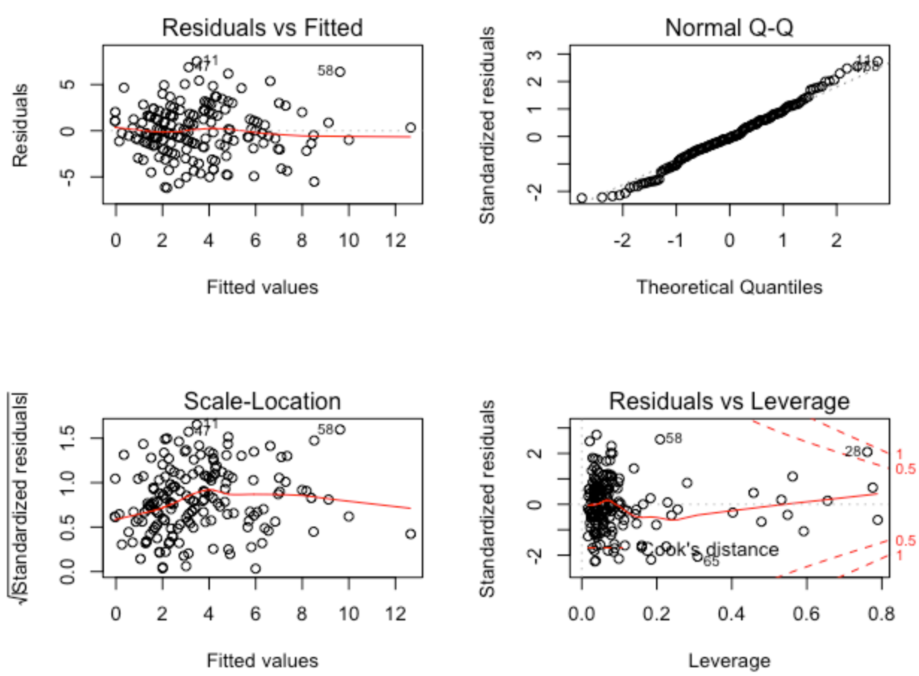

Figure 18. Residuals Analysis for Model fit

The variables used for the regression model were assessed for multicollinearity through measures of VIF (Table 6). There would be multicollinearity among the independent variables if sharing a linear relationship. Most of the test results are under 3, which means there is no significant multicollinearity found in the model, while there are few over 3. This study safely ignores VIF over 3 if the variables of interest have interacted with the indicator variable (Hair et al., 1998; Allison, 2012).

Table 6. VIF Test Results

Percent Single Household Age over 65	1.498
Percent Household type Family	1.406
Percent Hispanic	2.762
Percent Non-Hispanic Black	2.002
Percent Non-Hispanic Asian	1.911
Number of Community Centers	2.063
Number of Public Parks	1.682
Number of Health Facilities	1.428
Percent Single Household Age over 65 * (Dummy)	13.66
Percent Household type Family * (Dummy)	31.89
Percent Hispanic * (Dummy)	22.31
Percent Non-Hispanic Black * (Dummy)	25.31
Percent Non-Hispanic Asian * (Dummy)	6.111
Number of Community Centers * (Dummy)	5.393
Number of Public Parks * (Dummy)	7.824
Number of Health Facilities * (Dummy)	3.393
	Dummy =1: Income Less 30% AMI

Durbin-Watson (D-W) Test for spatial autocorrelations is also used to assess the residuals of the data in which the case is geographically adjacent. The null hypothesis of the D-W test is that there is no correlation among residuals, thus p-value < 0.05 from the test would indicate that the data might be autocorrelated and the observation is not independent of each other even though the measurement of the data was different. The D-W statistic (2.10) and the p-value (0.71) from the test for the model confirmed that there is no spatial autocorrelation observed in the model.

Prediction is also presented in order to measure how the model would perform with new data. A new model is rebuilt with randomly selected 80% of the existing sample to predict the dependent variable on the test data, the rest 36 (20%). By comparing the actual data with the predicted values for the test data, the model is tested for the measure of prediction accuracy (Figure 19). Calculated from a simple correlation accuracy test, 55.4% of the predicted and actual values have a similar directional movement, while Minimum/Maximum (Min/Max) Accuracy test indicates 43.5% of prediction matches the actual values. Min/Max Accuracy test compares the minimum and the maximum of the prediction and actuals for each data. The prediction model perfectly matches to the sample if the ratio of the two values is close to 1. Mean Absolute Percentage Error (MAPE) is not applied to test the model as the actual values of the dependent variable include 0.

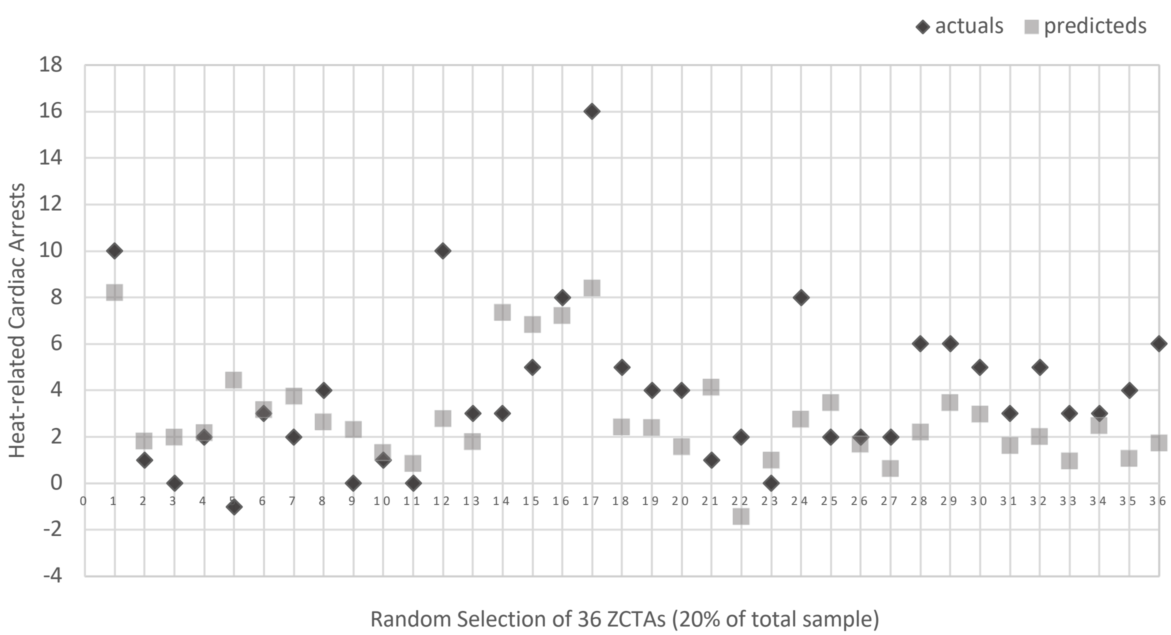

Figure 19. Comparison of the actual data with the predicted values for the test data

DISCUSSION

Household Types and Income

As the results from the Pearson's correlation and the bivariate relationship test between heat-related incidents and household types confirmed, an increase in the percentage-point of the general family households has a negative association with the number of heat-related cardiac arrests. Living with family and being out the risk for social isolation is negatively related to the increasing heat-related deaths as many other studies revealed (Klinenberg, 2002; Semenza et al.,1996). As families are supposed to take good care of each other that would result in reducing the risks of a health crisis, those in the med-high income neighborhoods reaffirmed the relationship in the model. However, the relationship is not statistically significant at 90% confidence level if the additional percent-point of family households was from the low-income neighborhoods.

On the other hand, the results from the multivariate model illustrate that more single seniors in the low-income ZCTAs are related to fewer heat-related cardiac arrest emergency calls while the variation of the explanatory variable does not have statistically significant power in the other neighborhoods. The significance of the correlation between the percentages of seniors living alone and the health risk during heat waves has been discussed in the other studies as well. While Rosenthal et al., (2014) found that living alone is not relevant to senior population's heat-related mortality in New York City, the relationship had been explicitly confirmed in other cities such as during the Chicago 1995 heat wave (Semenza et al.,1996).

In the meantime, the inconsistent results between the different income groups and the household types indicate that the combination of the risk factors may involve interesting and crucial implications. The dependent variable, the excessive number of cardiac arrest emergencies due to extreme heat, is a data that is limited to the incidents reported on the Emergency Medical

Service (EMS) system. In order to be regarded as an instance included in the data set, there should be someone to call for EMS when the tragedy occurs. With this fact, the declining number of single-living seniors' cardiac arrests in the low-income neighborhoods may result from a smaller number of the urgency informed to EMS. The statistical relationships between health risks and housing types need confirmation by comparing with the actual mortality in further research.

For the single living low-income seniors, a feasible "safety-net" is recommended to prevent the event of emergencies during heat waves. In New York City, the Department for the Aging and the NYC Service provide telephone reassurance service for people age 60 or older who live alone and have limited mobility. They use volunteers and social workers to place the calls and assess if any service is needed. Some people suggest wearable monitoring devices like pendants to wear around their neck or on wrists. However, neither of the check-in programs are cost-efficient, which could potentially strain budgets in large cities like NYC as more agents, and devices would be needed to check on a large number of seniors who might not answer.

One of the recommendations is to implement an automated system using technology like RUOK®, a computer program that automatically calls each subscriber in the system at a pre-set time every day (Figure 20). The program delivers a short-recorded message, which is in various languages when the senior responds on the phone. As it allows up to 150 calls per hour on a single phone line, the officer may monitor the responses through speakers while working on other duties. If the senior does not

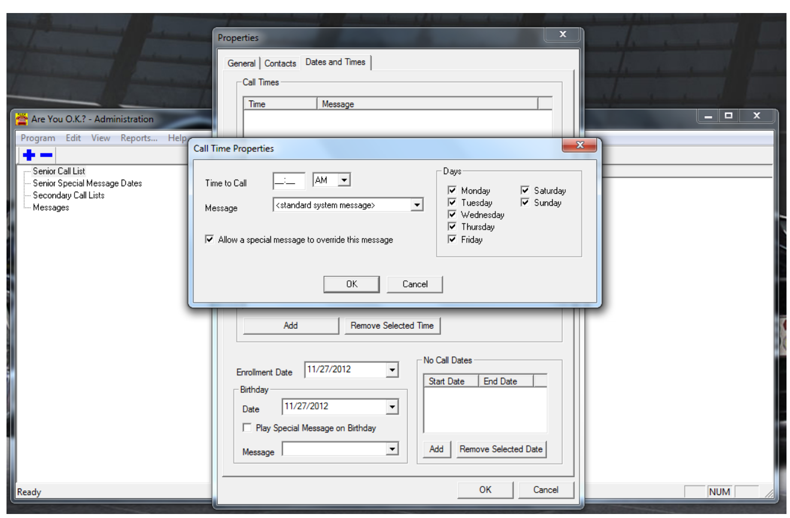

Figure 20. Example of Automated Reassurance System (https://www.ruok.com/)

answer after several attempts, the operator may get a visual alert on the computer screen, and a direct call or service will be requested in case of emergency. There are over 150 localities in North America as well as some counties in the New York State already using the system for their single-living seniors are. Although living alone with low-income as a senior can be a challenge in many ways, it would put them in the life-threatening risk during the heat waves. Therefore, the study suggests applying the system at a neighborhood-scale, which could be more cost-efficient when supporting the vulnerable population in the low-income communities to extreme heat.

Race

As seen in Figure 6 and Table 3, race and income are spatially dispersed, and the race is related to heat vulnerability ($p<0.05$). Due to high multicollinearity, the study included percentages of non-Hispanic Black, non-Hispanic Asian, and Hispanic population to test the impact of the demographic factor in the model. Increase in the percentage of Black is positively related to the number of the heat-related emergencies in both neighborhoods, while 0.30 more emergencies are found in the low-income neighborhoods, compared to the other income groups. Although the Hispanic population consists more than half of the total population in the low-income neighborhoods, variation in the percentage of the Hispanic population is not a statistically significant factor for the change in the incidents of heat emergencies.

The feature of the dependent variable may also explain the difference between Hispanic and Black. While a significant number of Medicaid-insured population in NYC resides in the low-income neighborhoods, studies demonstrate that those with the benefit tend to receive more emergency department care by EMS than the others with private insurance or uninsured (Hsia et al., 2018; Meisel et al., 2011). However, the results of the Health Care Coverage Status data from the BRFSS survey indicate that 29.7% of the Hispanic population in New York State are without health insurance in 2013 while 15.5% of non-Hispanic Black, 8.1% of non-Hispanic White, and 17.2% of other races are uninsured. Although a practical examination on the difference is desirable, the disparity in health care coverage by race might explain the significance of the difference between the number of heat-related cardiac arrest reported among the people of color in the low-income neighborhoods. The study suggests a holistic approach in further research to discuss the relationships between race and the difference of the heat-related emergencies and Medicaid beneficiaries among the different income neighborhoods.

Number of Community Facilities

A large quantity of the entire community facilities in New York City is located in the low-income neighborhoods (Figure 8). The 22 low-income neighborhoods have 126 community centers (average 5.73 per each ZCTA) while 327 centers are located in the 159 med-high income communities (average 2.06). The location of NYCHA facilities, senior centers, and public libraries are important places for the most low-income residents who are concerned about utility fees and decide not to use AC at home during the Summer as the local government designated the community centers as cooling centers during heat waves to serve those residents.

Figure 21. Appropriate signage for NYC cooling centers

However, the results from the statistical analysis revealed that more of the heat-related emergency calls are reported in the low-income neighborhoods where a higher number of the community centers are located.

One of the plausible explanations for the positive correlation in the low-income neighborhoods might be that the residents would watch over each other and make calls for EMS in the places where people have a strong sense of community (Stansfeld, 1999; Berkman and Glass, 2000). However, another possibility is that lots of community centers in the low-income neighborhood do not necessarily represent a large number of cooling centers functioning properly during the heat waves. Even in the recent years, not many residents in NYC visit the cooling centers as much as the City expect during sweltering weather as people prefer to stay at home even when dangerously hot (Lane et al., 2013). Moreover, older adults in New York City assume they are not particularly vulnerable to extreme heat as they are used to the hot weather in the city (Sampson et al., 2013). Therefore, the Cool Neighborhoods NYC report proposed distribution of Home Health Aids during the scorching weather. However, strategies should be diversified to tackle the issue. For instance, developing appropriate programs for the adults, such as recreational camps and cultural events, at the libraries and other community facilities in the low-income neighborhoods during the heat waves might encourage them to leave their homes and attend the cooling centers.

Public schools and colleges near the low-income neighborhoods could also be a help to serve the locals pragmatically during heat waves. Some universities, such as Western Illinois University in Macomb, open their residence halls and the University Union building to the people in the area during heat waves. In addition to functioning as a cooling center, public schools and colleges could open a free educational program during the hot days to better support the locals.

The opportunity would provide the low-income residents with educational and training opportunities while encouraging them to stay in air-conditioned places.

As the local government also acknowledges the same problem that people are ignorant of the function of cooling centers, in 2017, the NYC Emergency Management presented the improvement plans for the cooling centers. These plans include distribution of a 24” x 36” vinyl sign for each cooling center to display at their main entrance to notify the community that the facility is operating as a cooling center during heat waves (Figure 21). However, as Fumiko Lipp from the WNYC Harlem Heat Project team reported in August 2018, many of the cooling centers do not publicly display them (Figure 22). Although measuring the actual operation of each cooling center might be difficult, the City would have to put more effort on developing systematic operation guidelines as well as program evaluation for the cooling centers like Maricopa County in Arizona did (Berisha et al., 2017).

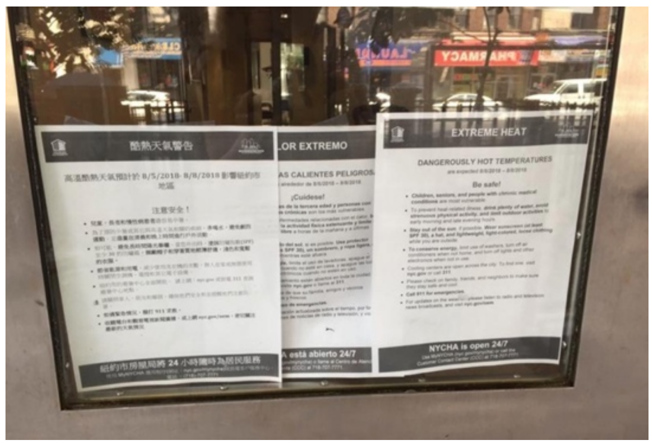

Figure 22. Inappropriate signage for NYC cooling centers

Public parks

An increase in the number of public parks statistically explained the decreasing number of cardiac emergencies in the low-income neighborhoods. In the meantime, the variation of the percent-point of tree canopy is not a statistical explanatory variable of the heat-related emergencies, and percentage of vegetation shades is not correlated to the number of parks in the neighborhood (r=0.09, p=0.21). In other words, having more parks in the neighborhood does not necessarily mean that there are more trees with a greater cooling effect on the high temperature during the heat waves.

In that case, the difference between the public parks and the street trees in the low-income neighborhoods is that the parks can become a place for physical activities and social integration. According to the National Recreation and Park Association (NRPA), public parks not only encourage exercise and reduce air pollution but also bring additional boosts to the local economy in low-income neighborhoods (2018). Proximity to the well-maintained parks generally increases property value, and they can be a platform for various programs and events.

The effect of the public parks on the heat-related extreme number of emergencies supports the City's Community Parks Initiative, which aims at improving neglected public parks in the low-income neighborhoods. The initiative has invested $285 million for physical improvement and program development with proper maintenance and upgrades in 67 community parks across the five boroughs. The study recommends that the expansion of the Community Parks Initiative may also involve an appropriate choice of species and shape of the parks that could maximize the cooling effect of the green spaces (Feyisa et al., 2014). It would be another relatively affordable and feasible option for extreme heat mitigation in the low-income neighborhoods.

LIMITATIONS

The results from the analysis reflect the limitations of the research. To the extent, they explain the vulnerability of low-income households to extreme heat in New York City. However, it might be challenging to ensure that the selection of the subjects mirrors the population in this study. First, the dependent variable is comprised of the EMS calls data which might be limited to define the excessive heat-related health crisis as same as the other heat vulnerability studies that compared temperature and mortality (Rosenthal, 2010; Rosenthal et al., 2014; Madrigano et al., 2015; Romero-Lankao et al., 2012). While a determination of a cause of death is different among various studies, the precedents adopt natural cause deaths to indicate the number of heat-related deaths. Due to the restricted access to the data of the deceased population in New York City, the study uses the most similar definition of the critical health outcome, cardiac arrests. However, some heat-related cardiac arrests might occur without being reported on the EMS system. Therefore, it is possible that the numbers of emergency calls are not explicitly representing the people in trauma that directly relates to the actual heat-related death.

Aggregation of the data to the ZCTAs also makes it intricate to explain the linear relationship between the heat-vulnerability of each person and the neighborhood-level characteristics. Moreover, it is not reasonable to apply the same results to a larger population. Finally, the study only assessed the vulnerability of the population based in the year of 2013 while the year of some independent variables does not precisely match with the other data sets due to limited availability and accessibility. Therefore, it is possible that selecting different year or multi-years might offer different results of the association.

Despite the limitations mentioned above, the study reaffirms the importance of addressing the relationship between the neighborhood-scale characteristics and the heat-related severe health crisis of the low-income population in New York City. The design of the study should be replicated in other studies and reproduced with different dependent variables and geographical settings. In this context, the comparison of the results with the actual mortality data is highly desirable. Such findings would suggest qualitative understanding in depth of the unusual association of the independent variables among the different income groups from health emergencies to actual death. Furthermore, financing models for different heat-related policies and strategies should also be discussed in further research.

CONCLUSION

The study identifies that the variation of the neighborhood factors, such as different household types, race, number of community facilities and public parks, is associated with the heat-related cardiac arrests among the different income groups in New York City. The statistical results proved that the heat emergencies occurred in the low-income neighborhoods are significantly linked to the percentages of single senior households and Black populations, the number of community centers, and public parks.

Although the City has put their efforts into providing more cooling services for the residents during the heat waves, these findings suggest that New York City should reevaluate and improve their strategies to prevent the heat emergencies in the low-income neighborhoods. Using advanced technology, the City should deliberate on reassurance programs for the low-income single seniors. Moreover, the effectiveness of the cooling facilities and the programs should be thoroughly programmed and managed by the public entity regardless of the quantity of cooling infrastructure within the neighborhood boundary. In addition, the existing initiatives and policies for improving parks in the low-income neighborhoods should involve climate mitigation planning to maximize the potential impact since the results identify the significant role of the parks in the areas.

Given the importance of preventing the worst cases of heat-related health crisis during heat waves, the study also suggests further research on the comparison of the EMS reports and the actual mortality in order to discover whether the higher number of reported incidents is absolute evidence indicating more deaths. Through the work of elaboration, New York City will be able to help the low-income residents to be more resilient to extreme heat.

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APPENDICES

<Appendix I> Information of the historic heat waves in New York City

Longest Heat Waves – Consecutive 90 Degrees + Days (1869 to Present)

A heat wave is defined as 3 or more consecutive 90 Degree + Days

Last Updated: 7/8/18

Days	Dates	Temperatures
12	August 24 - September 4, 1953	91,91,91,94,98,99,98,100,97,102,94,90
11	July 23 - August 2, 1999	92,97,97,93,96,97,93,92,90,98,90
10	July 7 - 16, 1993	98,100,101,102,97,94,94,91,90,90
	August 4 - 13, 1896	90,94,92,97,95,98,94,96,93,90
9	August 11 - 19, 2002	92,96,98,95,92,93,94,94,94
	July 13 - 21, 1977	93,92,96,98,97,100, 102,92,104
	July 6 - 14, 1966	91,93,91,91,91,94,99,101,95
	July 5 - 13, 1944	93,94,91,94,92,91,93,93,91
8	July 29 - August 5, 2002	96, 95, 95, 96, 97, 90, 92, 91
	August 2 - 9, 1980	91, 92, 91, 94, 93, 94, 96, 95
	August 28 - September 4, 1973	98, 95, 98, 94, 95, 94, 96, 93
	August 10 - 17, 1944	97, 102, 97, 96, 95, 95, 96, 95
	June 26 - July 3, 1901	91,91,93,95,95,100,100,94
7	July 14 - 20, 2013	90, 94, 94, 97, 98, 96, 93
	July 29 - August 4, 1995	93, 93, 91, 94, 96, 90, 96
	August 9 - 15, 1998	93, 93, 95, 94, 96, 99, 97
	July 15 - 21, 1991	90, 93, 96, 99, 96, 100, 102
	July 12 - 18, 1983	94, 93, 94, 98, 96, 93, 97
	July 7 - 13, 1981	94, 95, 96, 93, 94, 94, 93
	August 1 - 7, 1955	98, 100, 90, 95, 100, 97, 93
	July 15 - 21, 1953	92, 97, 100, 101, 91, 90, 90

Source: National Weather Service New York, US Department of Commerce, & NOAA (2018)

<Appendix II> Sources of data for analysis

Indicator	***Data***	***Measure***	***Source***	***Year***
Dependent Variable	Historic Heat Wave	Days	National Weather Service (CPK)	2013
	Emergency Response Incidents	Counts	NYC Office of Emergency Management (OEM)	2013
Independent Variable				
Socio-Economic	Age under 14 and 65+	Percent	American Community Survey (ACS)	2013
	Educational Attainment	Cohort	American Community Survey (ACS)	2013
	Race	Type	American Community Survey (ACS)	2013
	Household type (living alone)	Percent	American Community Survey (ACS)	2013
Built Environment	Vegetation cover (tree canopy)	Percent	The Built Environment & Health Project (BEH); Columbia University	2014
	Public Parks	Count	NYC Department of City Planning (DCP)	2011
	Community Gardens	Count	Department of City Planning	2014
	A/C at home	Percent	New York City Community Health Survey (CHS)	2013
Community Resource	Community Facilities	Count	Department of City Planning	2014
	Public Libraries	Count	NYC Emergency Management	2015
	Health Facilities	Count	NYC Emergency Management	2015
Health Risk	Adult obese	Percent	Centers for Disease Control and Prevention (CDC)	2014
	Adult with heart disease	Percent	Centers for Disease Control and Prevention (CDC)	2013

<Appendix III> Descriptive statistics with means and standard deviations of the all variables

* Difference between Calls during Heat Wave and Normal Hot days	mode	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
Heat Effect*	Count	181	3.44	3.53	3	3.23	2.97	-4	16	20	0.58	0.4	0.26
Calls during SU 2013	Count	181	29.44	19.86	26	27.63	19.27	1	84	83	0.73	-0.08	1.48
Calls during June23-30	Count	181	1.93	2.14	1	1.59	1.48	0	11	11	1.55	3	0.16
Calls during Heat Wave July14-20	Count	181	5.37	3.95	4	5.09	4.45	0	17	17	0.55	-0.6	0.29
Median Household Income	USD	181	35992.82	21057	29454	32166.53	12053.54	13112	133198	120086	2.05	4.83	1565.15
Household type Single Household Age over 65	%	181	10.42	5.37	9.9	9.99	3.56	0	59.7	59.7	4.43	37.4	0.4
Household type Living Together Age over 65	%	181	0.59	0.52	0.5	0.54	0.3	0	5.9	5.9	6.19	59.63	0.04
Household type Single Household	%	181	32.21	11.86	29.9	31.33	11.27	8.7	64.5	55.8	0.62	-0.23	0.88
Household type Family	%	181	60.3	15.16	63.1	61.51	15.86	20.4	87.4	67	-0.6	-0.44	1.13
Age under14	%	181	10.75	3.63	11.3	10.98	3.41	0	18.2	18.2	-0.56	-0.03	0.27
Age 65plus	%	181	13.7	7.36	12.5	13.08	4.15	0	87.2	87.2	5.59	52.75	0.55
Age 1465	%	181	24.45	7.37	24.8	24.38	3.85	2.6	87.2	84.6	3.03	28.25	0.55
Age Other	%	181	75.55	7.37	75.2	75.62	3.85	12.8	97.4	84.6	-3.03	28.25	0.55
Race Hispanic	%	181	25.39	19.9	17.6	22.36	13.05	0.8	74	73.2	1.14	0.13	1.48
Race Non-Hispanic White	%	181	38.29	27.94	40.1	37.36	38.84	0.6	98.1	97.5	0.15	-1.36	2.08
Race Non-Hispanic Black	%	181	20.11	24.73	7.1	15.29	9.19	0	90.1	90.1	1.41	0.85	1.84
Race Non-Hispanic Asian	%	181	13.39	13.08	8.9	11.32	9.79	0	70.4	70.4	1.42	1.93	0.97
Race Other	%	181	2.81	3.18	2.2	2.3	1.19	0	31.6	31.6	5.91	44.58	0.24
Edu less High School	%	181	46.18	18.85	50.7	47.68	15.72	5	76.8	71.8	-0.69	-0.54	1.4
Edu Some College No Degree	%	181	14.12	4.51	14.7	14.16	4.45	3.3	24.8	21.5	-0.14	-0.41	0.34
Edu BA or Higher	%	181	39.7	21.95	32.7	37.51	16.75	9	91.5	82.5	0.86	-0.39	1.63
NYCHA Community Centers	Count	181	2.5	4.49	0	1.54	0	0	36	36	3.57	18.57	0.33
Community Gardens	Count	181	2.41	5.86	0	0.92	0	0	43	43	3.92	19.05	0.44
Public Parks	Count	181	6.86	6.11	6	5.95	4.45	0	32	32	1.49	2.61	0.45
Health Facility	Count	181	0.45	0.95	0	0.21	0	0	5	5	2.29	5.01	0.07
Public Library	Count	181	0.08	0.27	0	0	0	0	1	1	3.14	7.89	0.02
Adults Reporting AC at Home	%	176	87.58	5.44	88.6	87.93	6.23	73.6	94.8	21.2	-0.52	-0.83	0.41
65+ Reporting AC at Home	%	87	82.71	9.15	83.6	83.25	11.56	58.4	95.8	37.4	-0.52	-0.42	0.98
Obesity	%	170	23.89	9.29	25.85	23.96	8.97	1.7	52.9	51.2	0.17	0.9	0.71
Heart Disease Age 65 plus	%	176	60.17	18.34	59.4	58.63	18.68	29.4	100	70.6	0.49	-0.46	1.38
Heart Disease Age 35 to 64	%	176	12.89	4.8	12.9	12.73	4.3	4.2	24.8	20.6	0.2	-0.53	0.36
Tree Canopy	%	176	18.66	7.01	17.59	18.14	6.13	7.08	46.93	39.85	0.96	1.86	0.53

<Appendix IV> Mean, median, and trimmed mean of all the explanatory variables

	NYC			Low Income ZCTA			Med-High Income ZCTA		
	Average	Median	Trimmed (<0.1)	Average	Median	Trimmed (<0.1)	Average	Median	Trimmed (<0.1)
Socio-demographics									
Single Households	32.21	(29.90)	31.33	30.94	(29.75)	30.67	32.38	(30.00)	31.54
Single Households (age over 65)	10.42	(9.90)	9.99	11.31	(9.85)	10.45	10.29	(9.90)	9.93
Households living with Family	60.30	(63.10)	61.51	63.55	(66.30)	63.61	59.85	(62.00)	60.96
Households living Together (age over 65)	0.59	(.50)	0.54	0.50	(.45)	0.48	0.61	(.50)	0.55
Age over 65	13.70	(12.50)	13.08	11.22	(9.20)	9.96	14.05	(13.10)	13.52
Age under 14	10.75	(11.30)	10.98	14.37	(15.20)	14.6	10.25	(11.00)	10.51
Age Other	75.55	(75.20)	75.62	74.41	(75.50)	75.22	75.71	(75.20)	75.73
Hispanic	25.39	(17.6)	22.36	53.86	(64.45)	56.13	21.45	(15.5)	18.8
Non-Hispanic White	38.29	(40.1)	37.36	11.96	(3.35)	8.28	41.94	(44.1)	41.67
Non-Hispanic Black	20.11	(7.1)	15.29	25.23	(23.9)	24.74	19.41	(6.4)	14.51
Non-Hispanic Asian	13.39	(8.9)	11.32	7.39	(2.45)	4.21	14.22	(9.8)	12.38
Other	2.81	(2.2)	2.3	1.56	(1.4)	1.48	2.99	(2.3)	2.43
Less than High School	46.18	(50.70)	47.68	66.35	(68.40)	66.76	43.39	(48.40)	44.65
Some College No Degree	14.12	(14.70)	14.16	15.64	(16.45)	16.04	13.91	(14.30)	13.88
Bachelors or Higher	39.70	(32.70)	37.51	18.01	(15.40)	17.17	42.70	(35.30)	40.76
Community Resources									
Community Centers	2.50	(.00)	1.54	5.73	(4.50)	4.72	2.06	(.00)	1.22
Health Facilities	0.45	(.00)	0.21	0.68	(.00)	0.5	0.42	(.00)	0.19
City-owned Public Library	0.08	(.00)	0	0.09	(.00)	0	0.08	(.00)	0
Characteristics of Built Environment									
Tree Canopy	18.66	(17.59)	18.14	16.56	(15.80)	16.51	18.95	(17.59)	18.34
Adults reporting AC at home	87.58	(88.60)	87.93	83.47	(81.00)	83.01	88.17	(89.20)	88.65
Adults over 65 reporting AC	82.71	(83.60)	83.25	75.17	(74.70)	74.9	84.40	(86.70)	84.59
Community Gardens	2.41	(.00)	0.92	6.45	(5.50)	5.78	1.86	(.00)	0.47
Public Parks	6.86	(6.00)	5.95	12.05	(9.50)	11.94	6.14	(5.00)	5.33
Health Risk Characteristics									
Adults Obese	23.89	(25.85)	23.96	33.03	(30.45)	32.71	22.53	(25.20)	22.89
65+ with Heart Disease	60.17	(59.40)	58.63	73.13	(69.20)	72.9	58.31	(59.00)	56.92
35-64 with Heart Disease	12.89	(12.90)	12.73	16.20	(16.70)	16.35	12.42	(12.35)	12.18