Thesis

Analyzing Vulnerability of Low-Income Population to Extreme Heat in NYC, 2013

Contents

Heat Wave Impact in Large Cities

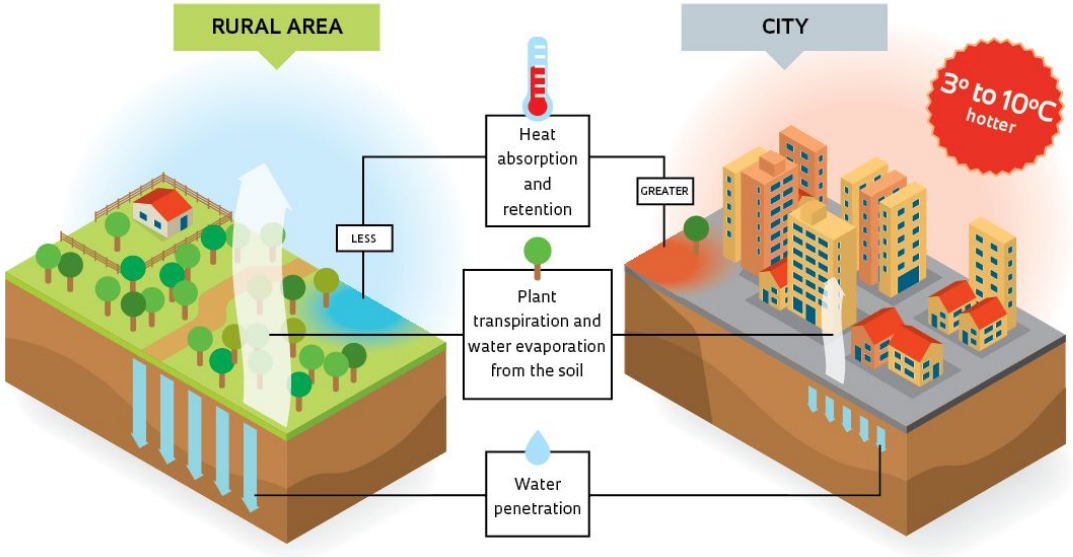
Heat wave
a period of abnormally hot and uncomfortably humid weather

Heat stress
heat related illness, which can result in death

Example
2006 North American Heat Wave: **225 heat related deaths** in the U.S. and Canada **in a month** *(Butler, 2011)*

Heat Wave Impact in Large Cities

24+ died in New York City
(10%+ of the total) (Pérez-Peña, 2006)



by Alexandre Affonso

Extreme Heat and Low Income Population

Seniors, outdoor workers, children, and low income households are more at risk of having heat-related illnesses than others. *(Centers for Disease Control and Prevention)*

Characteristics of low income neighbors

Built Environment
High rise buildings, long term disinvestment
(Santamouris & Kolokotsa, 2015)

Energy Poverty
Less likely to use A/C (fee, utility)
(White-Newsome et al., 2012)

Pre-existing Health Problems
Prone to heat-related illness
(Hatvani-Kovacs et al., 2016)

Purpose of the Study

To examine **neighborhood scale characteristics** of **low-income population** and their **vulnerability to extreme heat** in NYC, compared to other income groups.

Addressing gap

- Previous heat-vulnerability study in NYC focused on senior population. (Rosenthal & Kinney, 2014)

Planning implication

- **Vulnerability to natural disaster is different from resilience.** (Akter, 2013)
- **Understanding their neighborhood characteristics**;
  and **finding better public policy** to improve the **level of the population health.**

Research Design

Empirical research - examine sets of **numeric data** as variables to **test out the research hypotheses**

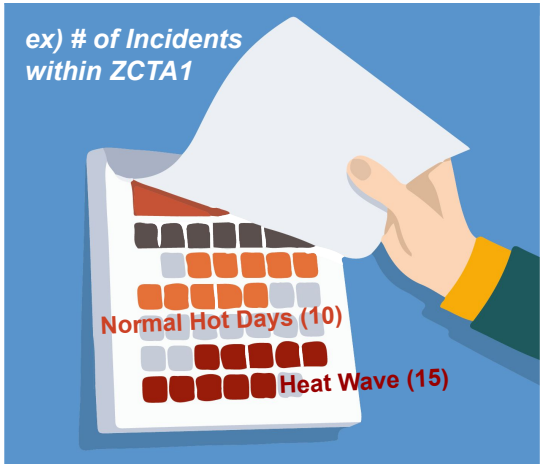
Research Hypotheses

- Low-incomes are more vulnerable to extreme heat than other income groups in NYC
- Neighborhood-scale factors indicate their vulnerability to extreme heat

Measuring Key Concepts

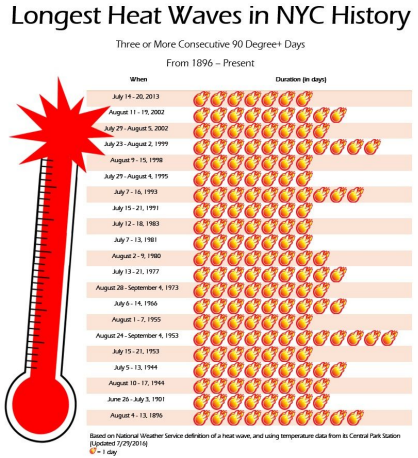
Dependent Variable *Excessive **Cardiac Arrests due to Extreme heat***

Cardiac Arrests
The abrupt loss of heart function, could indicate imminent death
(American Heart Association)



Heat-related Cardiac Arrests

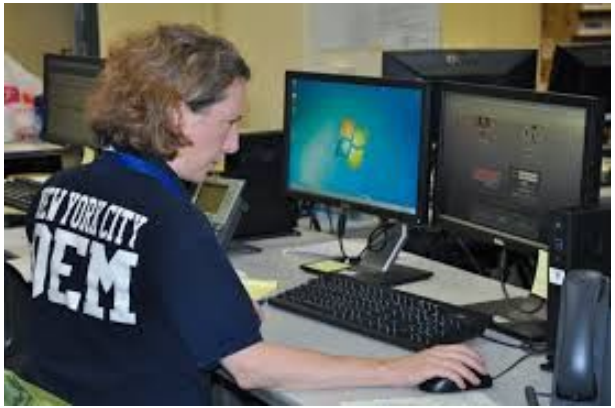
(heat wave) - (normal hot days) = (5)



2013 Heat Wave (July 14-20)
One of the longest heat waves in NYC history since 2000
(National Weather Service New York)

Measuring Key Concepts

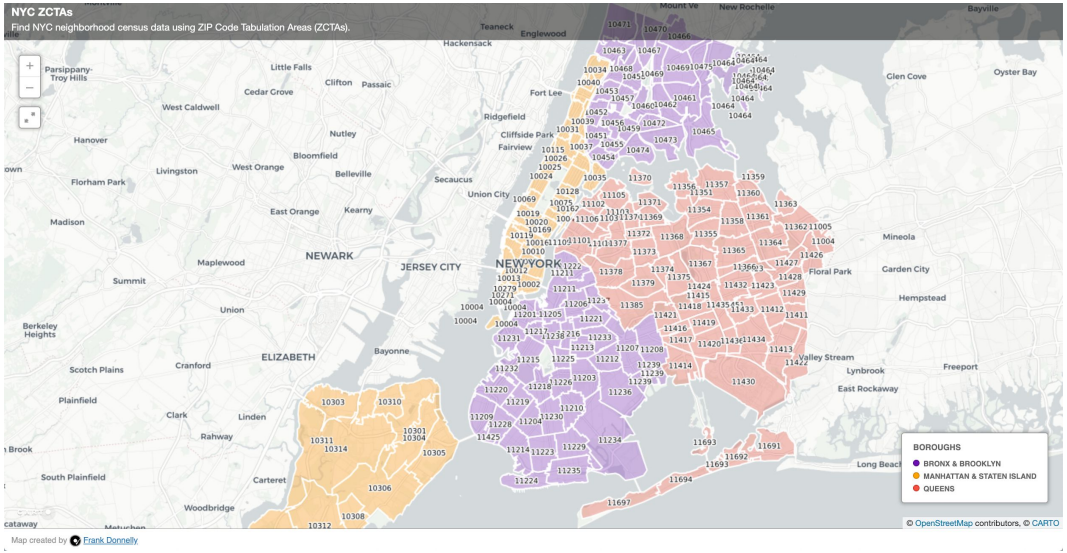
Dependent Variable *Excessive **Cardiac Arrests due to Extreme heat***



- Source:
  Emergency Medical Services **(EMS) calls data for cardiac arrests** during the appointed time periods in 2013
  (NYC Office of Emergency Management)
- Incidents cancelled, duplicated, unfounded, treated or condition corrected on site were removed from the data set
- **Aggregated to** the counts by each **ZCTA for use**
  Use of ZCTAs to **examine the relationship between built environment and health** outcomes *(Krieger et al., 2002)*

Spatial Unit of Analysis

ZIP Code Tabulation Area
(by US Bureau of Census)



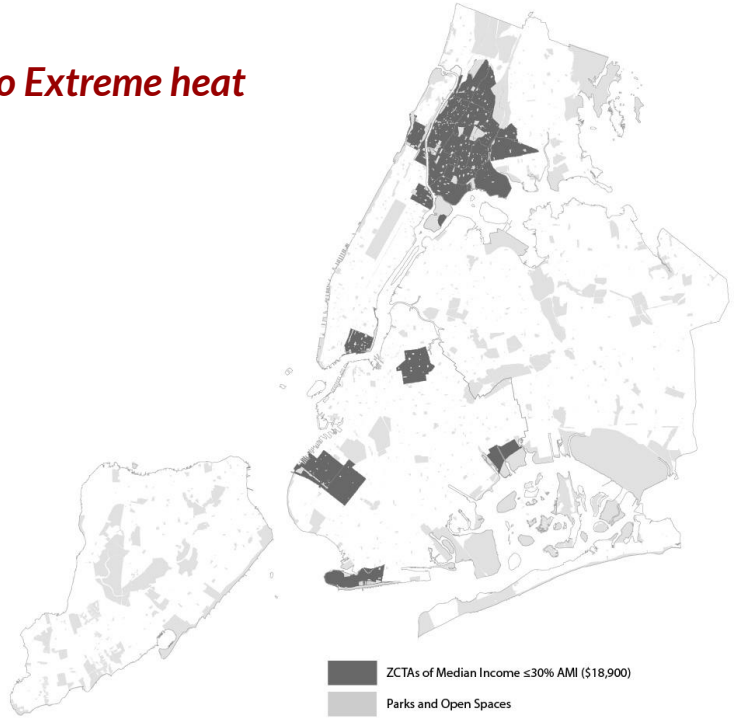
- **181** ZCTAs in NYC,
  typically have a population of about 7,000 each

- Use of ZCTAs to **examine the relationship between built environment and health** outcomes *(Krieger et al., 2002)*

Measuring Key Concepts

Dependent Variable *Excessive **Cardiac Arrests due to Extreme heat***

- **"low-income neighborhoods"** are defined as the ZCTAs with an **average income of below or at $18,900** measured in 2013, which is **30% of the NYC's AMI**.
- 22 low-income ZCTAs in 2013



Measuring Key Concepts

Indicators and Explanatory Variables

Socio-demographic Characteristics *(CDC)*

- *Age under 14 and 65+*
- *Education level (Hatvani-Kovacs et al., 2016)*
- *Race (NYC Environmental Justice Alliance, 2018)*
- *Household type (living alone)*

Heat Impact Mitigation Strategies *(Rosenzweig, 2015)*

- *Percent vegetation cover (Tree canopy)*
- *AC access in home (Hernández, 2013)*
- *Number of Parks and Open Spaces*

Community Resources *(NYC Emergency Management)*

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

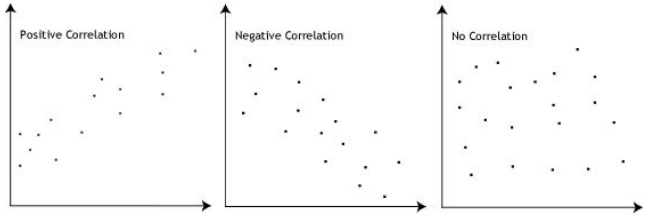
Health Risk Characteristics *(Hatvani-Kovacs et al., 2016)*

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

Statistical Analysis *(Rosenthal et al., 2014)*

Step 1: Pearson's correlation test

to select the most relevant variables for the use
in the multiple linear regression model



Step 2: Create Dummy Variable indicating low-income ZCTA (≤ 30%AMI = 1, otherwise 0)

to see the effect of low-income:
Comparison of low-income/moderate income ZCTAs
with the variation of explanatory variables

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*

Statistical Analysis

Step 3: Selection of independent variable

- Started with all candidate variables of **p-value < 0.10 in the Pearson's correlation** test result
- **Eliminated** those indicate **great multicollinearity** from the VIF test
- Try to **identify essential criteria in the model** that would explain the vulnerability of low-income neighborhoods during the heat wave.

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)
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181	Household type Single Household	0.149	0.045	*	(0.003	0.289)
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181	Age under14	0.042	0.574		(-0.104	0.187)
181	Age 65plus	-0.143	0.054	.	(-0.283	0.003)

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 * (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	

Statistical Analysis

Step 4: Linear Regression Model

- **Level of p<0.10** is considered variables significant
- alpha=0 .05 is used in the power test to ensure a statistical power of the model

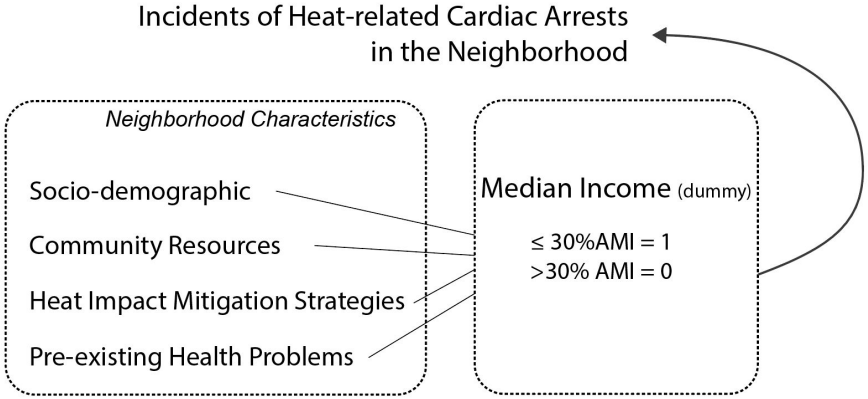


Table 4. Result of Multivariate Linear Regression Model

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*

Validity & Reliability

Ensuring the selection of the subjects mirrors the population

→ Closest definition of heat-related health impact to other studies:

cf) Natural death rates during (heat waves - normal hot days)

(Rosenthal, 2010; Rosenthal et al., 2014; Madrigano et al., 2015; Romero-Lankao et al., 2012)

Possibility of incidents excluded in the database

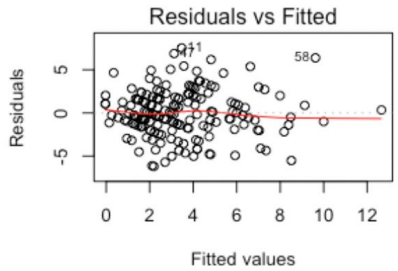
Some heat-related cardiac arrests might occur *without* being reported on the EMS system

→ limited accessibility, suggesting further research using the same method

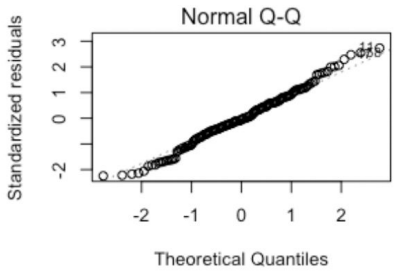
Methodological reliability and validity

⟶ same statistical approach as other heat vulnerability studies; model fit diagnostics

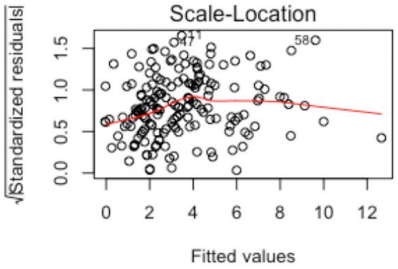
Regression Diagnostics



Linearity and homoscedasticity



Assumption of normality



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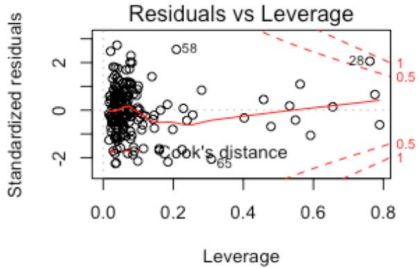


No significant influencer

Residual diagnostic plots

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

Multicollinearity test if sharing a linear relationship

Most <3, ignore variables with interaction terms

(Hair et al., 1998; Allison, 2012)

Regression Diagnostics

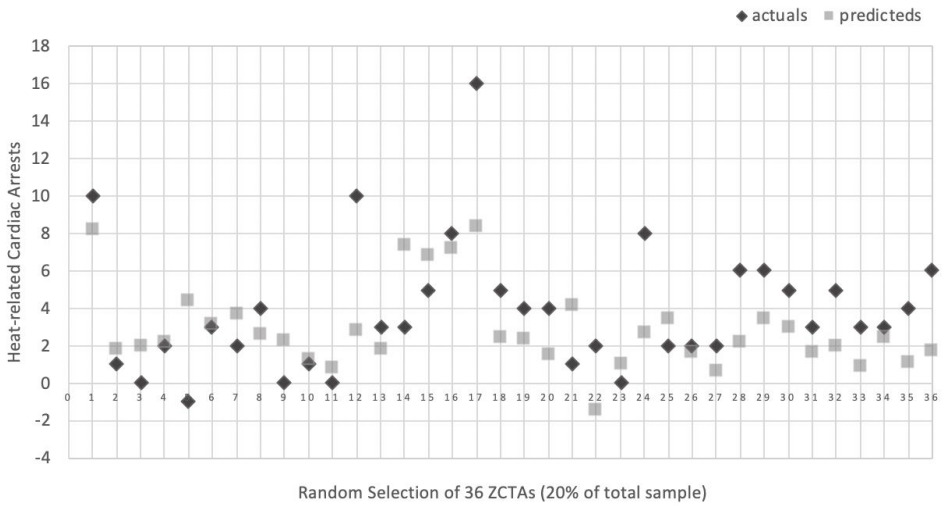


Figure 19. Comparison of the actual data with the predicted values for the test data

Prediction *(how model performs with new data)*

New model rebuilt with randomly selected 80% of the existing sample to predict the dependent variable on the test data, the rest 36 (20%).

Simple correlation accuracy test= 55.4%
of predicted and actuals have similar directional movement

Min/Max Accuracy test = 43.5%
of prediction matches the actual values

Socio-Demographic Characteristics

Compared to other income groups, in the low-income ZCTAs…

- 2% ***more*** households live together
- 1% ***less*** of senior population
- 38 % ***more*** of Hispanic & non-hispanic Black
- ***Less*** of non-hispanic White and Asian

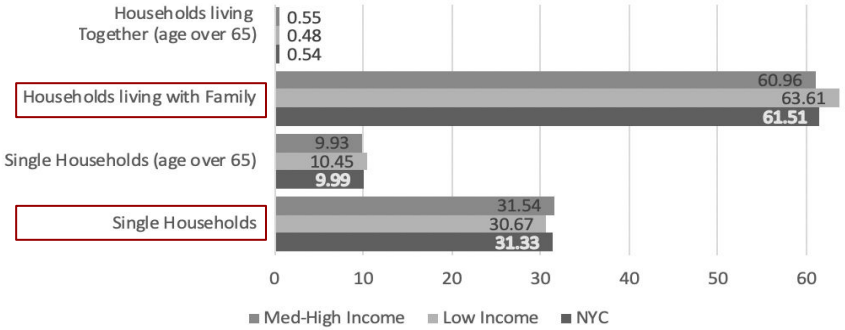


Figure 4. Comparison of Household Types (Trimmed-mean: %)

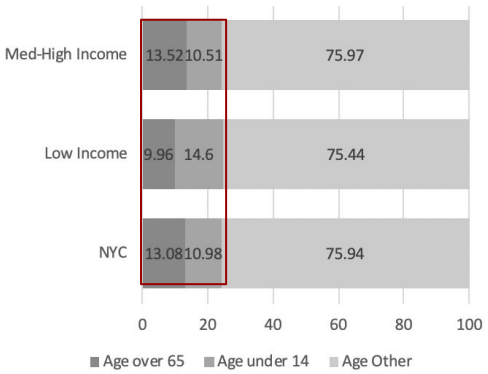


Figure 5. Comparison of Age (Trimmed-mean: %)

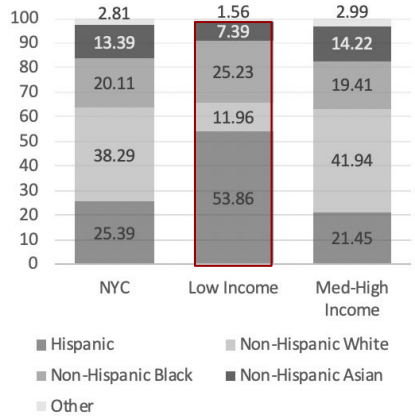


Figure 6. Comparison of Race (Trimmed-mean: %)

Community Resources & Access to AC at home

In low-income ZCTAs…

- 126 community centers (cooling centers) out of 453 in NYC

  = Average of 4.72/ZCTA

  cf. 1.54 in each med-high income ZCTA

- ***Less*** % of adults reporting AC access

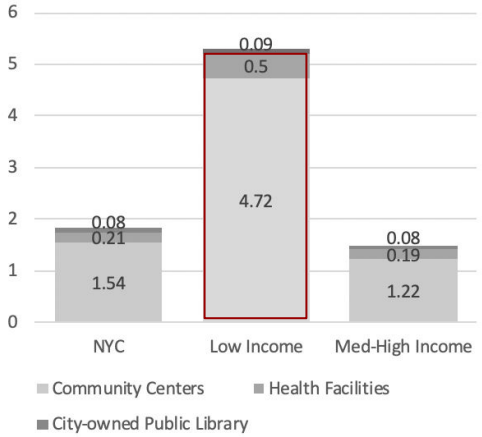


Figure 8. Count of Community Facilities (Trimmed-mean)

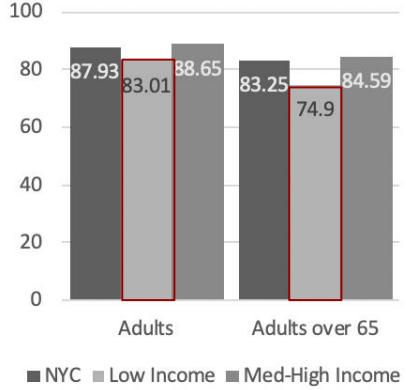


Figure 11. Comparison of Adults Reporting AC at home (Trimmed-mean: %)

Strategies to Heat Impact Mitigation

In low-income ZCTAs…

- 2% ***less*** tree shades covering land
- But a lot ***more*** number of public parks, and community gardens

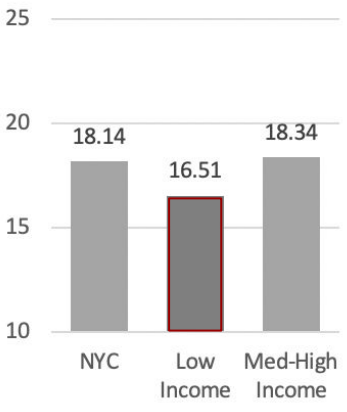


Figure 9. Comparison of Tree Canopy (Trimmed-mean: %)

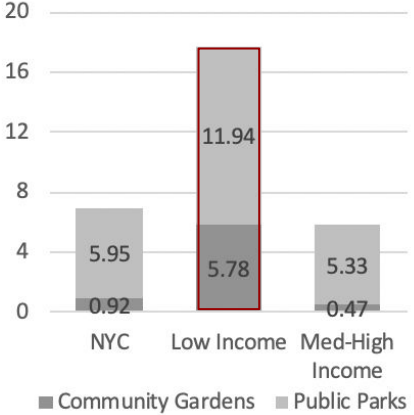


Figure 10. Comparison of Parks and Gardens (Trimmed-mean: Count)

Pre-existing Health Risks

In low-income ZCTAs…

- 10% ***more*** adults obese
- ***More*** adults with chronic heart disease

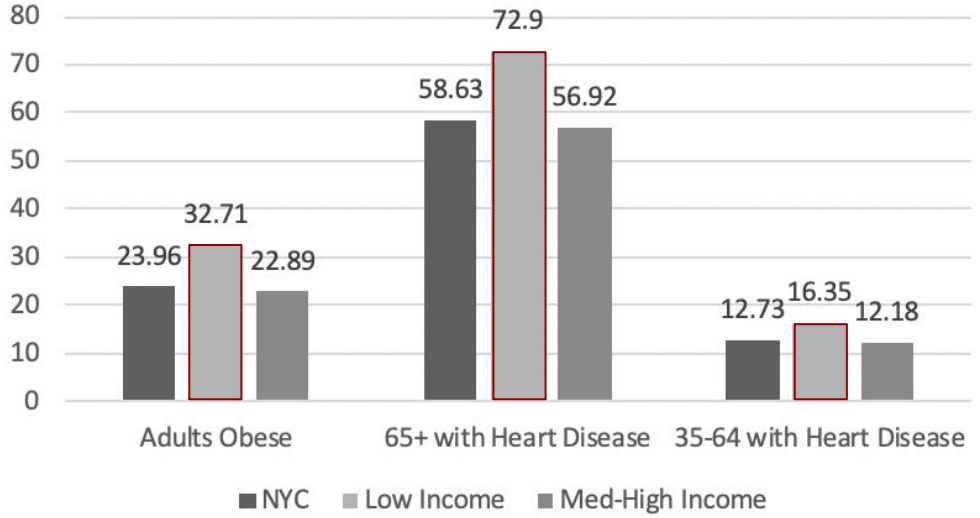
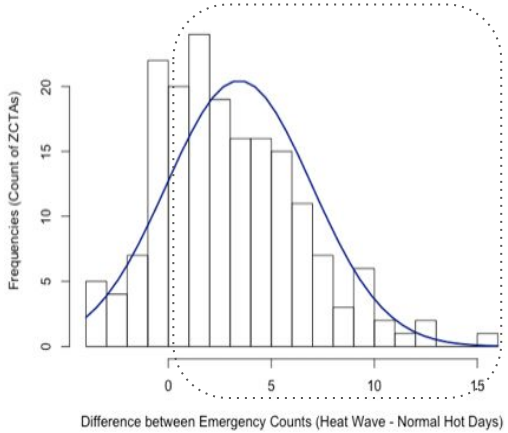
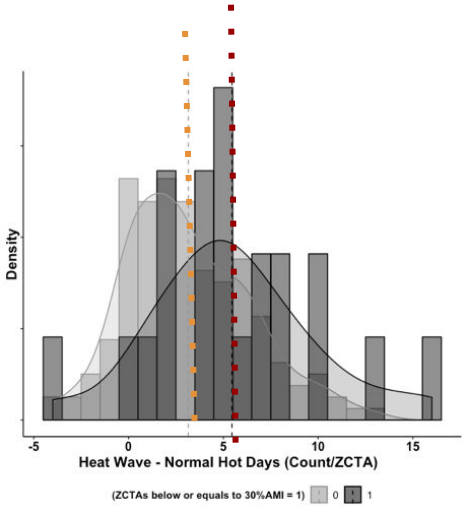
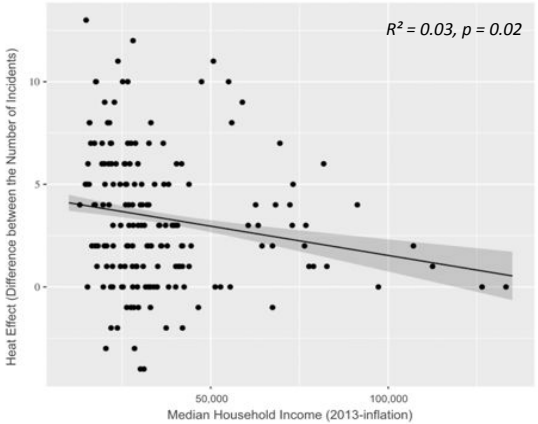


Figure 12. Comparison of Health Characteristics (%)

Low-income is More Vulnerable to Extreme Heat in NYC







Distribution of Heat-related Cardiac Arrests

Range from -4 to 16 (mean 3.44; median 3),
73% of ZCTAs reported heat-related incidents

Comparison between Income Groups

Neighborhoods of **below 30% AMI** ($18,900) in 2013 **are more vulnerable** than the other neighborhoods in NYC

Heat-related Emergencies and Median Income

increment of 0.028 heat-related cardiac emergencies *can be explained by $1,000* ***less of median income*** *would explain at 95% confidence level*

Neighborhood Characteristics Explaining Heat Vulnerability

Most relevant variables with heat vulnerability

(Pearson's correlation test result, significant at 90% CI)

Positive relationship

- % single households;
- % people of color;
- Number of community and health facilities;
- Number of public parks

Negative relationship

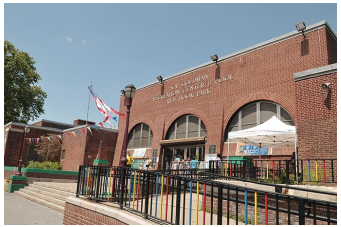
- % family households;
- % people of White/Asian;

Major takeaways from regression results

compared to med-high income,

+1 ppt **single * senior * low-income**
→ *-0.71* of heat-related cardiac arrests (p<0.01)

+1 ppt **Black * low-income**
→ *+0.30 heat-related* arrests (p<0.05)



+1 community center * low-income
→ *+0.36* arrests (p<0.1)

+1 **public park * low-income**
→ *-0.27* arrests (p<0.05)

Senior & Living Alone & Low-Income *(negative relationship)*

"living alone is not relevant to senior population's heat-related mortality in New York City" (Rosenthal et al., 2014)

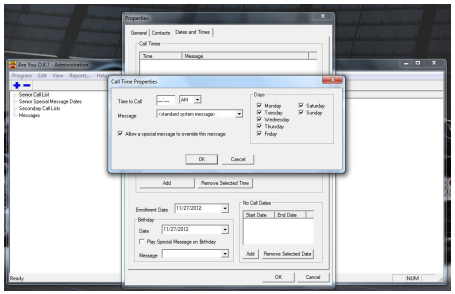
dependent variable is a dataset limited to the incidents reported on the EMS system
→ **less informed to EMS?**

- "Tend to stay home & alone. Feel insecure (perceived neighborhood safety)" (Klinenberg, 2002)
- Comparison with the actual mortality of low-income single seniors is needed in further research

Recommendation to NYC Department for the Aging, NYC nyc.gov/service, NYC Housing Authority

Improve their reassurance program using technology

- 4 counties in NYS, 150 localities in North America already applied the system
- Find cost-efficient way at neighborhood-scale



Ex. Automated telephone reassurance program RUOK

% Black is positively related, but % Hispanic is statistically insignificant

dependent variable is a dataset limited to the incidents reported on the EMS system
→ **less informed to EMS?**

- "People with the **Medicaid benefit receive more emergency department care by EMS** than the others with a private insurance or uninsured" (Hsia et al., 2018; Meisel et al., 2011)
- **29.7% of Hispanic in NYS are without health insurance** in 2013 while 13% of Black, 8.1% of White, and 12% of other are uninsured (Health Care Coverage Status data from the BRFSS survey)

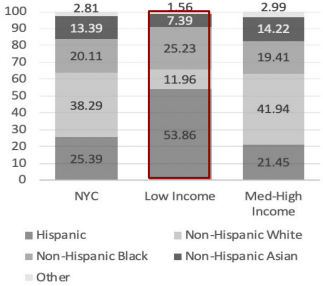
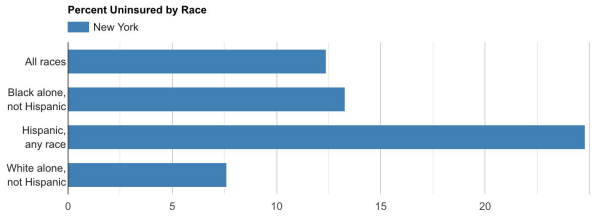


Figure 6. Comparison of Race (Trimmed-mean: %)

Percent Uninsured by Race API



But practical examination on the difference is desirable,
*to discuss the relationships between **race**, heat-related **emergencies** and **Health insurance beneficiaries** among different **income groups***

Positive relationship with number of community centers = Cooling Centers

Large number of cooling centers located in low-income neighborhoods (average 5.7/each ZCTA)

But, "people prefer to stay at home even when dangerously hot" (Lane et al., 2013) ;
"Older adults in New York City assume they are used to the hot weather" (Sampson et al., 2013)

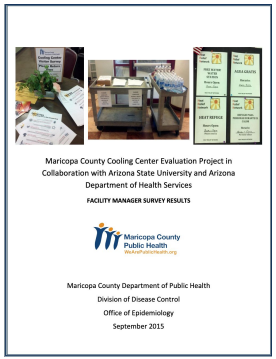
NYC Emergency Management

Cool Neighborhoods NYC report proposed distribution of *Home Health Aids*, *but* **Strategies should be diversified, with max use of cooling centers:**

1) Evaluate programs of the cooling centers (Berisha et al., 2017)

2) Develop appropriate programs for the adults
ex. recreational camps and cultural events at the libraries and community facilities

3) Public schools open a free educational program during the hot days (Western Illinois University in Macomb)


Maricopa County Cooling Center Evaluation Project in Collaboration with Arizona State University and Arizona Department of Health Services

FACILITY MANAGER SURVEY RESULTS

Maricopa County Public Health

Maricopa County Department of Public Health
Division of Disease Control
Office of Epidemiology
September 2015

Negative relationship with Number of Public Parks

Public park as a place for **physical activities** and **social integration (+ cooling effect)**

"Encourage exercise and reduce air pollution, but also bring additional boosts to the local economy in low-income neighborhoods" (National Recreation and Park Association, 2018)

Support the City's ***Community Parks Initiative*** NYC Parks

→ invested $285 million for physical improvement and program development with maintenance and upgrades in 67 parks in the low-income neighborhoods across the five boroughs.

- should 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)

Limitation & Further Research

The results from analysis reflect the limitation of the research.

1. **EMS calls data is limited as the heat vulnerability indicator**
   - Different definition from other heat-related studies
   - Some occasions might be neglected in the EMS data
2. **Assessed the vulnerability in the year of 2013**
3. **Aggregation of data to ZCTA**
   makes intricate to precisely explain individual vulnerability with the neighborhood-level characteristics

→ *Suggest selection of different year or* ***multiple years;*** *use of* ***smaller geographic area; mortality*** *as dependent variable in the same model*

→ *Study on* ***racial disparity of health care coverage*** *and* ***heat-related severe health impact***

→ ***Cooling center evaluation &***
Cost & benefit analysis *on different heat-related policy and strategies for low-income*

Conclusion

*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.*

- Findings suggest **qualitative understanding** in depth of the association of the independent variables with heat vulnerability of low-income neighborhoods
- **Improve model** with more precise health outcomes data
- **Improve various heat-related policies and strategies** :
  be more target-oriented; cost-efficient and
  effective use of social infrastructure and resources

Thank you