Effects of socioeconomic status and greenspace on respiratory emergency department visits under short-term temperature variations: An age-stratified case time-series study

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Abstract

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Introduction: Neighborhood socioeconomic status (SES) and greenspace can affect respiratory health. However, it is unclear whether effects of neighborhood SES and greenspace on respiratory health still exist regardless of temperature variations.

Methods: This paper conducted a two-stage, age-stratified case time-series study. The first goal is to examine the associations between two temperature metrics (daily mean temperature [DMT] and diurnal temperature range [DTR]) and respiratory emergency department (ED) visits among four age groups in New York City. The second goal is to evaluate whether neighborhood SES and greenspace would be determinants of respiratory ED visits independent from temperature varying factors. A distributed lag nonlinear model was applied on ED data from 135 zip codes (October 2016 - February 2020).

Results: Our first-stage analysis indicated that older adults aged 65+ had higher risks of ED visit (RR=2.78, 95% eCI: 2.41, 3.22; with 7 days of lag) on days with low DMT (-10°C), followed by adults aged 18-64 (RR=2.48, 95% eCI: 2.32, 2.65), children and youth aged 5-17 (RR=1.38, 95% eCI: 1.24, 1.53), and young children aged 0-4 (RR=1.04, 95% eCI: 0.96, 1.13). However, no excess respiratory ED visits were observed on days with high DMT (30°C). Higher DTR was associated with higher risks, with children and youth more susceptible when DTR was high (DTR 20°C; RR=5.70, 95% eCI: 3.42, 9.49; with 7 days of lag). The second-stage analysis indicated neighborhood SES and greenspace had significant associations with respiratory ED visits regardless of temperature variations. Specifically, Higher income and greenspace exposure were negatively associated with ED visits among all age groups.

Conclusions: Neighborhood SES and greenspace could affect respiratory morbidity regardless of weather conditions. Daily temperature variations accelerated the short-term risk among population subgroups under different weather conditions (e.g., higher risk of days with low DMT among older adults, higher risk of days with high DTR among children and youth aged 5-17), which could create co-effects with neighborhood SES and greenspace on respiratory health.

Keywords: Emergency department visit, diurnal temperature range (DTR), daily mean temperature (DMT), respiratory disease, greenspace, neighborhood SES

1. Introduction

Respiratory morbidity is a major health burden worldwide. A global study has found that cases of chronic respiratory diseases have increased by 39.5% from 1990 through 2017 (Xie et al., 2020). Other than genetic and lifestyle

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factors (e.g., tobacco smoke), neighborhood environment is also a key determinant that can affect respiratory health. Specifically, neighborhood socioeconomic status (SES) and greenspace can be major factors influencing respiratory health of an individual in the long term, due to spatial disparity and environmental inequality across a city (Mueller et al., 2022). A 20-year follow-up cohort study found that individuals living in neighborhoods with low SES had a greater decline in respiratory function (Thatipelli et al., 2022). Another follow-up cohort study found that higher greenness and the presence of urban greenspace within neighborhood environment were positively associated with respiratory functions, which were independent of air pollution, urbanicity, and SES (Fuertes et al., 2020).

Despite identified as major environmental determinants, no studies have further examined whether effects of neighborhood SES and greenspace on respiratory health could still exist when daily temperature varying factors were included in modelling. This question is critical, as temperature extremes such as extremes in daily mean temperature (DMT) and days with large diurnal temperature range (DTR) can increase short-term risk of respiratory diseases. For example, studies have identified the positive associations between DTR and several respiratory ED visits, including respiratory tract infections (Ge et al., 2013) and acute upper respiratory tract infections (Jang and Chun, 2021). Thus, it is believed that daily temperature variations (i.e., DMT and DTR) might dominate the short-term effects on respiratory morbidity and mortality, such as respiratory ED visits, while neighborhood environment would only be an effect modifier because of the spatial variability across a city. However, long-term impacts of social or geophysical environment might sometimes be larger than the short-term impacts of temperature variations. One notable example is an U.S. study that examined vulnerability of extreme heat due to spatial variability of socio-demographic characteristics and neighborhood greenspace (Gronlund et al., 2015). This study compared the odds of different subgroups (e.g., greenspace vs. non-greenspace) and found a consistent modifying effect of neighborhood environment (e.g., greenspace) on cardiovascular mortality. However, when it was compared for respiratory mortality, the results became inconsistent and insignificant. These results indicated that neighborhood factors such as SES and greenspace may not be the effect modifiers of temperature variations but only influencing respiratory health independently from the temperature effects, which needs to be further studied.

To address the issues stated above, this study conducted a two-stage analysis with an age-stratified case time-series design 1) to first examine whether an association between two temperature metrics (DMT and DTR) and respiratory ED visits existed among four age groups living in New York City, and 2) to further evaluate whether neighborhood SES and greenspace would be associated with respiratory ED visits when including temperature varying factors in modelling. A distributed lag nonlinear model was applied on ED data from 135 zip codes from October 2016 to February 2020.

2. Data and Method

2.1. Data

2.1.1. Daily counts of respiratory emergency department visits

Daily counts of respiratory ED visits of New York City are available at the zip code level from NYC Health Portal. These ED visits were geocoded into 135 merged zip codes based on self-reported residential addresses (if available). Valid geocoded ED visit data are available since October 1, 2016. Due to the Covid-19 outbreak and lockdown since March 2020 in New York City (1st confirmed case on 2020-03-01), only data between 2016-10-01 and 2020-02-29 were used in this study. The study period of 1246 days includes four winters and three summers. The total number of geocoded ED visits is 214,670. (One-week data from 2019-07-31 to 2019-08-06 were missing.) The ED visit data are labeled with four age groups (0-4, 5-17, 18-64, and 65+), which were analyzed and discussed separately as young children (age 0-4), children and youth (age 5-17), adults (age 18-64), and older adults (age 65+) in this study. Figure 1 shows the study area along with the total number of ED visits of the 135 zip codes in the study period (1246 days).

2.1.2. Temperature

Temperature data were extracted from three airport weather stations (JFK, LGA, EWR) in the New York City area from NOAA. We calculated the daily minimum, maximum, mean, and range based on the average of the three stations. We tested some intracity temperature datasets, including Daymet (Thornton et al., 2022), ECOSTRESS (Fisher et al., 2020), and MODIS land surface temperature and found them not suitable for our study due to limitations on resolution and temporal coverage.

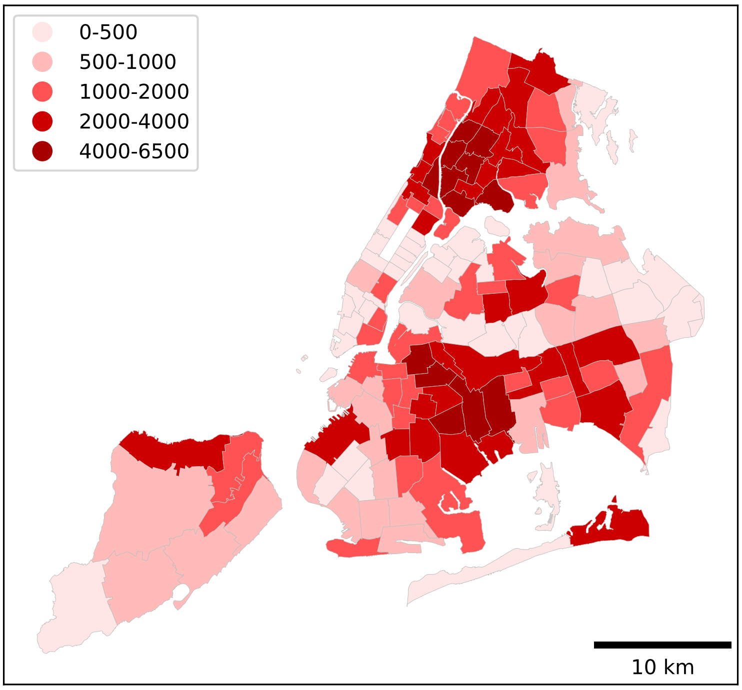

Figure 1: Number of respiratory ED visits of 135 zip codes of New York City, 2016-10-01 to 2020-02-29.

2.1.3. Neighborhood SES

Neighborhood-level SES was measured by median household income data, which were extracted from the 2019 American Community Survey 5-year estimates. The SES data were matched based on zip codes. The income data were coded in per US$10,000.

2.1.4. Greenspace

Greenspace proxied by normalized difference vegetation index (NDVI) was calculated as the median Landsat-8 NDVI between 2016 and 2020 from Google Earth Engine. The NDVI value of each zip code was averaged from all valid observations within the zip code boundary. The NDVI value ranges from -1 to 1, with a large value indicating more greenspace exposure.

2.1.5. Air pollution

City-wide daily air pollution data (PM2.5) were extracted from the Environmental Protection Agency (EPA). The data were collected at the standard unit of micrograms per cubic meter of air, with a high value indicating poor air quality. We also tested other air pollutants such as ozone and found the inclusion of PM2.5 is sufficient.

2.2. Statistical methods

The study is based on an age-stratified case time-series design (Gasparrini, 2022) using a quasi-Poisson regression model:

$$Y_{d,z} = Poisson\left(u_{d,z}\right) \tag{1}$$

$$u_{d,z} = exp\left(dlnm\left(t_{d,z}\right) + dlnm\left(DTR_{d,z}\right) + SES_{d,z} + Air_{d,z} + L_{d,z}\right) \tag{2}$$

where $Y_{d,z}$ is the number of ED visits of day d in zip code z ($d \in D$, $z \in Z$; D and Z are the sets of study days and zip codes), $u_{d,z}$ is determined by a set of variables including daily mean temperature $t_{d,z}$, diurnal temperature range $DTR_{d,z}$, air pollution level $Air_{d,z}$, socioeconomic status $SES_{d,z}$, greenspace $L_{d,z}$ of day d in zip code z, and $dlnm\left(\cdot\right)$ denotes the distributed lag non-linear model (Gasparrini, 2014). In this study, all zip codes share one daily temperature averaged from three weather stations, SES considers median household income, greenspace considers NDVI, and air pollution considers PM2.5.

We used a quadratic B-spline in *dlnm* with two knots to model the exposure-response curve for DMT and DTR. In modelling, two knots were set at the 10th percentile (1°C) and 90th percentile (24°C) for DMT. For DTR, two knots were set at 10th percentile (5°C) and 90th percentile (14°C). We also controlled for air pollution, day of year, and day of week in the model. The days of lag was set at up to 7 days because of the short-term nature of respiratory ED visit compared to mortality (Delfino et al., 1998; Malig et al., 2016; Jang and Chun, 2021; Rahman et al., 2022). In generating the RR curves as a function of temperature characteristics, we set the centered values, i.e., the reference, as 12°C for DMT and 8°C for DTR, respectively. All analyses were conducted in R using the package *"dlnm."*

3. Results

3.1. Descriptive analysis

Table 1 shows the basic characteristics of the cases by age group. There were a total of 82,506, 29,731, 87,946, and 14,381 cases for the four age groups chronologically, respectively. Age group 5-17 had a slightly lower DMT exposure than other groups. The 50th percentiles of other variables were similar for all four age groups.

Table 1: Basic characteristics of the cases by age group.

Age Group	0-4	5-17	18-64	65+
N cases	82,506	29,731	87,946	14,381
Daily Mean Temperature (DMT)				
25th percentile	3.57	2.83	3.47	3.33
50th percentile	7.87	7.00	8.00	7.8
75th percentile	15.73	14.27	16.87	16.73
Diurnal Temperature Range (DTR)				
25th percentile	5.73	5.90	5.73	5.87
50th percentile	7.60	7.63	7.70	7.77
75th percentile	9.57	9.60	9.63	9.63
Income (neighborhood SES)				
25th percentile	3.37	3.70	3.70	3.98
50th percentile	5.33	5.35	5.40	5.46
75th percentile	6.37	6.46	6.88	7.37
NDVI (Greenspace)				
25th percentile	0.173	0.173	0.173	0.172
50th percentile	0.192	0.192	0.191	0.191
75th percentile	0.241	0.241	0.242	0.246
PM2.5 (Air pollution)				
25th percentile	3.55	3.60	3.60	3.55
50th percentile	5.35	5.45	5.45	5.50
75th percentile	8.20	8.35	8.25	8.35

Figure 2 shows the trend of DMT along with the range (in gray color) and the daily respiratory ED visit counts. The number of respiratory ED visit is high when the DMT is low (winter), and vice versa. This negative relationship was shown in a scatter plot in Figure 3. A strong negative linear association (R^2=0.5462, p<0.0001) was found between the DMT and ED visits.

We also checked other three types of temperature characteristics in addition to daily mean (daily maximum, minimum, and range), and the results are showed in Table 2. The linear associations are similar for daily mean, maximum, and minimum temperature, but weak for DTR (but remember this test only applies to linear relationship). Based on this inspection, we used DMT as it was collinear with daily minimum and maximum. We also considered DTR in our model to include within-day temperature variation information because the DTR-ED visit association may not be linear.

3.2. Effects of temperature variations by age group

Figure 4 shows the relative risk (RR) of respiratory ED visit as a function of DMT stratified by age group (from left to right: age 0-4, 5-17, 18-64, and 65+). The RR is shown with 95% empirical CI (shaded gray). Consistent with

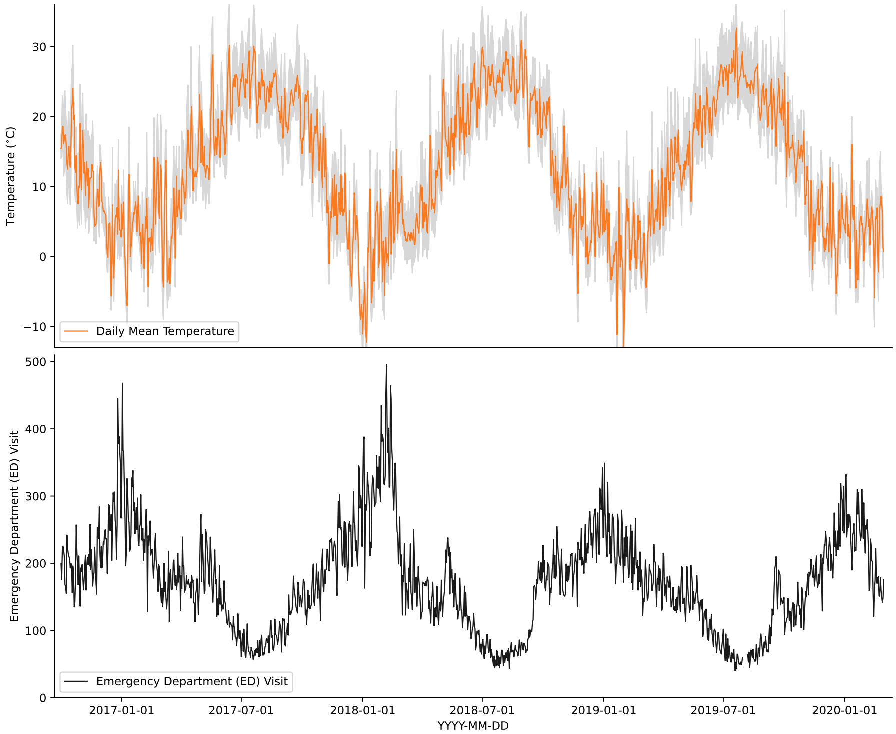

Figure 2: Daily mean temperature with the range in shaded color, and counts of daily respiratory emergency department (ED) visit.

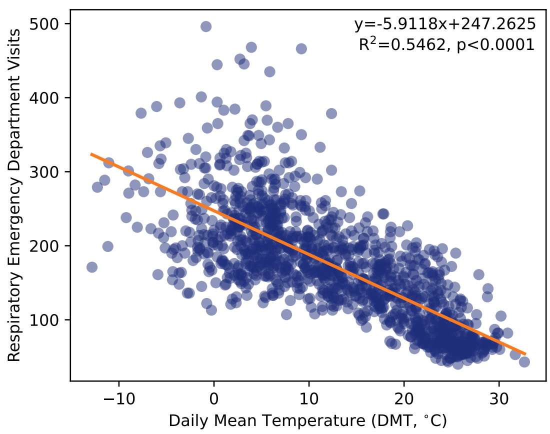

Figure 3: Scatter plot between respiratory ED visits and daily mean temperature

Table 2: Pearson R correlation coefficient between four temperature characteristics and respiratory ED visits

Type of Temperature	Pearson R	R^2
Daily Mean Temperature	-0.7391	0.5462
Daily Maximum Temperature	-0.7213	0.5202
Daily Minimum Temperature	-0.7391	0.5462
Diurnal Temperature Range (DTR)	-0.1312	0.0172

the descriptive analysis, the RR of ED visits was higher with lower DMT for all age groups. Older adults and adults were more susceptible to lower DMT.

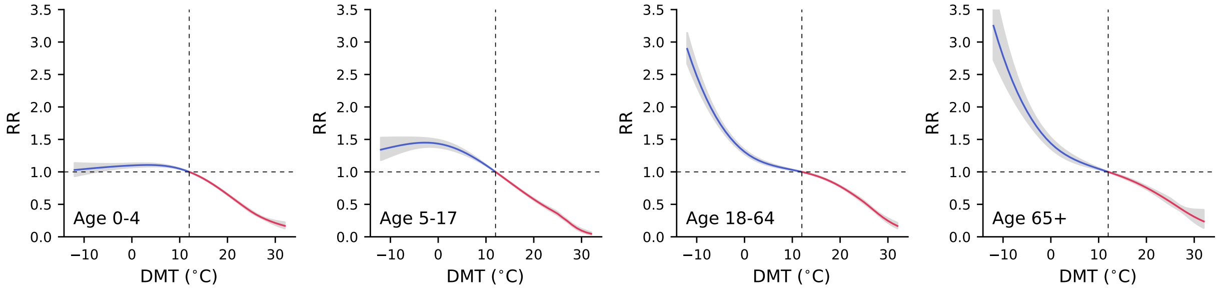

Figure 4: Relative risk (RR) of respiratory ED visit as a function of daily mean temperature (DMT) obtained via the fitted models (95% empirical CI, shaded grey) stratified by four age groups (0-4, 5-17, 18-64, and 65+).

In Table 3, we list the RR values in two scenarios for DMT and two scenarios for DTR, with 0-7 days of lag. During days with low DMT (-10°C) compared to the referenced DMT of 12°C, the RRs from old age to young were 2.78 (2.41-3.22), 2.48 (2.32-2.65), 1.38 (1.24-1.53), and 1.04 (0.96-1.13), respectively.

Table 3: Relative risk (RR) of daily mean temperature (DMT) and diurnal temperature range (DTR), by age group, with 0-7 days of lag. 95% empirical CI are shown in brackets. The reference group is 12°C for DMT and 8°C for DTR, respectively.

	Daily Mean Temperature		Diurnal Temperature Range (DTR)	
	Low (-10°C)	High (30°C)	Low (2°C)	High (20°C)
All Age Group	1.72 (1.51-1.95)	0.20 (0.16-0.25)	0.90 (0.73-1.1)	1.88 (1.06-3.34)
Age 0-4 (Young Children)	1.04 (0.96-1.13)	0.21 (0.18-0.25)	0.77 (0.70-0.85)	1.32 (0.94-1.86)
Age 5-17 (Children and Youth)	1.38 (1.24-1.53)	0.10 (0.07-0.12)	0.77 (0.67-0.90)	5.70 (3.42-9.49)
Age 18-64 (Adults)	2.48 (2.32-2.65)	0.25 (0.21-0.29)	1.21 (1.11-1.33)	2.32 (1.69-3.18)
Age 65+ (Older Adults)	2.78 (2.41-3.22)	0.31 (0.23-0.42)	1.01 (0.82-1.23)	1.82 (0.90-3.68)

Figure 5 shows the RR of respiratory ED visit as a function of DTR. For all four age groups, instead of a linear relationship, we observed a sudden increase in RR when DTR was larger than 15°C. The increase was exponential when DTR was high (>15°C). Children and youth aged 5-17 and older adults aged 65+ were more susceptible to the increase of DTR; with DTR as high as 20°C, the RR was as high as 5.70 (95% eCI 3.42-9.49). Older adults aged 65+ and adults aged 18-64 were also susceptible to the increase of DTR, with RR of 1.82 (95% eCI 0.90-3.68) and 2.32 (95% eCI 1.69-3.18), respectively, when DTR was 20°C (Table 3).

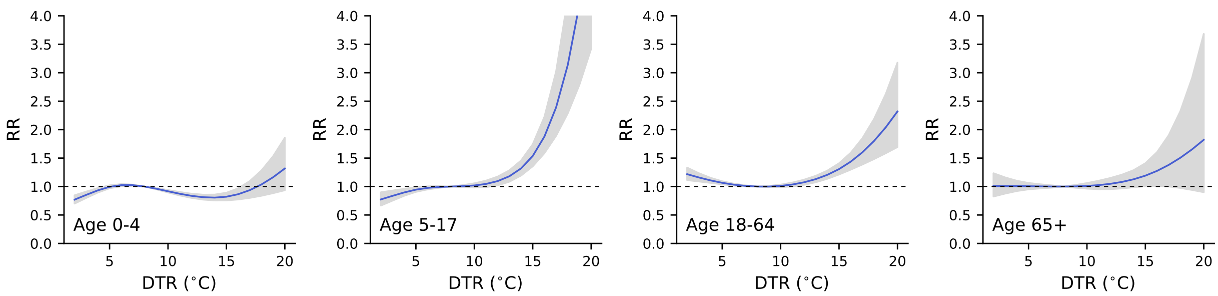

Figure 5: Relative risk (RR) of respiratory ED visit as a function of diurnal temperature range obtained via the fitted models (95% empirical CI, shaded grey) stratified by four age groups (0-4, 5-17, 18-64, and 65+).

3.3. Effects of neighborhood SES and greenspace

Income was applied as a proxy of neighborhood SES, and NDVI was applied as a proxy of greenspace exposure. Figure 6 shows the independent effects of income and NDVI on the RR of respiratory ED visit. Regardless of age group, within New York City, both higher income and NDVI were associated with lower RR of respiratory ED visit, after adjusting for two temperature varying materics (DMT, DTR). Per US$10,000 increase in median household income, RR decreased by 0.01092 (95% eCI: 0.01086, 0.01098). Per 0.1 increase in NDVI, RR decreased by 0.1532 (95% eCI: 0.1504, 0.1558). Young children (0-4) were more sensitive to income than other age groups. Older adults and adults were more sensitive to NDVI than other age groups.

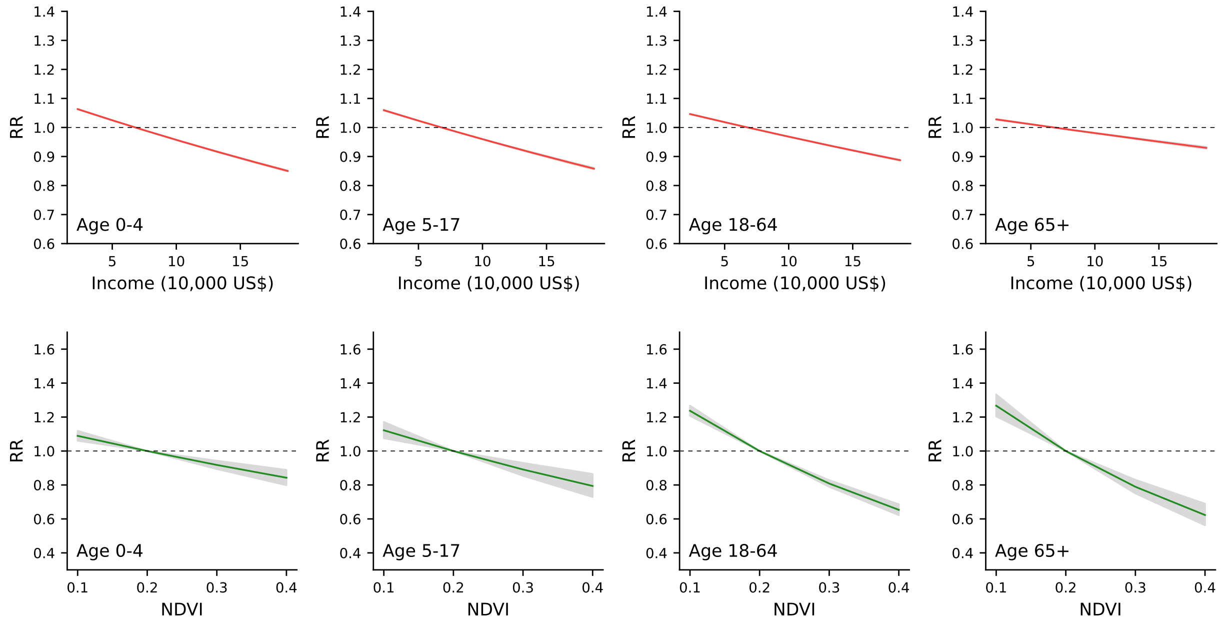

Figure 6: Relative risk (RR) of ED visits as functions of income (10,000 USD) and NDVI obtained via the fitted models of four age groups: 0-4, 5-17, 18-64, and 65+. Shaded grey area marks the 95% empirical CI.

3.4. Sensitivity analysis

Figure 7 shows the 3D plots of the DMT-ED visit and DTR-ED visit relationships, stratified by age group, with 3-28 days of lag. For DMT, we observed a consistent trend of higher risk in cold days regardless of lag days. With lag days increasing up to 28, we observed a higher risk on respiratory ED visit, especially for older adults (age 65+). For DTR, we observed a dramastic higher risk with higher DTR for children and youth (age 5-17), compared to other age groups, regardless of lag days. Within 3-28 days of lag, we observed double peaks, roughly at 14 and 21 days of lag. Since the temperature-ED visit response is short-term in theory, we used 14 days of lag in the main analysis.

4. Discussion

This study aimed to investigate whether neighborhood SES and greenspace could affect respiratory health of an individual regardless of weather conditions. We used a two-stage, age-stratified case time-series study design 1) to first investigate the effects of daily mean temperature (DMT) and diurnal temperature range (DTR) on respiratory emergency department (ED) visits of 135 zip codes in New York City during 2016-10-01 and 2020-02-29, and 2) to examine the co-effects of neighborhood SES and greenspace exposure, in order to determine whether neighborhood effect would be independent from the short-term impacts of temperature variations. In other words, we want to know if neighborhood SES and greenspace affect respiratory health of an individual regardless of weather conditions. Our

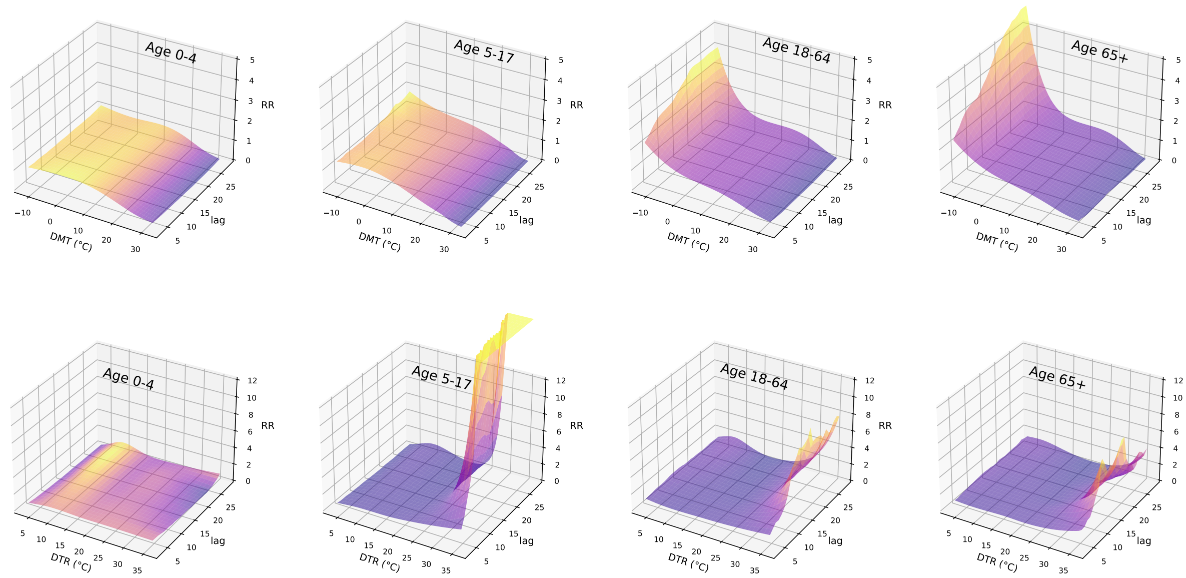

Figure 7: Sensitivity analysis on the number of lag days.

first-stage results indicated that individuals in New York City were more susceptible to low DMT but not high DMT. Older adults aged 65+ were more susceptible to lower DMT, with RR of 2.78 (95% eCI 2.41-3.22); and young children aged 0-4 were less susceptible to low DMT, with RR of 1.04 (95% eCI 0.96-1.13). Higher DTR was also associated with higher risks, with children and youth (age 5-17) more susceptible when DTR was high (DTR 20°C; RR=5.70, 95% eCI: 3.42, 9.49). More importantly, by considering income as a proxy of neighborhood SES and NDVI as a proxy of greenspace exposure, the second-stage analysis showed the co-effect of neighborhood SES and greenspace on respiratory morbidity, based on linear responses of RR of respiratory ED visit due to income and NDVI independent from temperature varying factors (DMT, DTR). These results indicated that higher SES and more greenspace were associated with lower RR of respiratory ED visit regardless of age groups and independent from two temperature varying factors (DMT, DTR), while young children (0-4) were more sensitive to income than other age groups.

These results were consistent with existing literature. Lower risk of respiratory ED visit was associated with higher DMT (not higher than 30°C), such as studies in New Zealand (Gosai et al., 2009). Older adults were more susceptible to low temperature. Older adults are likely with pre-existing conditions such as chronic obstructive pulmonary diseases and diabetes, which could make them more vulnerable with low temperature (Schwartz, 2005; Yu et al., 2010; Sun et al., 2016). With increasing age, human body becomes less efficient at regulating internal temperature and the immune system weakens, making older adults more susceptible to respiratory-related infections and diseases (Kan et al., 2008; El Chakhtoura et al., 2017; Soriano et al., 2020).

This study has several strengths. 1) This study examined the effects of both DMT and DTR on respiratory ED visit. DTR has been an overlooked yet important health factor in climate and health studies (Berrang-Ford et al., 2021). Previous studies have identified the positive associations between DTR and several respiratory related ED visits, including respiratory tract infections and acute upper respiratory tract infections. Our results controlling for daily mean temperature, socioeconomic status and greenspace exposure further pinpointed the significant effect of DTR on respiratory ED visit. 2) The unique value of this study is that we consider the co-effects of socioeconomic status and urban landscape within a single mega city — New York City — where every resident in the city is facing the similar DMT and DTR. By using an intracity case time-series study, we eliminated the potential confounding introduced by using data from various cities that may be regional climate-dependent. Our results also indicated that higher income and higher greenspace exposures were associated with a lower risk of respiratory ED visit, which are independent from temperature varying factors. With an intracity study like ours, the difference in risk is due to (a) individual's such as socioeconomic status and (b) urban landscape (e.g., greenspace) that is due to city planning. 3) These two factors are changeable that it is possible for us to work at local level to minimize the risk. Another strength is that we adopted an age-stratified analysis so that it is possible to understand the potential mechanism for each age group. These could help identifying vulnerable subgroups that may be faced with co-effects on short-term temperature variations and long-term neighborhood impacts (e.g. SES, greenspace).

There were also interesting phenomena in our study. First, we did not observe an increase of ED visits during days with high DMT. Although for most studies on DMT and health outcome, a U-shaped relationship is expected, studies related to emergency department visits or hospital admissions showed a different trend (Gosai et al., 2009; Basu et al., 2012; Zhao et al., 2017; Krefis et al., 2018; Iñiguez et al., 2021). In Germany and Spain, more respiratory ED visits were found in winter and fewer in summer (Krefis et al., 2018; Iñiguez et al., 2021). A New Zealand study showed a similar negative association between daily minimum temperature and hospital admissions related to bronchitis and asthma (Gosai et al., 2009). Basu et al. (2012) found the increased ED visits for nine categories of diseases (ischemic heart disease, ischemic stroke, cardiac dysrhymia, hypotension, diabetes, etc.) but did not find an increase of respiratory ED visits during hot days in California. In Zhao et al. (2017), only a weak increase of ED visits was observed during hot days in central China compared to other regions, which apparently was dependent on regional climate. There might be several potential explanations behind the unique effect of DMT on respiratory ED visit. First, respiratory-related disease is a broad category that often includes virus or bacteria dominant in cold winter, including the recent outbreak of respiratory syncytial virus (RSV) and influenza in the United States (Meerhoff et al., 2009; Moriyama et al., 2020; Ferrero et al., 2022). Second, regional climate might play a role. In existing climate and health studies, regional climate modifies the association between temperature and health outcomes (Zhao et al., 2021). Under climate change, urban citizens in temperate cities (e.g., New York City) may be acclimatized to extreme heat events and had developed a good sense of aware and a set of self-protective strategies. In contrast, health awareness and coping strategies for cold events might be decreased, especially strategies with cold-related infectious disease such as flu. This might enlarge the health impact. Third, ED visit behavior is essentially different from other health outcomes such as death (Wai et al., 2022). Unlike all-cause mortality, which is a fatal outcome without intention of individuals, ED visits were somewhat depended on the needs of the patients. For individuals with high awareness, the ability to seek help in an emergency room means mild yet long-lasting effects on human bodies, which implied a signal of the degrade of life quality with urgent needs of medical services. However, for individuals with low awareness or resources, they may not actively seek medical support including ED visit. Thus, these individuals with low awareness or resources may sometimes had higher fatal risk because of low medical support. Under climate change, cold events sometimes induced a severer perceived change than hot events. It may be the reasons why more respiratory ED visits during cold events than hot events.

Second, it is expected that the RR of respiratory ED visit was higher with larger DTR (Ge et al., 2013). Yet, our study did not find a linear association, but rather a sharp increase when DTR was large. For DTR smaller than 15°C, the effect was small; and with DTR increasing from 15°C, the RR increased exponentially. Human body's thermoregulation mechanism is limited. With large DTR and sudden temperature change, the stimulated skin receptors will increase blood catecholamine level and thus could lead to vasoconstriction, tachycardia, and increased blood pressure (Giorgini et al., 2017). Children and youth aged 5-17, compared to other age groups, were more susceptible to large DTR. Children and youth are at active school age that they are likely to have more social interactions with other people due to high population density and high occupancy in school environments (Markovich et al., 2015). Additionally, symptoms among school-aged students are likely better monitored in school environments, and parents would care more about their children and take them to emergency room (Berry et al., 2008). School-aged children and youth (age 5-17), compared to young children (age 0-4), work professional adults (age 18-64), and older adults (age 65+), are more active that they are likely to spend more time outdoors, making them more exposed to outdoor temperatures without heat during winter times.

Third, although higher SES and more greenspace were associated with lower RR of respiratory ED visit regardless of age groups and independent from temperature varying factors (DMT, DTR), young children (0-4) were more sensitive to income than other age groups. Young children spent most of their time at home, and indoor thermal comfort requires resources, i.e., income, which may explain the RR sensitivity to income. Consequently, young children spent less time outdoors, and thus less sensitive to the outdoor greenspace (NDVI). For adults and older adults, as they were likely to spend more time outdoors, the modification effects from greenspace played a more important role than in other age groups.

Some limitations should be noted. Although this study adopted a time-series case time-series study design where the reference group is the zip code itself, it is still subject to ecological fallacy that the conclusion drawn from an aggregated level may not apply to individuals (Piantadosi et al., 1988). But given that the time element in the causal relationship was ensured in the case time-series design, only those elements also varied with time could be confounders, and thus we are confident in our findings that are consistent with some studies using individual data (Idrovo, 2011). Due to the unexpected Covid-19, we could only use data from four winters and three summers, which is relatively short. The usage of three temperature stations for all zip codes in New York City is somehow limited due to the lack of temperature data with both high spatial and temporal resolutions. In this study, other types of intracity daily temperature estimates were considered but not adopted, including Daymet (Thornton et al., 2022) due to a visible lack of intracity variability, ECOSTRESS (Fisher et al., 2020) and MODIS land surface temperature data due to a lack of high-temporal-resolution valid observations that are limited by clouds, and PurpleAir network due to a lack of historical data dating back to 2017. However, since local temperature is influenced by urban landscape, the inclusion of NDVI as green space exposure (which is the major channel via which we mitigate local climate and temperature) should reflect this local temperature variation in our study. In the future, we plan to develop high spatiotemporal temperature data for intracity temperature-health outcome studies.

5. Conclusions

Our study used an age-stratified case time-series study to examine the effects of daily mean temperature (DMT) and diurnal temperature range (DTR) on respiratory emergency department (ED) visit of 135 zip codes in New York City. Regardless of age group, high risk of respiratory ED visit was associated with lower temperature. Older adults were more vulnerable in cold days. High risk of respiratory ED visit was found when DTR was large (>15°C), but the effect was marginal and insignificant with small and moderate DTR. Children and youth aged 5-17 were more susceptible to large DTR. Higher income (socioeconomic status) and higher NDVI (green space exposure) showed linear linear protective co-effects on respiratory ED visit independent from temperature varying factors.

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