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Chronic Conditions and Pediatric Healthcare Utilization during Warm Weather Days in New York City

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Introduction

High temperatures are associated with considerable morbidity.¹ Children are particularly vulnerable to the adverse effect of heat due to physiologic and developmental susceptibilities and social vulnerabilities (e.g., higher exposure per body weight, less ability to regulate core body temperature, unique behavioral patterns).^{2,3} A growing body of research has shown increased pediatric hospitalizations and emergency department (ED) visits associated with high temperatures.⁴⁻⁹ Some subgroups of children have been found to have a higher risks of morbidity associated with heat compared to the general pediatric population. For example, our group previously found higher risk of pediatric healthcare utilizations for children under 5 years associated with higher ambient temperatures for heat-related conditions (i.e., heat stroke, heat stress), as well as several conditions not traditionally associated with heat, such as respiratory illness, gastrointestinal illness, and viral infection.^{10,11}

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To advance understanding of variation in children's susceptibility to heat, we build on our and other's prior research^{11,12} establishing the association of warmer temperature and children's ED and hospitalization risk. Here, we examine whether heat impacts are elevated among children with chronic diseases/conditions that we hypothesize might confer additional heat susceptibility.^{2,13} We considered chronic conditions for which the prevalence is large and growing among children (i.e., asthma, obesity, and mental health disorders) and those that are rare but often severe (i.e., sickle cell disease, sickle cell trait, cerebral palsy, and cystic fibrosis). The number of children with chronic conditions is growing; the group represents 13-27% of children in the United States (US) depending on the definition used.^{14,15} These types of chronic conditions lend themselves to medical complexity, and affected children may be particularly vulnerable to high temperatures given their underlying physiologic susceptibility (e.g., impaired cooling mechanisms), use of medication that blunts thirst response or increases the risk of dehydration, limited communication or ability to control their own exposures, or other complicating factors associated with access to or aspects of care. Considering their existing high healthcare needs, heat may further exacerbate the difficulties faced by children with chronic conditions and lead to increased healthcare utilization burden.¹⁶ Understanding heat susceptibility in this vulnerable population can substantially inform clinical and public health interventions.

To begin to address this gap in the literature, we examined the association between warm-season high ambient temperatures and risk of ED visits or hospitalization among children with chronic conditions in New York City (NYC). Using the New York Statewide Planning and Research Cooperative System (SPARCS), we identified children with chronic medical conditions using the extensive diagnostic codes. First, we explored specific chronic conditions (i.e., asthma, obesity, cerebral palsy, cystic fibrosis, sickle cell disease, sickle cell trait, and mental health disorders). We selected these conditions because they represent heat- and dehydration-sensitive conditions that plausibly enhance susceptibility to heat.² We also considered cases of admitted children with a complex chronic condition (CCC), defined using the classification scheme developed by Feudtner et al.¹⁷ CCCs have been used to identify medical complexities that typically can last at least 12 months and are severe enough to require specialty pediatric care with potential hospitalizations.^{17,18} Of note, CCCs do not include asthma, obesity, attention deficit hyperactivity disorder, or other behavioral health conditions (e.g., depression, bipolar disorder) but instead conditions more strongly associated with mortality and complex care.¹⁹

NYC is the most populated city in the US. Children living in NYC are subjected to rising temperatures, with even hotter temperatures expected in the coming decades due to climate change.^{20,21} Children from resource-limited communities of color are more likely to be exposed to greater heat due to uneven urban heat-island effects and lower air-conditioning prevalence.²² Further, given existing racial and socioeconomic disparities in the prevalence of chronic conditions,²³ it is an even more important environmental justice issue to understand the environmental contributors that disproportionately impact vulnerable populations.

Methods

Health Data

This study used all ED visit (outpatient) and hospitalization (inpatient) records for children aged 0 to 18 years in NYC in years 2005-2011--for which data was available--from SPARCS. SPARCS is a comprehensive all-payer administrative database that collects patient-level data from all hospital ED visits and inpatient stays in New York state.²⁴ We restricted our analysis to NYC ED visits and hospitalizations that occurred during the warm season between 2005 and 2011 (May 1 to September 30), as we were interested in studying the associations between hot outdoor temperatures and child morbidity.⁴ SPARCS data included the date, month, and year of each ED visit and hospitalization.

We used all available primary and secondary diagnostic codes (up to 25) available in SPARCS to identify children with chronic conditions. We coded the following chronic conditions based on International Classification of Diseases, Ninth Revisions (ICD-9) codes: asthma (493), obesity and overweight (278), cerebral palsy (343), cystic fibrosis (277), sickle cell disease (282.6), sickle cell trait (282.5), and mental health disorders (290-319, including neurodevelopmental [e.g., attention deficit] and psychological [e.g., schizophrenia] diagnoses). We coded these conditions using both primary and non-primary diagnostic codes to identify children admitted because of a specific chronic disease as well as those who were already sick from an underlying chronic condition. In other words, we were not primarily interested in whether heat makes a specific condition worse but rather if children with specific conditions have higher healthcare utilization during warmer weather. A child with more than one diagnosis (such as obesity and asthma) for a single ED visit or hospitalization was included in both the asthma and obesity subgroup analyses. Finally, we identified children with chronic conditions using the pediatric CCC scheme developed by Feudtner et al.^{17,18} Of the specific chronic conditions examined, all or almost all children with sickle cell disease, sickle cell trait, cerebral palsy, or cystic fibrosis cases were classified as CCC (Table 1).

Climate Exposure Data

We obtained data on daily maximum temperature recorded by the four meteorological stations in the NYC area (JFK International Airport, LaGuardia Airport, Central Park, Newark International Airport) from the National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (NCDC).²⁵ We chose to use temperature data from LaGuardia Airport because a single site was most parsimonious and prior work had demonstrated high correlation between the stations ($r_s > 0.93$).²⁰ We used maximum temperature (Tmax) as our main exposure variable because it provided the best fit for heat-health models in children in several prior studies.^{4,5,26} Tmax was also highly correlated with minimum temperature ($r = 0.87$) and mean temperature ($r = 0.97$). Relative humidity (RH) was calculated from mean temperature and dew point temperature using the standard NOAA equation.²⁷

Statistical Analysis

We conducted a time-stratified, case-crossover study. The case-crossover design is commonly used to study associations between transient exposures and outcomes.²⁸ For every child 0-18 years of age who had an ED visit or hospital admission, we used the date of visit as a case day. We matched control days to case days based on day of the week, month, and year, resulting in 3 or 4 control days per case.²⁹ By selecting control days on the same day of the week as the case day and within the same month, the analysis adjusts for long-term time trends, seasonality, and day of week.⁷ This approach also inherently adjusts for confounding by individual-level characteristics such as age, sex, race/ethnicity, and socioeconomic position, since cases serve as their own controls.²⁸

For the case-crossover analysis, we used conditional logistic regression models to examine associations between temperature and ED visits or hospitalizations among children. We examined combined ED and hospital admissions in the main analysis to increase our sample size. We considered ED visits and hospitalizations as separate outcomes. We used distributed lag non-linear models (DLNMs) to estimate the delayed and possible non-linear effects of temperature on the risk of pediatric ED and hospital admissions.³⁰ We modeled the effect of Tmax over lag days 0 to 5, where lag 0 day represented the case or control day. We selected a 6-day lag period *a priori*, based on previous research showing that the heat effects on child morbidity are relatively acute, with the most adverse effects of heat apparent within several days.¹ We used a constrained linear structure for the lag-response function to improve the precision in estimating the distributed lag curve.³¹ We modeled Tmax as a linear term based on the shape of the temperature-response associations, described in more detail in Niu et al.¹¹

We first examined the association between Tmax and pediatric admissions among children with the specific chronic conditions or groupings (i.e., asthma, obesity, cerebral palsy, cystic fibrosis, sickle cell disease, sickle cell trait, and mental health disorders). Second, we examined these associations among children who had CCCs. In all models, we estimated the excess risk (ER) and its 95% confidence interval per interquartile range (IQR, 13°F) increase in Tmax. As a reference, we also examined the association between Tmax and admissions among all children regardless of conditions. We report the excess risk of pediatric admissions accumulated over lag days 0 to 5 (referred to as the “cumulative” lag). Excess risks at individual lag days are also reported. In sensitivity testing, we examined ED visits and hospitalizations in separate models and explored these associations, limited to cases during the summer months of June, July, and August.

All statistical analyses were conducted using the R statistical software version 4.0.2 (R Core Team 2015) with the “dlnm” and “coxph” packages.³² Institutional review boards at Icahn School of Medicine at Mount Sinai, Drexel University, and the University at Pittsburgh approved this study.

Results

In NYC, there were 2,480,556 healthcare encounters for children aged 0 to 18 years from May through September between 2005 and 2011 (Table 2). Among the cases with the

specific chronic conditions we examined, children with asthma represented the largest group (8.3%, $n = 204,705$), followed by those with mental health disorders (3.8%, $n = 93,871$); those with sickle cell disease make up the third largest group, accounting for 0.4% of combined ED and hospital admissions ($n = 11,067$); children with other conditions represented even smaller proportions. CCCs accounted for 2.7% ($n = 67,218$) of combined pediatric admissions. The range of Tmax over the study period was 50°F to 104°F, with a mean of 80.3°F (standard deviation = 9.1°F, IQR = 13°F). The average relative humidity was 62.4% (range 28.5%-93.2%).

Combined ED and Hospital Admissions

In our main admission model (combining ED visits and hospital admissions) with Tmax parameterized as a linear term (Table 3), a 13°F (IQR) increase in Tmax was associated with a 6-day cumulative ER of 1.35% (95% CI 0.98, 1.71%) of admissions for all pediatric cases during the warm season. Higher Tmax was associated with a cumulative decreased risk for admissions among children with asthma (ER = -13.52, 95% CI -14.69, -12.34%); children with obesity/overweight (ER = -10.12, 95% CI -16.80, -2.90%); and children with mental health diagnoses (ER = -4.51, 95% CI -6.42, -2.56%). Tmax was not significantly associated with pediatric admissions for children with cerebral palsy, cystic fibrosis, sickle cell disease, and sickle cell trait, and for children classified as having a ccc.

In examining the lag structure of the various models, we saw increased risk for all pediatric admissions from the same day to lag day 3, and decreased risk on lag days 4 and 5. Specific conditions demonstrated a more extended association. For example, among both children with asthma and mental health diagnoses, the magnitude of the effect increased through lag day 5 in a protective direction (Table 4), whereas among children with sickle cell trait, the magnitude of the effect increased through lag day 5, elevating risk for pediatric admissions (although not statistically significant).

Sensitivity Tests

In models examining ED visits ($n = 2,252,500$) and hospitalizations ($n = 228,002$) separately (Table 5), Tmax was significantly associated with ED visits with a 6-day cumulative ER of 1.63% (95% CI 1.21, 2.06%) for all pediatric cases. Hospitalization risk was in the same direction, but the association was closer to the null and less precise (ER=1.17, 95% CI -2.14, 4.60%). Other results that differed from our main model were that the risk of hospitalization was no longer significant for children with asthma or obesity/overweight; children with sickle cell trait showed increased risk of ED visit (ER = 23.21, 95% CI 2.08, 48.71%) (same direction but now significant); and children with mental health disorder diagnoses had increased risk of hospitalization (ER = 9.99, 95% CI 0.44, 20.44%) (opposite of the direction seen in combined admissions and ED visits).

In models that limited the cases to the summer months of June, July, and August (Table 3; Table 4 for full lag structure), the direction and significance of the cumulative effect estimates were the same except that children with a CCC now showed significantly increased risk from heat (ER = 4.50, 95% CI 1.10, 8.02%); the reduced risk of admission for children with asthma and for children with obesity/overweight, seen in the main model,

was no longer statistically significant; and heat was associated with an elevated risk (not significant) among children with mental health disorder diagnoses.

Discussion

Our study found a complex pattern of risk between daily maximum temperatures and pediatric ED and hospital admissions for children with chronic conditions in NYC during warm seasons between 2005 and 2011. The direction and the strength of the associations varied by the chronic conditions, timeframe, and healthcare utilization types. While we found an increase in overall pediatric admissions associated with heat, we found decreased risks associated with high temperatures among children with some specific categories of chronic conditions, including asthma, obesity, and mental health disorders. For children with CCCs, we observed increased risk of pediatric admissions associated with temperature during only the summer months. Further, when considering ED visits and hospitalizations separately, children with sickle cell trait had increased risk of ED visit and children with mental health disorder diagnoses had increased risk of hospitalization. These findings contribute to the scarce literature on the variation of susceptibility to heat among children. With further replication, our findings can help inform preparedness of the health system for prevention measures.

Our results align with several previous studies that have found ambient temperature negatively correlated with pediatric admission for asthma.^{33,34} It was suggested that high temperatures may be protective for children with asthma because children may be less exposed to triggers for asthma including increased bacterial survival, inhalation of cold air, airway irritation, and respiratory allergens in high temperature as compared to low temperature. Additionally, relevant to the high proportion of children who have exercise-induced asthma,³⁵ uncomfortably hot temperatures may reduce outdoor exercise thereby altering other trigger exposures as well. However, other studies have shown increased respiratory admissions (including asthma) associated with high temperature.^{10,36-38} For example, a study found that elevated ambient temperature in hot weather was associated with risk for admission for respiratory diseases in young children in California.³⁶ It is likely that indoor allergens and ozone increase with heat, which could irritate the underdeveloped respiratory systems in children. Further, outdoor air pollution and other concomitant exposures may also play a role in determining risk.³⁹ Additional data are needed to confirm these associations with pediatric admissions for children with asthma. The diminished protective effect we saw when limiting to the summer months of June, July, and August suggest that the spring pollen season and the return to school in the fall likely also play a role in this multifactorial disease.

Our examination of children with other chronic conditions--with notably smaller sample sizes--such as sickle cell disease, cerebral palsy, and cystic fibrosis showed mainly nonsignificant associations with heat. We had selected these *a priori* because sickle cell disease, cerebral palsy, and cystic fibrosis are heat- and dehydration-sensitive medical conditions with enhanced physiological susceptibility to heat. Affected children have impaired thermoregulation and movement limitations that can increase heat exhaustion.² We did not observe elevated susceptibility to heat among children with these chronic

conditions, likely because of behavioral modifications on the part of their caregivers or by the children themselves to mitigate exposures on extreme heat days.¹⁰ For example, parents and caregivers of children with chronic conditions may have already taken greater precautions to avoid outdoor heat exposures. Children's protective activity patterns, such as time spent indoors, low to moderate physical activity level, and adequate nutrition, are additional factors that could alleviate their susceptibility to heat. Another plausible explanation is that high existing healthcare utilization among children with severe and CCCs may obscure the association between temperature and hospitalization. In addition, while we treated children with CCCs as a single group in the analysis, they are a heterogeneous population with varying disease severities and healthcare needs and may respond to heat stress differently. Additional work is needed to better characterize the role chronic disease plays as it pertains to heat health risk among children, including using alternative algorithms to define complex conditions.

As for mental health disorders, we found heat conferred decreased risks for combined admissions and ED visits, but increased risks for pediatric hospitalizations. Several previous studies among adults have found that individuals with mental health disorders are at elevated risk from extreme heat.⁴⁰ For example, Basu et al found that high temperatures were associated with an increase in ED visits for mental health disorders among adults in California.⁴¹ Potential mechanisms include physiologic vulnerability, heat-triggered irritability and acute psychologic distress, sleep disturbance, and reduced cognitive function to avoid outdoor heat exposures.⁴²⁻⁴⁴ Side effects of medications such as impairment of the thermoregulation processes and suppressed thirst can also interfere with physiological homeostasis and contribute to greater admissions during hot weather. In our study, children with mental health disorders had increased risk for hospitalizations but decreased risk for ED visits associated with heat. This difference could suggest a shift in severity of morbidity among children with mental health disorders on hot days that resulted in a subset of children who would have otherwise only had an ED visit then being admitted into the hospital. More research is needed to further understand how mental health problems impact heat susceptibility in the child and adolescent population.

Limitations

First, there was possible misclassification or underreporting of diagnostic codes that may confound the effect of temperature as some chronic conditions (e.g., obesity) were not always coded during an admission. For example, compared to our ED admissions, there was a higher proportion of obesity/overweight diagnostic codes for children admitted to the hospital, where more thorough diagnostic codes are given. To partially address this issue, we used all available diagnosis code fields to identify chronic conditions, instead of relying only on primary diagnoses to capture chronic conditions. Nevertheless, we know that population prevalence of chronic conditions is still higher than that seen in our dataset. Second, our stratified analyses were limited by the relatively small sample size for severe chronic conditions such as cerebral palsy and cystic fibrosis, and we may be underpowered to detect heat effects among children with specific diagnoses. Further analyses with larger, more detailed, and more years of data sets are needed to further explore effect modification by medically CCCs. Third, while the SPARCS data structure accounts for double counting

between ED and hospital cases (e.g., only a single hospital record would remain if a patient was admitted to the hospital from the ED), there are few cases where patients were in both ED and hospital data (e.g., if they were discharged from ED but admitted to the hospital on a later day). To address the potential bias with the combined ED and hospital cases, we also examined them as separate outcomes. Finally, our study is cross-sectional, preventing us from making causal assumptions between heat and morbidity. The negative association between temperature and ED visits for certain chronic conditions could reflect a reduced likelihood to endorse multiple diagnostic codes or asthma codes on hot days, rather than reduced heat risk. Future studies that conduct extensive chart reviews of electronic medical records would help validate the diagnostic codes and examine causal pathways linking temperature and child morbidity.

Conclusion

Investigating whether children with chronic conditions are vulnerable to higher temperatures, we found that these children show a complex pattern of risk of healthcare utilization. Studying specific conditions may help better guide clinical and public health prevention practices to promote environmental justice and better climate resilience. While we observed that children with some chronic conditions such as asthma and obesity had lower risk of morbidity when temperatures were high, children with other conditions, such as mental health disorders, showed variation in risk based on specific months and type of healthcare utilization examined. If these negative and null associations we observed are true, our findings could represent successful behavioral adaptations that protect children who are physiologically vulnerable to heat. Additional investigation is needed to further strengthen protective responses while avoiding unintended consequences such as limited physical activity for children with chronic illness.

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Table 1.

Frequency of Specific Chronic Conditions for Children With and Without Complex Chronic Conditions Among Combined Pediatric Emergency Department and Hospital Admissions During the Warm Season (May to September), New York City, 2005-2011

Specific Conditions/Groupings	No CCC (n = 2,413,338)		One or More CCCs (n = 67,218)	
	Frequency	Percentage	Frequency	Percentage
Asthma	197,396	96.4%	7309	3.6%
Obesity/overweight	5,673	86.6%	876	13.4%
Cerebral palsy	0	0.0%	4267	100.0%
Cystic fibrosis	48	4.6%	999	95.4%
Sickle cell disease	0	0.0%	11,067	100.0%
Sickle cell trait	0	0.0%	2511	100.0%
Mental health disorders	84,936	90.5%	8935	9.5%

CCC=chronic complex condition.

Table 2.

Descriptive Statistics of Pediatric Emergency Department and Hospital Admissions in New York City, During the Warm Season (May to September) 2005-2011

Characteristics	All Admissions (n=2,480,556)	
	Frequency	Percentage
Age (y)		
0-4	1,101,423	44.4%
5-12	626,940	25.3%
13-18	752,193	30.3%
Sex		
Female	1,170,011	47.2%
Male	1,310,545	52.8%
Race/ethnicity		
Hispanic	799,479	32.2%
Non-Hispanic Black	816,995	32.9%
Non-Hispanic Other	575,411	23.2%
Non-Hispanic White	277,224	11.2%
Unknown	11,447	0.5%
Specific conditions/groupings		
Asthma	204,705	8.3%
Obesity/overweight	6549	0.3%
Cerebral palsy	4267	0.2%
Cystic fibrosis	1047	0.0%
Sickle cell disease	11,067	0.4%
Sickle cell trait	2511	0.1%
Mental health disorders	93,871	3.8%
Chronic complex conditions (CCCs)		
No CCC	2,413,338	97.3%
One or more CCCs	67,218	2.7%

Notes: Specific chronic conditions were coded using primary and non-primary diagnostic codes. ICD-9 codes included: asthma (493), obesity and overweight (278), cerebral palsy (343), cystic fibrosis (277), sickle cell disease (282.6), sickle cell trait (282.5), and mental health disorders (290-319, including neurodevelopmental [e.g., attention deficit] and psychological [e.g., schizophrenia] diagnoses).

Table 3. Percent Excess Risk for Combined Pediatric Emergency Department and Hospital Admissions per Interquartile Range (13°F) Increase in Daily Maximum Temperature Accumulated over Lags 0 to 5 Days, Stratified by Chronic Conditions for Entire Warm Season (May to September) and Summer Months Only (June to August), New York City, 2005-2011

	May-September	June-August
All admissions	1.35 (0.98, 1.71)	0.91 (0.36, 1.47)
Specific conditions/groupings		
Asthma	-13.52 (-14.69, -12.34)	-1.57 (-3.67, 0.58)
Obesity/overweight	-10.12 (-16.80, -2.90)	1.19 (-9.53, 13.19)
Cerebral palsy	-8.92 (-17.32, 0.34)	-8.89 (-20.22, 4.05)
Cystic fibrosis	6.62 (-12.31, 29.64)	16.90 (-10.87, 53.33)
Sickle cell disease	-4.33 (-9.90, 1.58)	-5.17 (-12.57, 2.85)
Sickle cell trait	5.22 (-7.37, 19.51)	6.60 (-10.21, 26.56)
Mental health disorders	-4.51 (-6.42, -2.56)	2.80 (-0.14, 5.83)
Chronic complex conditions (CCCs)		
No CCC	1.34 (0.97, 1.72)	0.86 (0.29, 1.42)
One or more CCCs	0.35 (-2.05, 2.81)	4.50 (1.10, 8.02)

Notes: Daily maximum temperature was fitted from a distributed lag nonlinear model accumulated over lags 0 to 5 days using a linear term, with a constrained linear structure for lags. All models were adjusted for relative humidity using a natural spline with 3 degrees of freedom. Significant associations where the 95% CI does not overlap zero appear in boldface.

Table 4.

Percent Excess Risk for Combined Pediatric Emergency Department and Hospital Admissions per Interquartile Range (13°F) Increase in Daily Maximum Temperature Over Lags 0 to 5 days, Stratified by Chronic Conditions for Entire Warm Season (May-September) and Summer Months Only (June to August), New York City, 2005-2011

Lag Day	May-September		June-August	
	% Excess Risk (95% CI)	% Excess Risk (95% CI)	% Excess Risk (95% CI)	% Excess Risk (95% CI)
<i>All admissions</i>				
Lag0	1.00 (0.84, 1.15)		0.34 (0.12, 0.55)	
Lag1	0.69 (0.58, 0.79)		0.26 (0.11, 0.41)	
Lag2	0.38 (0.31, 0.44)		0.19 (0.09, 0.29)	
Lag3	0.07 (0.00, 0.13)		0.11 (0.02, 0.21)	
Lag4	-0.24 (-0.34, -0.14)		0.04 (-0.10, 0.18)	
Lag5	-0.55 (-0.69, -0.40)		-0.03 (-0.24, 0.17)	
Cumulative	1.35 (0.98, 1.71)		0.91 (0.36, 1.47)	
<i>Specific conditions/groupings</i>				
Asthma				
Lag0	-2.30 (-2.82, -1.78)		0.24 (-0.60, 1.08)	
Lag1	-2.34 (-2.70, -1.98)		0.04 (-0.55, 0.62)	
Lag2	-2.37 (-2.61, -2.13)		-0.16 (-0.56, 0.23)	
Lag3	-2.41 (-2.65, -2.17)		-0.36 (-0.74, 0.02)	
Lag4	-2.45 (-2.81, -2.09)		-0.56 (-1.12, 0.00)	
Lag5	-2.48 (-3.00, -1.96)		-0.76 (-1.56, 0.05)	
Cumulative	-13.52 (-14.69, -12.34)		-1.57 (-3.67, 0.58)	
Obesity/overweight				
Lag0	-0.96 (-3.90, 2.06)		-1.97 (-6.06, 2.30)	
Lag1	-1.28 (-3.32, 0.79)		-1.11 (-4.01, 1.89)	
Lag2	-1.60 (-2.97, -0.22)		-0.24 (-2.25, 1.81)	
Lag3	-1.92 (-3.28, -0.54)		0.64 (-1.35, 2.66)	
Lag4	-2.24 (-4.24, -0.19)		1.52 (-1.36, 4.49)	
Lag5	-2.55 (-5.43, 0.41)		2.41 (-1.75, 6.75)	
Cumulative	-10.12 (-16.80, -2.90)		1.19 (-9.53, 13.19)	

Lag Day	May-September		June-August	
	% Excess Risk (95% CI)		% Excess Risk (95% CI)	
Cerebral palsy				
Lag0	-1.12 (-4.74, 2.64)	-0.32 (-5.22, 4.82)		
Lag1	-1.29 (-3.81, 1.30)	-0.81 (-4.24, 2.74)		
Lag2	-1.46 (-3.17, 0.28)	-1.30 (-3.64, 1.11)		
Lag3	-1.63 (-3.33, 0.10)	-1.78 (-4.08, 0.57)		
Lag4	-1.80 (-4.30, 0.77)	-2.26 (-5.57, 1.16)		
Lag5	-1.97 (-5.56, 1.75)	-2.74 (-7.44, 2.19)		
Cumulative	-8.92 (-17.32, 0.34)	-8.89 (-20.22, 4.05)		
Cystic fibrosis				
Lag0	6.65 (-1.36, 15.31)	5.95 (-4.89, 18.02)		
Lag1	4.38 (-1.10, 10.17)	4.61 (-2.97, 12.78)		
Lag2	2.17 (-1.44, 5.90)	3.29 (-1.77, 8.62)		
Lag3	-0.01 (-3.44, 3.55)	1.99 (-2.76, 6.97)		
Lag4	-2.13 (-7.09, 3.10)	0.70 (-6.11, 8.00)		
Lag5	-4.21 (-11.21, 3.34)	-0.57 (-10.21, 10.10)		
Cumulative	6.62 (-12.31, 29.64)	16.90 (-10.87, 53.33)		
Sickle cell disease				
Lag0	-2.53 (-4.76, -0.25)	-3.29 (-6.28, -0.20)		
Lag1	-1.82 (-3.38, -0.23)	-2.33 (-4.46, -0.16)		
Lag2	-1.10 (-2.17, -0.01)	-1.37 (-2.83, 0.11)		
Lag3	-0.37 (-1.44, 0.70)	-0.39 (-1.81, 1.05)		
Lag4	0.36 (-1.21, 1.95)	0.59 (-1.48, 2.71)		
Lag5	1.10 (-1.18, 3.42)	1.59 (-1.42, 4.69)		
Cumulative	-4.33 (-9.90, 1.58)	-5.17 (-12.57, 2.85)		
Sickle cell trait				
Lag0	-0.53 (-5.20, 4.38)	-3.42 (-9.68, 3.27)		
Lag1	0.02 (-3.27, 3.43)	-1.65 (-6.13, 3.04)		
Lag2	0.57 (-1.70, 2.90)	0.16 (-2.94, 3.35)		
Lag3	1.13 (-1.17, 3.48)	1.99 (-1.08, 5.17)		
Lag4	1.69 (-1.67, 5.16)	3.87 (-0.71, 8.65)		

Lag Day	May-September		June-August	
	% Excess Risk (95% CI)		% Excess Risk (95% CI)	
Lag5	2.25 (-2.57, 7.31)	5.77 (-0.91, 12.91)		
Cumulative	5.22 (-7.37, 19.51)	6.60 (-10.21, 26.56)		
Mental health disorders				
Lag0	-0.43 (-1.21, 0.35)	0.69 (-0.41, 1.82)		
Lag1	-0.56 (-1.10, -0.02)	0.60 (-0.17, 1.38)		
Lag2	-0.70 (-1.06, -0.34)	0.51 (-0.02, 1.04)		
Lag3	-0.83 (-1.19, -0.47)	0.42 (-0.10, 0.93)		
Lag4	-0.97 (-1.50, -0.43)	0.32 (-0.43, 1.08)		
Lag5	-1.10 (-1.87, -0.33)	0.23 (-0.85, 1.32)		
Cumulative	-4.51 (-6.42, -2.56)	2.80 (-0.14, 5.83)		
<i>Chronic complex conditions (CCC's)</i>				
No CCC				
Lag0	1.03 (0.87, 1.19)	0.32 (0.11, 0.54)		
Lag1	0.71 (0.60, 0.81)	0.25 (0.10, 0.40)		
Lag2	0.38 (0.31, 0.45)	0.18 (0.08, 0.28)		
Lag3	0.06 (-0.01, 0.13)	0.11 (0.01, 0.20)		
Lag4	-0.26 (-0.36, -0.16)	0.03 (-0.11, 0.18)		
Lag5	-0.58 (-0.73, -0.43)	-0.04 (-0.25, 0.17)		
Cumulative	1.34 (0.97, 1.72)	0.86 (0.29, 1.42)		
One or more CCC's				
Lag0	-0.05 (-0.98, 0.90)	0.38 (-0.88, 1.67)		
Lag1	0.00 (-0.65, 0.65)	0.52 (-0.36, 1.42)		
Lag2	0.04 (-0.40, 0.48)	0.67 (0.06, 1.28)		
Lag3	0.08 (-0.36, 0.52)	0.81 (0.22, 1.40)		
Lag4	0.12 (-0.52, 0.77)	0.95 (0.09, 1.81)		
Lag5	0.16 (-0.77, 1.10)	1.09 (-0.14, 2.34)		
Cumulative	0.35 (-2.05, 2.81)	4.50 (1.10, 8.02)		

Notes: Daily maximum temperature was fitted from a distributed lag nonlinear model accumulated over lags 0 to 5 days using a linear term, with a constrained linear structure for lags. All models were adjusted for relative humidity using a natural spline with 3 degrees of freedom. Significant associations where the 95% CI does not overlap zero appear in boldface.

Table 5.

Percent Excess Risk for Emergency Department Visits and for Hospital Admissions per Interquartile Range (13°F) Increase in Daily Maximum Temperature Accumulated Over Lags 0 to 5 Days, Stratified by Chronic Conditions During Warm Season (May to September), New York City, 2005-2011

Chronic Conditions	Emergency Department Visits		Hospital Admissions	
	n	% Excess Risk (95% CI)	n	% Excess Risk (95% CI)
All admissions	2,145,861	1.63 (1.21, 2.06)	219,785	1.17 (-2.14, 4.60)
Specific conditions/groupings				
Asthma	85,884	-14.75 (-16.07, -13.40)	20,170	-7.65 (-15.12, 0.48)
Obesity/overweight	102	-17.56 (-29.17, -4.05)	114	-3.32 (-23.48, 22.15)
Cerebral palsy	49	-7.74 (-24.75, 13.11)	121	-19.20 (-39.02, 7.07)
Cystic fibrosis	92	1.62 (-31.33, 50.38)	268	0.60 (-42.01, 74.53)
Sickle cell disease	2036	-7.61 (-16.38, 2.09)	173,525	-2.80 (-19.56, 17.45)
Sickle cell trait	23	23.21 (2.08, 48.71)	4	-19.76 (-48.09, 24.02)
Mental health disorders	47,070	-5.98 (-8.29, -3.62)	13,939	9.99 (0.44, 20.44)
Chronic complex conditions (CCCs)				
No CCC	2,145,861	1.65 (1.23, 2.08)	173,525	0.01 (-3.68, 3.85)
One or more CCCs	18,634	-0.42 (-4.85, 4.21)	46,260	5.54 (-1.76, 13.38)

Notes: Daily maximum temperature was fitted from a distributed lag nonlinear model accumulated over lags 0 to 5 days using a linear term, with a constrained linear structure for lags. All models were adjusted for relative humidity using a natural spline with 3 degrees of freedom. Significant associations where the 95% CI does not overlap zero appear in boldface.