Published in final edited form as:
Public Health. 2018 August ; 161: 119–126. doi:10.1016/j.puhe.2018.06.004.

Not so little differences: Variation in hot weather risk to young children in New York City

Perry E. Sheffield[1], **M. Teresa Herrera**[1], **Ellen J. Kinnee**[2], and **Jane E. Clougherty**[3]

[1]Department of Environmental Medicine and Public Health, Icahn School of Medicine at Mount Sinai, New York, NY 10029, USA

[2]Department of Environmental and Occupational Health, University of Pittsburgh Graduate School of Public Health, Pittsburgh, PA 15219, USA

[3]Department of Environmental and Occupational Health, Dornsife School of Public Health, Drexel University, Philadelphia, PA 19104, USA

Abstract

Objectives—High ambient temperatures are associated with significant health risk in the United States. The risk to children has been minimally explored and often young children are considered as a single age group despite marked physiologic and social variation among this population from infancy through preschool. This study explored the heterogeneity of risk of heat among young children.

Study Design—Using a time-stratified, case-crossover design, we evaluated associations between maximum daily temperature (Tmax) and ED visits (n=1,002,951) to NYC metropolitan area hospitals for children aged 0–4 years in for May – September, 2005–2011.

Methods—Conditional logistic regression analysis estimated risks for an interquartile range of Tmax for 0–6 lag days. Stratified analyses explored age strata by year, race/ethnic groups, and diagnostic codes. Sensitivity analyses controlled for same day ambient ozone, particulate matter <2.5 microns, and relative humidity and, separately, explored race groups without ethnicity and different diagnostic code groupings.

Results—Children ages 0 – 4 years had increased risk of emergency department visits with increased Tmax on lag days 0, 1, and 3. The association was strongest on lag day 0, when an increase in Tmax of 13°F conferred an excess risk of 2.6 % (95% CI 2.2 – 3.0). Stratifying by age, we observed significant positive associations for same-day exposures, for 1- to 4-year-olds. Children less than one year of age showed a significant positive association with Tmax only on lag day 3.

The race/ethnicity stratified analysis revealed a similar lag pattern for all subgroups. The diagnostic group analysis showed percent excess risk for heat specific diagnoses [16.6% (95% CI

Corresponding author: Perry Sheffield, Icahn School of Medicine at Mount Sinai, Box 1057, EMPH, 1 Gustave L. Levy Pl., New York, NY 10029, perry.sheffield@mssm.edu.

Competing interests: The authors have no competing financial interests to disclose.

Ethical approval: Institutional review boards at the University of Pittsburgh and Icahn School of Medicine at Mount Sinai approved this study.

3.0 – 31.9)]; general symptoms [10.1% (95% CI 8.2 – 11.9)]; infectious [4.9% (95% CI 3.9 – 5.9)]; and injury [5.1% (95% CI 3.8 – 6.4)] diagnoses.

Conclusion—We found a significant risk of ED visits in young children with elevated Tmax. Risk patterns vary based on year of age with infants showing delayed risk and toddlers and preschools with same day risk. Additionally, the finding of increased risk of injury associated with higher temperatures is novel. Altogether, these findings suggest a need for a tailored public health response – such as different messages to caregivers of different age children - to protect children from the effects of heat. Next steps include examining specific subcategories of diagnoses to develop protective strategies and better anticipate the needs of population health in future scenarios of climate change.

Keywords

extreme heat; vulnerability; climate change; morbidity; urban; pediatric

Introduction

High outdoor temperatures create a significant public health burden even in highly industrialized countries,1 and climate change is expected to worsen these health impacts[2]. To date, the relationship between heat and mortality[3–4,5,6] and morbidity[1] has been demonstrated across multiple municipalities and regions throughout the U.S., with highest sensitivity among elderly, working, or young populations, depending on the outcomes examined and types of temperature metrics (e.g., continuous temperature versus heat wave events) used.[7–,8,9,10] Among young populations, effects seen in 0–4 year olds are often greater than older age groups.[11] However, children under five years of age are typically categorized as a single group,[12] with some literature indicating that infants (children under 1 year of age) may have greater risk of adverse health effects from heat.[3,13] Children under age five are highly heterogeneous, and include several American Academy of Pediatrics defined age groups, including newborn, infant, toddler, and preschooler.[14] Physiologic and developmental variation among children less than five years old could indicate different risk and thus different public health actions needed to protect their health.

Climate change is predicted to increase temperature variability and to break current temperature records. Furthermore, the majority of the world's population now lives in urban settings where heat risk is increased due to the urban heat island effect.[15] Given the increased vulnerability of young children, poorly explored heterogeneity within the youngest age group, and worsening exposure risk, particularly in urban settings, the aim of this study was to better characterize the associations between temperature and specific health effects among young children aged 0–4 years, and to examine the variability of health effects within this age group in the urban setting of New York City.

Methods

Health Outcome Data

The health data included emergency department (ED) visits (outpatient) (all-cause ICD-9 codes) from 2005–2011 (May 1st - September 30th) for children aged 0–4 years old living in

NYC, obtained from New York City Statewide Planning and Research Cooperative System (SPARCS). SPARCS is a comprehensive New York statewide all-payer dataset of hospitalization and emergency department visits. The system was established in 1979 as a healthcare industry and government collaboration. Each record in our dataset represented a single ED visit.

Age in years, sex, and race/ethnicity were extracted along with health data from SPARCS records. Race and ethnicity are coded separately, and we combined the two variables into the following groups using SPARCS terminology: Spanish/Hispanic origin (SHO); Black (non-SHO); white (non-SHO); other (non-SHO) which included Asian, Native American, Pacific Islander, and other; or unknown. Race and ethnicity classifications are primarily self-reported and are social constructs rather than physiologic classifications. We chose to include them as race and ethnicity are significant for health disparities in the U.S. and important markers of individuals' lived experiences, relating potentially to multiple social determinants of health such as the experience of racism and health care access.

ICD-9 Groups

Using principal diagnostic codes (those assigned after health provider assessments and diagnostic tests, in contrast to intake/ triage chief complaint), we classified ICD-9 codes into groups according to existing literature on childhood heat morbidity[9,12] and the proportional distribution of ICD-9 codes in our own dataset. The following six groups were identified: general symptoms (ICD-9 code 780); injury (800–904, 910–929, 950–959); respiratory illness (460–519, 786), viral and ear infections (070–079, 382); heat-related illness (276, 992); and digestion-related illness (564, 787). While there are over 600 ICD-9 codes reported across all ED events, these six groups of approximately 200 codes capture greater than 75% of cases.

Environmental Exposure Data

We averaged daily temperature data of the four meteorological stations in the NYC area (JFK International Airport, LaGuardia Airport, Central Park, Newark International Airport) from the NOAA National Climatic Data Center (NCDC) for mean temperature (Tavg), minimum temperature (Tmin), and maximum temperature (Tmax). We calculated relative humidity (RH) from Tavg and dew point temperature using the standard NOAA equation. Average heat index (HI), or apparent temperature, was calculated from Tavg and RH using the National Weather Service's Heat Index formula.[16] To enable adjustment for potential confounding by co-pollutant exposures in our sensitivity analyses, fine particulate matter ($PM_{2.5}$) and ozone (O_3) daily time-series were constructed using the average of scaled daily values, to account for between-site differences in means and variances in regulatory monitoring data, as reported previously[17] and as in Schwartz (2000).[18]

Statistical Analysis

We used a case-crossover approach, an established method for studying temperature morbidity.[19–,20,21,22,23] By comparing individuals to themselves (exposures on day of event vs. exposures on control days), case-crossover allows for examination of potential time-variant confounders (e.g., spatio-temporal temperature exposures), while controlling for time-invariant confounding (e.g., sex). We used a time-stratified approach[24] for referent selection, wherein the control days for each case are the same day of week, within the same month, resulting in 3–4 controls per case.

Using conditional logistic regression, we estimated excess risk per interquartile range (IQR) increase in temperature. We implemented models estimating effects of exposures on the case day, and for lag days 1 to 6 (1 to 6 days prior to ED visit), to capture delayed effects of temperature exposures.[25] While maximum temperature is commonly used in studies of heat effects on health generally,[26] and particularly for child morbidity,[27] we examined models using maximum temperature, minimum temperature, average temperature, and average heat index. Except when using heat index, a function of temperature and relative humidity, as the primary predictor, we controlled for RH using a natural spline with four degrees of freedom, as humidity has shown an independent relationship to child health.[28]

To examine potential heterogeneity to heat vulnerability, we stratified by year of age among zero to four year olds. To better understand health disparities in our population across racial/ethnicity groupings, we stratified by race/ethnicity, excluding those with unknown (unreported) ethnicity and race. Those with unknown (unreported) race but Spanish/Hispanic origin ethnicity were included.

To better understand the sensitivity of specific diagnostic categories to temperature, we stratified by the six diagnostic categories (general symptoms, injury, respiratory illness, viral and ear infections, heat-related illness, and digestion-related illness). These diagnostic code analyses included only cases in the subgroup of 1– 3 year olds, where we found the strongest associations with all-cause ED visits.

Statistical analyses were conducted in SAS (v9.4, SAS Institute Inc., Cary, NC) and R statistical software version 3.2.2 (R Core Team 2015).

Sensitivity Analysis

To explore potential confounding by air pollution on the temperature – ED visit association, we included $PM_{2.5}$ and O_3 in the model, each with normal spline and three degrees of freedom. Separate models were run for the entire sample, stratified by age, and limited to respiratory diagnoses for one to three year olds. In two additional sensitivity analyses, we modified our category of respiratory diagnoses to include just asthma (493). Finally, we modified the race/ethnicity categorization to include only race, without ethnicity.

Results

There were 1,002,951 New York City metropolitan ED visits for children ages zero to four years living in NYC during May-September 2005 – 2011, an average of 936 events (SD = 139.2) per day during our study period. The characteristics of these children are found in Table 1. Almost 28% of cases were among children less than one year old, with decreasing percentages with each year of age, and fewer than 13% in the 4-year-old age group.

Figure 1 shows ICD-9 frequencies by age for: general symptoms (ICD-9 code 780); digestion-related illness (564, 787); viral and ear infections (070–079, 382); respiratory illness (460–519, 786); heat-specific illness (276, 992); and injury (800–904, 910–929, 950–959). For all age strata, heat-specific illness represents the smallest proportion (< 1%) of cases but was included because of relevance to the exposure. Injury diagnoses increased from 6% of all cases among those less than one year old, to 21% among 4-year-olds. Viral and ear infection diagnoses represent the largest proportion of cases (24 – 34%) among children of all ages less than four years.

Case-crossover analysis

The temperature metrics of Tmax, Tmin, Tavg, and HI showed similar magnitude of associations with ED visits, and similar lag structure across days. Tmax was selected for our primary model based on best fit per the log likelihood ratio test, and known physiologic susceptibility of this young age group to temperature extremes.[26,27]

Children ages 0 – 4 years had increased risk of emergency department visits with increased Tmax on lag days 0, 1, and 3 (Figure 2A). The association was strongest on lag day 0, when an increase in Tmax of 13°F conferred an excess risk of 2.6 % (95% CI 2.2 – 3.0).

Stratifying by age, we observed significant positive associations for same-day exposures, for all ages except for those less than one year old. Percent excess risk on same-day Tmax exposure for 1-year-olds was 3.2% (95% CI 2.4 – 4.0); for 2-year-olds, it was 4.3% (95% CI 3.4 – 5.2); 3-year-olds had excess risk of 4.0% (95% CI: 3.0 – 5.0), and 4-year-olds had excess risk of 1.9% (95% CI 0.8 – 3.0). Children less than one year of age showed a smaller but significant positive association with Tmax, but only on lag day 3 [0.6% (95% CI 0.1 – 1.1)], rather than on lag day 0, as observed for children of other ages. Those in the 3- and 4-year-old age groups showed significant negative associations on lag days 6 (for 3-year-olds) and days 4 and 5 (for 4-year-olds).

In the stratified analysis by race/ethnicity (Figure 2B), we again saw a similar lag pattern with peak effects on lag day 0 and tapering off over subsequent days for all subgroups. The SHO, Black non-SHO, and Other non-SHO subgroups showed similar magnitude as the full group. The White non-SHO subgroup showed the highest magnitude of association with Tmax [lag day 0: 5.2% (95% CI 3.9 – 6.5)] with wider confidence interval than other subgroups due to fewer cases in this subgroup.

Lastly, we examined different diagnostic groups again limiting to children ages 1–3 years of age (Figure 3). The percent excess risk of ED visits per 13°F for same day Tmax exposure was highest for heat specific diagnoses [16.6% (95% CI 3.0 – 31.9)]. Risk of ED visits for general symptoms [10.1% (95% CI 8.2 – 11.9)], infectious [4.9% (95% CI 3.9 – 5.9)], and injury [5.1% (95% CI 3.8 – 6.4)] diagnostic codes was also elevated while risk for ED visits for digestive and respiratory showed no significant association.

Sensitivity analyses

When including co-pollutants $PM_{2.5}$ and O_3 in our main model, we saw diminished magnitude of associations [e.g. lag day 0 (1.3% (95% CI 0.7 – 1.8))] that retained significance on lag days 0 and 3 (data not shown). For the age-stratified models with co-pollutants, the significant result for children less than one year old on lag day 3 was unchanged and the other lag days remained not statistically significant. For ages 1–3 years, same day Tmax was still associated with an elevated risk of ED visits with the peak association now for 3 year olds on lag day 0 [3.3% (95% CI 1.8 – 4.8)]. The 4 year old age groups showed no significant positive association and we again observed negative associations for this age group on lag days 2 and 4.

When we controlled for $PM_{2.5}$ and O_3 in the respiratory diagnostic code subgroup among 1–3 year olds, we again observed a negative association between ED visits and an increase in Tmax of 13°F but the association was now statistically significant [lag day 0 (−3.7% (95% CI −5.1 - −2.2))]. Then controlling just for RH, we further explored the respiratory category by limiting the diagnostic codes to asthma (493) among 1–3 year olds and again saw a significantly negative association [lag day 0 (−3.7 (95% CI −6.1 - −1.3))].

To further explore racial/ethnic categorizations, we ran the model using only race (i.e. all cases were either Black, white, or other and Spanish/Hispanic origin was not a separate category). We observed significantly positive peak effects – with slightly diminished magnitude – for all three race categories. The Black group had significant positive associations on lag days 0–2 and a significant negative association on lag day 6 (−0.6% (95% CI −1 - −0.1); the white group had significant positive associations through lag day 4 with the largest magnitude association on lag day 0 (4.2% (95% CI 3.3 – 5.1); and the other race group had significant positive associations on lag days 0 and 1.

Discussion

In this study, we found an association between all-cause ED visits and daily maximum temperature increases during the warm season for young children living in New York City. Furthermore, we observed the strongest association with same day temperature and found substantial heterogeneity among the different age groups with the toddlers and early preschool age children (1- to 3-year-olds) having the strongest effect size. Interestingly, children under one year old only showed a significant effect on lag day 3, representing potentially the larger role that the viral and ear infection diagnoses - with a more prolonged clinical course - played proportionally among this age group. Meanwhile, the protective effect seen in 4 year olds in lag days 4 and 5 may point to some behavioral and environmental changes for these preschool age children.

While the effects of temperature on various race and ethnic groups vary throughout the literature, [29,20] the results from our stratified analysis by race and ethnicity were counterintuitive compared with other temperature morbidity literature.[29,30] The White, non-SHO racial/ethnic category showed the highest percent excess risk on same day exposure compared to other categories. Latino/Hispanic children were also at an increased risk of visiting the emergency department with increasing Tmax on lag days 0, 1, and 3 but at a lesser magnitude. Communities of color may face additional barriers preventing them from seeking care when needed and, thus, our metric of utilization of health care facilities might underestimate actual morbidity that would be missed by this study design. Additionally, despite the lower effect estimate, the overall health burden from high temperatures could be higher among Black and Latino/Hispanic populations given the larger absolute size of these populations and number of ED cases from these populations in NYC. As we are unable to fully flesh out the mechanism underlying the observed differences by race and ethnicity, further research is needed.

In terms of diagnostic categories, the most surprising finding was the association with injury diagnoses. This ICD-9 category is generally excluded from temperature morbidity studies so we found no comparable risk associations. However, injury diagnoses seemed germane given that heat has been shown to increase violence and aggression[31] with plausible effects directly via the child's behavior and also indirectly via changes in caregiver behavior or supervision. Further investigation of more specific diagnostic codes among injuries is warranted to better understand this observed association.

Overall, this study was strengthened by a use of a large administrative dataset with citywide coverage. However, our study also had several limitations. This study does not measure a heat wave effect. Constraints on time in the case-crossover model make studying multiple day heat waves difficult because of the selection of the reference group. In a time- stratified or bidirectional case-crossover models, some references are only one week from cases such that multi-day heat waves could make it difficult to separate effects of the heat wave from controls which are close in date to the heat wave. Furthermore, in terms of the exposure assignment, we used a citywide metric for temperature rather than a more spatially resolved estimate or personal monitoring. Such exposure misclassification likely biases our results toward the null, but, at least, we know that very few (less than 2%) of the cases, all of whom had NYC residential addresses, were treated at emergency departments outside the city suggesting that children both resided and sought care within the city limits. Still, more resolved exposure estimates are encouraged in further work.

Additionally, in terms of limitations, we had no proxy for socioeconomic status as the insurance data was too limited in this dataset for a sub-analysis. Insurance status would have permitted further exploration of the effects seen at later lag days that could be a reflection of delayed treatment as is common among under- or uninsured populations.[32] Finally, the study did not examine the non-linear effects of maximum temperature which could be an area of further investigation particularly if expanding the study period to include cold season.

Our findings support the idea that among children under five years of age there is different risk based on age and race/ethnicity. Additionally, the diagnostic subgroups provide some insight into potential mechanism through which the heat is influencing health. This heterogeneity and insight could inform future research as well as public health interventions. The small proportion of heat-specific illness ICD-9 codes reveals what may be an overlooked diagnostic category in this age group and an area of potential health professional training to raise awareness for better detection and public health planning and messaging. For example, the messaging to caretakers of infants and toddlers in heat should be different than to families of children who are entering preschool. Such tailored approaches and refined understanding will become increasingly important as we continue to try to anticipate the needs of children in multiple scenarios of a changing climate.

Acknowledgements

Funding: This work was supported by the National Institutes of Health [grant numbers NIH R21ES021429 (JEC, PES), K23ES024127 (PES), and NHLBI R25HL108857 (MTH)].

References

1. Ye X, Wolff R, Yu W, Vaneckova P, Pan X, Tong S. Ambient temperature and morbidity: a review of epidemiological evidence. Environ Health Perspect. 2012;120:19–28. doi:10.1289/ehp.1003198. [PubMed: 21824855]
2. Peng RD, Bobb JF, Tebaldi C, McDaniel L, Bell ML, Dominici F. Toward a quantitative estimate of future heat wave mortality under global climate change. Environ Health Perspect. 2011;119:701–6. doi:10.1289/ehp.1002430. [PubMed: 21193384]
3. Basu R, Ostro BD. A multicounty analysis identifying the populations vulnerable to mortality associated with high ambient temperature in California. Am J Epidemiol. 2008;168:632–7. doi: 10.1093/aje/kwn170. [PubMed: 18663214]
4. Stafoggia M, Forastiere F, Agostini D, Biggeri A, Bisanti L, Cadum E, et al. Vulnerability to heat-related mortality: a multicity, population-based, case-crossover analysis. Epidemiology. 2006 5;17:315–23. [PubMed: 16570026]
5. Kovats RS, Johnson H, Griffith C. Mortality in southern England during the 2003 heat wave by place of death Health Stat Q. 2006; Spring:6–8.
6. Basu R, Samet JM. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. Epidemiol Rev 2002; 24:190–202. [PubMed: 12762092]
7. Wang Y, Bobb JF, Papi B, Wang Y, Kosheleva A, Di Q, Schwartz JD, Dominici F. Heat stroke admissions during heat waves in 1,916 US counties for the period from 1999 to 2010 and their effect modifiers. Environ Health. 2016;15:83. doi: 10.1186/s12940-016-0167-3. [PubMed: 27503399]
8. Bobb JF, Obermeyer Z, Wang Y, Dominici F. Cause-specific risk of hospital admission related to extreme heat in older adults. JAMA. 2014 12 24–31;312:2659–67. doi: 10.1001/jama.2014.15715. [PubMed: 25536257]
9. Knowlton K, Rotkin-Ellman M, King G, Margolis HG, Smith D, Solomon G, et al. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. Environ Health Perspect 2009;117:61–7. doi: 10.1289/ehp.11594. [PubMed: 19165388]
10. Kovats RS, Hajat S, Wilkinson P. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. Occup Environ Med 2004;61:893–8. [PubMed: 15477282]
11. Xu Z, Huang C, Hu W, Turner LR, Su H, Tong S. Extreme temperatures and emergency department admissions for childhood asthma in Brisbane, Australia. Occup Environ Med 2013 10;70:730–5. [PubMed: 23884454]
12. Xu Z, Etzel RA, Su H, Huang C, Guo Y, Tong S. Impact of ambient temperature on children's health: a systematic review. Environ Res 2012;117:120–31. doi:10.1016/j.envres.2012.07.002. [PubMed: 22831555]
13. Basagaña X, Sartini C, Barrera-Gómez J, et al. Heat waves and cause-specific mortality at all ages. Epidemiology 2011;22:765–772. doi:10.1097/EDE.0b013e31823031c5. [PubMed: 21968768]
14. American Academy of Pediatrics Council on Environmental Health Chapter 3: Children's Unique Vulnerabilities to Environmental Hazards In: Etzel RA, Balk SJ, editors. Pediatric Environmental Health, 3rd Edition, Elk Grove Village, IL: American Academy of Pediatrics; 2012, p. 13–26.
15. Li D, Bou-Zeid E. Synergistic Interactions between Urban Heat Islands and Heat Waves: The Impact in Cities Is Larger than the Sum of Its Parts. J Appl Meteor Climatol 2013;52:2051–4. doi: 10.1175/JAMC-D-13-02.1.
16. Anderson GB, Bell ML, Peng RD. Methods to calculate the heat index as an exposure metric in environmental health research. Environ Health Perspect 2013;121:1111–9. [PubMed: 23934704]

17. Sheffield PE, Zhou J, Shmool JL, Clougherty JE. Ambient ozone exposure and children's acute asthma in New York City: a case-crossover analysis. Environ Health 2015;18;14:25. doi: 10.1186/s12940-015-0010-2.
18. Schwartz J The distributed lag between air pollution and daily deaths. Epidemiology 2000;11:320–6. [PubMed: 10784251]
19. Green RS, Basu R, Malig B, Broadwin R, Kim JJ, Ostro B. The effect of temperature on hospital admissions in nine California counties. Int J Public Health 2010;55:113–21. doi: 10.1007/s00038-009-0076-0. [PubMed: 19771392]
20. Gronlund CJ, Zanobetti A, Schwartz JD, Wellenius GA, O'Neill MS. Heat, heat waves, and hospital admissions among the elderly in the United States, 1992–2006. Environ Health Perspect 2014;122:1187–92. doi: 10.1289/ehp.1206132. [PubMed: 24905551]
21. Ha S, Talbott EO, Kan H, Prins CA, Xu X. The effects of heat stress and its effect modifiers on stroke hospitalizations in Allegheny County, Pennsylvania. Int Arch Occup Environ Health 2014;87:557–65. doi:10.1007/s00420-013-0897-2. [PubMed: 23897226]
22. Basu R, Pearson D, Malig B, Broadwin R, Green R. The effect of high ambient temperature on emergency room visits. Epidemiology 2012;23:813–20. doi: 10.1097/EDE.0b013e31826b7f97. [PubMed: 23007039]
23. Kyobutungi C, Grau A, Stieglbauer G, Becher H. Absolute temperature, temperature changes and stroke risk: a case-crossover study. Eur J Epidemiol 2005;20:693–8. [PubMed: 16151883]
24. Janes H, Sheppard L, Lumley T. Case-crossover analyses of air pollution exposure data: referent selection strategies and their implications for bias. Epidemiology 2005;16:717–26. [PubMed: 16222160]
25. Heidari L, Winquist A, Klein M, O'Lenick C, Grundstein A, Sarnat, SE. Susceptibility to Heat-Related Fluid and Electrolyte Imbalance Emergency Department Visits in Atlanta, Georgia, USA. Int J Environ Res Public Health 2016;13:982. doi:10.3390/ijerph13100982
26. Barnett AG, Tong S, Clements AC. What measure of temperature is the best predictor of mortality? Environ Res 2010;110:604–11. doi:10.1016/j.envres.2010.05.006. [PubMed: 20519131]
27. Winquist A, Grundstein A, Chang HH, Hess J, Sarnat SE. Warm season temperatures and emergency department visits in Atlanta, Georgia. Environ Res 2016;147:314–23. doi: 10.1016/j.envres.2016.02.022. [PubMed: 26922412]
28. Gao J, Sun Y, Lu Y, Li L. Impact of ambient humidity on child health: a systematic review. PLoS One 2014;9:e112508. doi: 10.1371/journal.pone.0112508.
29. Gronlund CJ. Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. Curr Epidemiol Rep 2014;1:165–73. [PubMed: 25512891]
30. Ye X, Wolff R, Yu W, Vaneckova P, Pan X, Tong S. Ambient Temperature and Morbidity: A Review of Epidemiological Evidence. Environ Health Perspect 2012;120:19–28. [PubMed: 21824855]
31. Anderson CA. Heat and Violence. Curr Dir Psychol Sci 2001;10:33–8.
32. Kogan MD, Newacheck PW, Blumberg SJ, Ghandour RM, Singh GK, Strickland BB, et al. Underinsurance among children in the United States. N Engl J Med 2010;363:841–51. doi: 10.1056/NEJMsa0909994. [PubMed: 20818845]

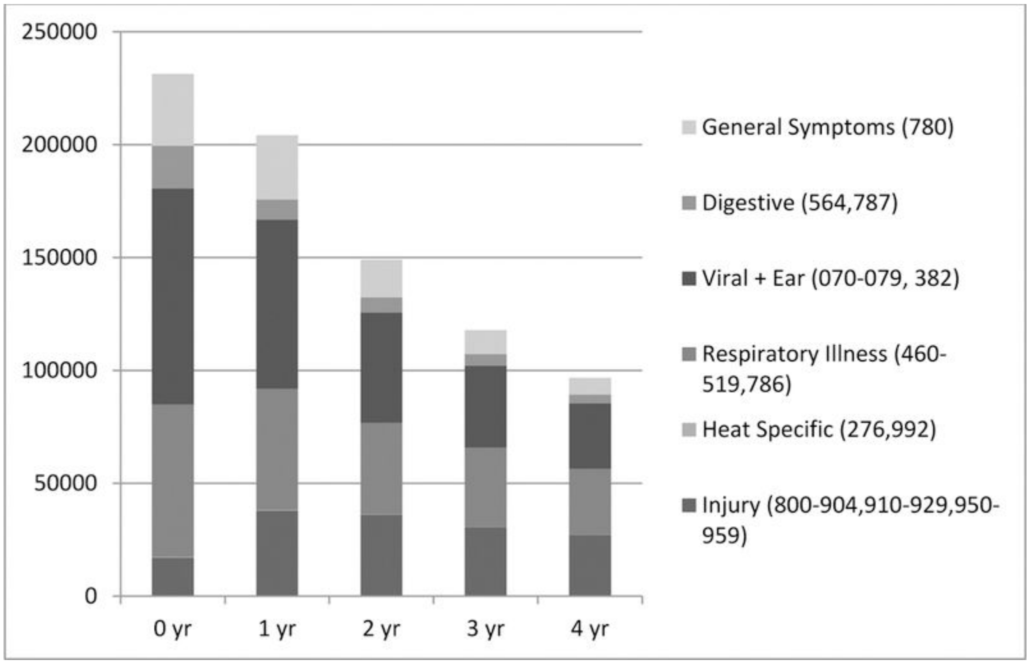

Figure 1:

Frequency of ICD-9 diagnostic groups for NYC metropolitan emergency department visits during the warm seaon (May – September) 2005–2011, among children aged 0–4 years living within New York City. General Symptoms included ICD-9 codes 780 (fever, altered consciousness, excessive crying, sleep disturbances, fussy infant, and convulsions). Digestive cases included ICD-9 code 564 (functional digestive disorder) and 787 (symptoms involving the digestive system). The viral and ear infection group included ICD-9 codes 070–079 (other diseases due to viruses and chlamydiae) and 382 (suppurative and unspecified otitis media). Cases were considered in the respiratory group if the principal diagnostic ICD-9 code was 460–519 (asthma, respiratory infections, and diseases) or 786 (wheezing, cough, chest pain, hemoptysis, hyperventilation, and more). Our heat-specific category (visible only as a thin line in 0–3 year age strata near the bottom of the bars) included ICD-9 codes 276 (fluid electrolyte imbalance, dehydration) and 992 (heat stroke, heat cramps, and heat fatigue). Injury cases included ICD-9 codes 800–904 (fractures, dislocations, sprains, internal injury, open wounds, injury to blood vessels), 910–929 (superficial injury, contusion with intact skin surface), 950–959 (nerve and spinal cord injury, certain traumatic complications and unspecified injuries.

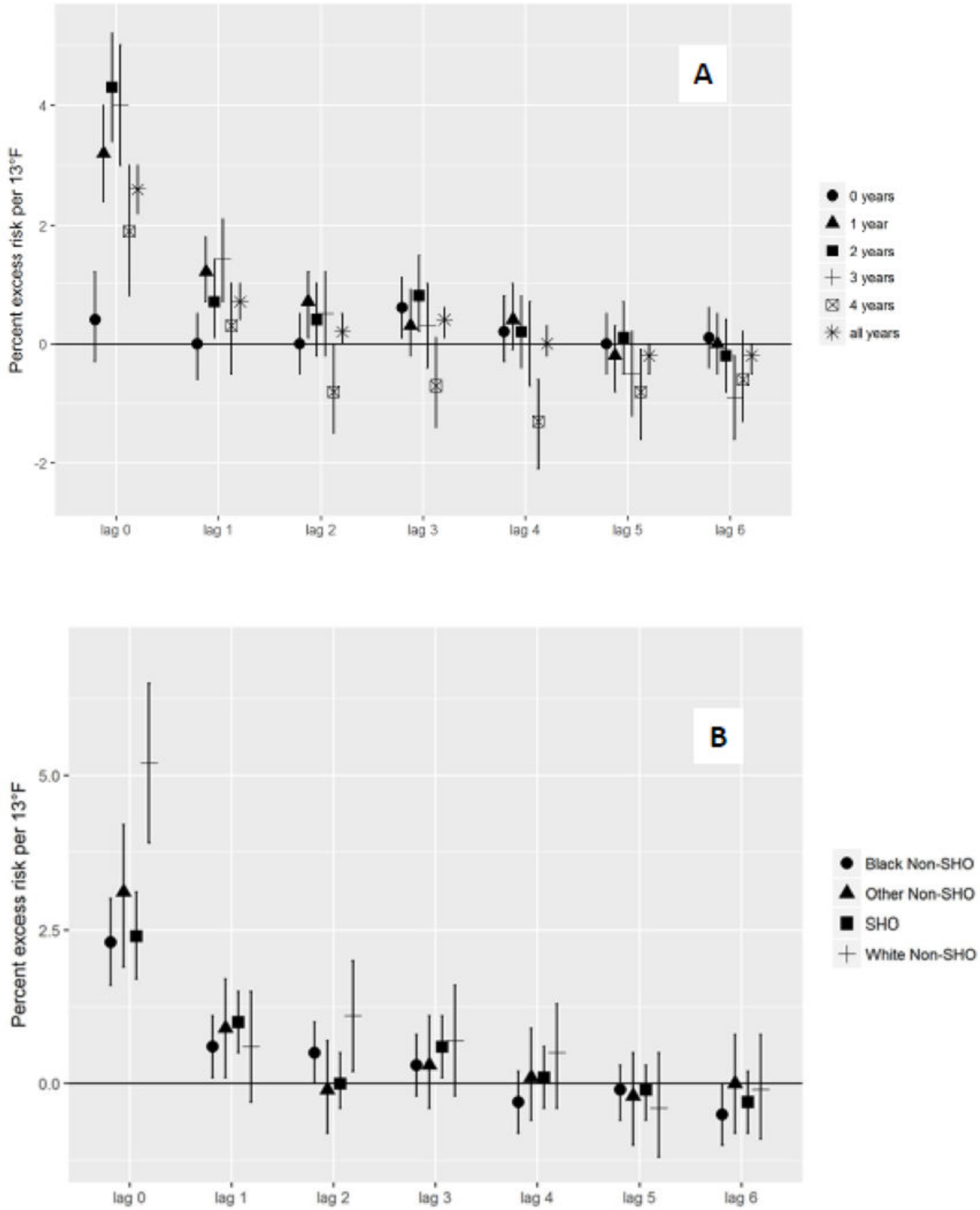

Figure 2:

Percent excess risk per 13°F increase on same day and lag days 1–6 exposure of all-cause Emergency Department visits for children age 0–4 years living in New York City for A: whole group and stratified by age group, 2005–11; B: Stratified by Race and Ethnicity Type, 2005–11, SHO = Spanish/Hispanic origin.

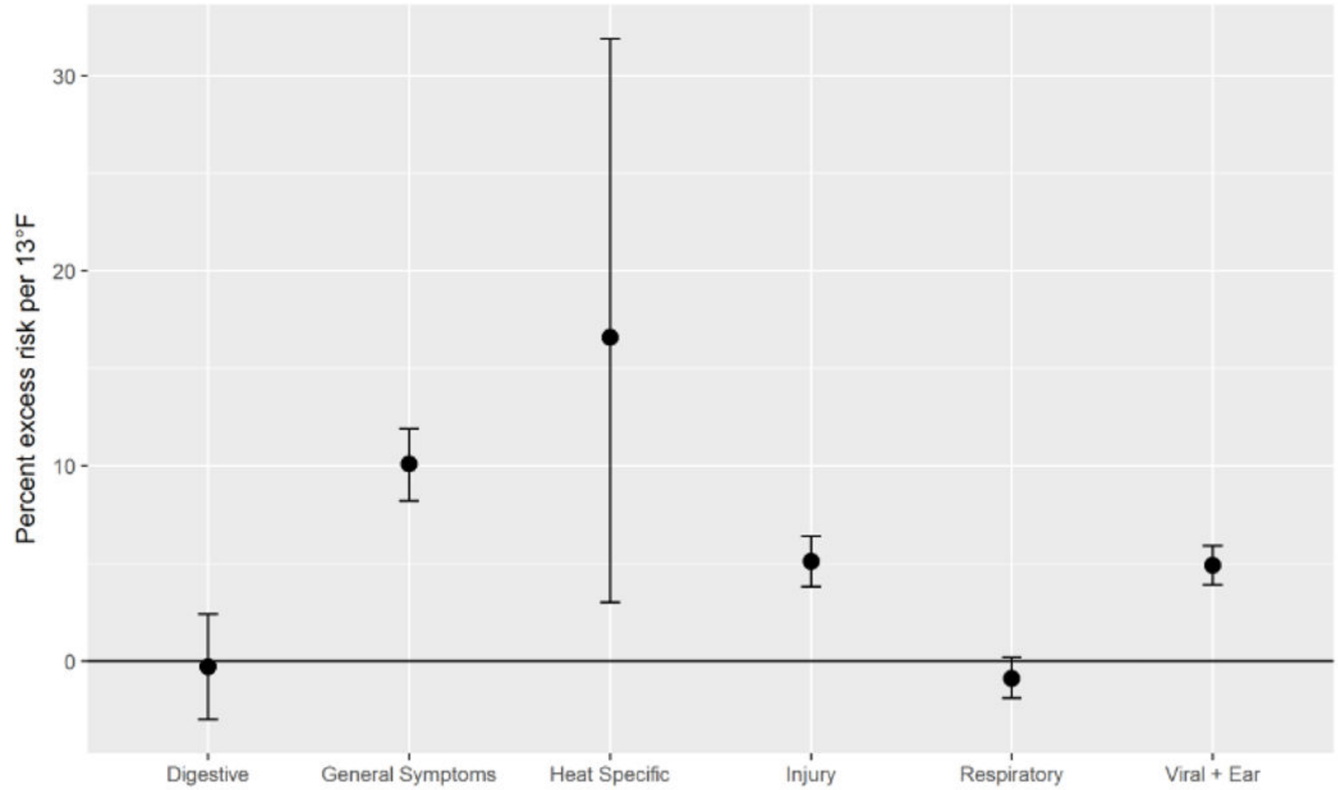

Figure 3.
Percent excess risk per 13°F increase in same day maximum temperature exposure of Emergency Department visits for children age 1–3 years living in New York City, 2005–11, by diagnostic code groups. Digestive includes ICD-9 code 564 (functional digestive disorder). General Symptoms included ICD-9 codes 780 (fever, altered consciousness, excessive crying, sleep disturbances, fussy infant, and convulsions). Heat specific includes ICD-9 codes 276 (fluid electrolyte imbalance, dehydration) and 992 (heat stroke, heat cramps, and heat fatigue). Injury includes ICD-9 codes 800–904 (fractures, dislocations, sprains, internal injury, open wounds, injury to blood vessels), 910–929 (superficial injury, contusion with intact skin surface), 950–959 (nerve and spinal cord injury, certain traumatic complications and unspecified injuries). Respiratory includes ICD-9 codes 460–519 (asthma, respiratory infections, and diseases) or 786 (wheezing, cough, chest pain, hemoptysis, hyperventilation, and more). Viral and ear infections includes ICD-9 codes 070–079 (other diseases due to viruses and chlamydiae) and 382 (suppurative and unspecified otitis media).

Table 1:

Demographic characteristics for all NYC-resident children aged 0 to 4 years presenting in NYC metropolitan emergency departments during the warm season (May – September), 2005 – 2011 (n= 1,002,951), SHO = Spanish/Hispanic origin.

	Overall	
	n	**%**
Age		
0 years	278,114	27.7
1 year	252,021	25.1
2 years	190,741	19.0
3 years	153,516	15.3
4 years	128,559	12.8
Sex		
Female	450,314	44.9
Male	552,631	55.1
Missing	6	0
Race		
Spanish/Hispanic Origin (SHO)	338,430	33.7
Black (Non-SHO)	300,007	29.9
Other (Asian, Native American, Pacific Islander, Other) (Non-SHO)	124,979	12.5
White (Non-SHO)	96,278	9.6
Unknown/unreported	143,257	14.3
Hospital Location		
NYC	984,879	98.2
NYC Metropolitan Area	18,072	1.8
Residence County		
Bronx	289,873	28.9
Kings	286,346	28.6
Manhattan	139,475	13.9
Queens	246,801	24.6
Richmond	40,456	4.0