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Warm season temperatures and emergency department visits in Atlanta, Georgia

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ABSTRACT

Purpose: Extreme heat events will likely increase in frequency with climate change. Heat-related health effects are better documented among the elderly than among younger age groups. We assessed associations between warm-season ambient temperature and emergency department (ED) visits across ages in Atlanta during 1993–2012.

Methods: We examined daily counts of ED visits with primary diagnoses of heat illness, fluid/electrolyte imbalances, renal disease, cardiorespiratory diseases, and intestinal infections by age group (0–4, 5–18, 19–64, 65+years) in relation to daily maximum temperature (TMX) using Poisson time series models that included cubic terms for TMX at single-day lags of 0–6 days, controlling for maximum dew-point temperature, time trends, week day, holidays, and hospital participation periods. We estimated rate ratios (RRs) and 95% confidence intervals (CI) for TMX changes from 27 °C to 32 °C (25th to 75th percentile) and conducted extensive sensitivity analyses.

Results: We observed associations between TMX and ED visits for all internal causes, heat illness, fluid/electrolyte imbalances, renal diseases, asthma/wheeze, diabetes, and intestinal infections. Age groups with the strongest observed associations were 65+years for all internal causes [lag 0 RR (CI)=1.022 (1.016–1.028)] and diabetes [lag 0 RR=1.050 (1.008–1.095)]; 19–64 years for fluid/electrolyte imbalances [lag 0 RR=1.170 (1.136–1.205)] and renal disease [lag 1 RR=1.082 (1.065–1.099)]; and 5–18 years for asthma/wheeze [lag 2 RR=1.059 (1.030–1.088)] and intestinal infections [lag 1 RR=1.120 (1.041–1.205)].

Conclusions: Varying strengths of associations between TMX and ED visits by age suggest that optimal interventions and health-impact projections would account for varying heat health impacts across ages.

1. Introduction

Climate change is expected to lead to higher warm-season temperatures and an increased frequency, intensity and duration of heat waves (Meehl and Tebaldi, 2004; Watts et al., 2015). A growing body of evidence demonstrates that extreme heat can have adverse health effects (Kravchenko et al., 2013; O'Neill and Ebi, 2009). An understanding of the health effects of extreme heat is important for developing the infrastructure, policy, and public health messages to help vulnerable populations avoid unhealthy exposures and to prepare for and adapt to future climate change (Portier et al., 2010).

Associations have been well established between high ambient temperatures and increased all-cause mortality as well as mortality from specific causes such as cardiovascular disease, cerebrovascular disease, respiratory disease, and heat-related causes (e.g. heat stroke) (Basu, 2009; Kilbourne, 1999; Kravchenko et al., 2013; O'Neill and Ebi, 2009; Portier et al., 2010). Some studies have also found associations between high ambient temperatures and morbidity from these types of health conditions using outcome measures such as counts of hospitalizations or emergency department (ED) visits (Green et al., 2010; Knowlton et al., 2009; Lin

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Abbreviations: ED, emergency department; RR, rate ratio; INTERN, All internal causes; HEAT, Heat illness; FLEL, Fluid and electrolyte imbalance; RENAL, All renal disease; NEPH, Nephritis and nephrotic syndrome; CIRC, All circulatory system disease; HT, Hypertension; IHD, Ischemic heart disease; DYS, Dysrhythmia; CHF, Congestive heart failure; STK, Ischemic stroke; RESP, All respiratory system disease; PNEU, Pneumonia; COPD, Chronic Obstructive Pulmonary Disease; ASW, Asthma/wheeze; DIA, Diabetes mellitus; GI, Intestinal infection

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et al., 2009; Michelozzi et al., 2009; Pudpong and Hajat, 2011; Schwartz et al., 2004; Semenza et al., 1999; Turner et al., 2012; Ye et al., 2012). Assessment of associations between high temperatures and morbidity using ED visits may be particularly useful for some clinical conditions and for younger populations that tend to have more ED visits than hospital admissions or deaths. A study by Knowlton et al. (2009) of the health effects of the 2006 heat wave in California found that the increase in ED visits during the heat wave was more pronounced than the increase in hospital admissions. Nevertheless, relatively few US studies have assessed the health effects of heat waves or high temperatures using ED visits (Basu et al., 2012; Buckley and Richardson, 2012; Jones et al., 1982; Knowlton et al., 2009; Lippmann et al., 2013; Rydman et al., 1999; Saha et al., 2015).

The elderly have been found to be particularly susceptible to health effects of extreme heat (Astrom et al., 2011; Basu, 2009; Green et al., 2010; Knowlton et al., 2009; Ye et al., 2012). However, there is comparatively less information regarding heat health effects in children, partially due to the fact that population-based data are sometimes restricted to elderly populations by nature (e.g., mortality, cardiovascular outcomes) or by source (e.g., Medicare data on hospitalizations). Children may also have higher susceptibility to adverse health impacts from heat, particularly in relation to morbidity rather than mortality (Bartlett, 2008; Ebi and Paulson, 2007; Kravchenko et al., 2013; Sheffield and Landrigan, 2011; Xu et al., 2012, 2014). Several studies conducted outside the US have found associations between high temperatures or heat waves and various measures of morbidity among children (Checkley et al., 2000; Chou et al., 2010; Hashizume et al., 2007; Kovats et al., 2004; Lam, 2007; Leonardi et al., 2006; Nitschke et al., 2011; Onozuka and Hashizume, 2011; Pudpong and Hajat, 2011; Xu et al., 2012, 2013, 2014). In the US, assessment of age-stratified associations between ambient temperature and morbidity with evaluation of effects across the full age range, including children, has been conducted with limited geographic coverage (Basu et al., 2012; Fletcher et al., 2012; Green et al., 2010; Lin et al., 2009; Li et al., 2012; Lippmann et al., 2013). There is a need for expanding the literature on age-specific risk to additional US locations for proper population-wide risk assessment. Assessment of age-specific risks across the full age range has significant implications for targeted interventions (e.g. school athletic programming) and for enhanced accuracy of health impact projections that account for demographic shifts over time.

Effect estimates for the association between extreme heat and health outcomes vary by location, possibly due to population adaptation to local temperatures (Anderson and Bell, 2009; O'Neill and Ebi, 2009; Saha et al., 2015). Multicity studies can give an overall estimate of heat-related health effects across locations, but location-specific information about heat health effects is also needed for local public health planning and emergency preparedness related to climate change. Extreme heat events in sprawling metro areas, including Atlanta, have increased at a faster rate than in compact metro areas (Stone et al., 2010). In Atlanta, the frequency and duration of heat waves have already significantly increased over the period from 1961 to 2010, like in other US cities, but the rate of increase in Atlanta has been higher than the national average (Habeeb et al., 2015). Assessment of the Atlanta population is thus timely and relevant.

We build on prior studies to conduct a comprehensive assessment of heat-related morbidity among all age groups in Atlanta using ED visits as the morbidity measure. Data come from the Study of Particles and Health in Atlanta, a major research effort examining air quality and acute morbidity (Darrow et al., 2012; Metzger et al., 2004; Peel et al., 2005; Sarnat et al., 2010; Strickland et al., 2010; Tolbert et al., 2000). The 20-year study period makes this one of the largest studies of heat and morbidity to date, offering high power for assessing age-specific associations for a range of outcomes. Objectives of our analysis were to examine effects of heat on ED visits for specific health conditions, with consideration of effects of heat by age group across all ages, using analyses that examine possible non-linear effects, effects at various lags, and the impact on the observed associations of decisions regarding outcome definitions, heat metrics and modeling decisions.

2. Materials and methods

2.1. Data sources

Hourly meteorological data for Atlanta were obtained from the National Solar Radiation Database for the automated surface observing station (ASOS) located at Atlanta Hartsfield International Airport for the period January 1, 1993 through December 31, 2012 (Wilcox, 2012). These data were used to calculate daily metrics (i.e., minimum, maximum, and average) of temperature, dewpoint temperature, apparent temperature, and wind speed, as well as daily average barometric pressure and total precipitation. Daily data on major ambient air pollutant concentrations (including 1-h maximum carbon monoxide, nitrogen dioxide, and sulfur dioxide; 8-h maximum ozone, and 24-h average particulate matter less than 10 μm in diameter) were obtained from ambient monitoring networks in Atlanta. Daily pollutant measurements across monitors were combined using population weighting (Ivy et al., 2008); these air pollutant data were only available through 2010 at the time of this analysis.

Data on ED visits to hospitals in the Atlanta metropolitan area were obtained from individual hospitals (for the period 1993–2004) and from the Georgia Hospital Association (for the period 2005–2012). Data were restricted to patients whose ZIP code was at least partially within one of the 20 counties in the Atlanta metropolitan area. We assessed daily counts of ED visits for 17 outcomes of interest. In our primary analyses, these outcomes were defined based on the primary international classification of disease, version 9 (ICD-9) codes only, and secondary analyses considered these outcomes as defined by the presence of the selected codes in any of the diagnoses listed on patients' ED records. The outcomes of interest included ED visits for all internal causes (INTERN; ICD-9 codes 001-799), heat illness (HEAT; ICD-9 code 992), fluid and electrolyte imbalances (FLEL; ICD-9 code 276), all renal disease (RENAL; ICD-9 codes 580-593), nephritis and nephrotic syndrome (NEPH; ICD-9 codes 580-589), all circulatory system disease (CIRC; ICD-9 codes 390-459), hypertension (HT; ICD-9 codes 401-405), ischemic heart disease (IHD; ICD-9 codes 410-414), dysrhythmia (DYS; ICD-9 code 427), congestive heart failure (CHF; ICD-9 code 428), ischemic stroke (STK; ICD-9 codes 433-437), all respiratory system disease (RESP; ICD-9 codes 460-519), pneumonia (PNEU; ICD-9 codes 480-486), chronic obstructive pulmonary disease (COPD; ICD-9 codes 491-492, and 496), asthma/wheeze (ASW; ICD-9 codes 493 or 7896.09/.07), diabetes mellitus (DIA; ICD-9 codes 250 or 249), and intestinal infection (GI; ICD-9 codes 001-009). Use of the ED data was in accordance with agreements with the hospitals and the Georgia Hospital Association and this study was approved prior to its conduct by the Emory University Institutional Review Board.

2.2. Statistical methods

Analyses were restricted to the warm season, which was defined as May-September. Analyses were conducted using Poisson generalized linear models allowing for overdispersion. The primary models assessed the relationship between daily maximum