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Ambient temperature and emergency department visits for heat-related illness in North Carolina, 2007–2008

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ABSTRACT

Purpose: To estimate the association between environmental temperatures and the occurrence of emergency department visits for heat-related illness in North Carolina, a large Southern state with 85 rural and 15 urban counties; approximately half the state's population resides in urban counties.
Methods: County-level daily emergency department visit counts and daily mean temperatures for the period 1/1/2007–12/31/2008 were merged to form a time-series data structure. Incidence rates were calculated by sex, age group, region, day of week, and month. Incidence rate ratios were estimated using categorical and linear spline Poisson regression models and heterogeneity of the temperature-emergency department visit association was assessed using product interaction terms in the Poisson models.
Results: In 2007–2008, there were 2539 emergency department visits with heat-related illness as the primary diagnosis. Incidence rates were highest among young adult males (19–44 year age group), in rural counties, and in the Sandhills region. Incidence rates increased exponentially with temperatures over 15.6 °C (60 °F). The overall incidence rate ratio for each 1 °C increase over 15.6 °C in daily mean temperature was 1.43 (95%CI: 1.41, 1.45); temperature effects were greater for males than females, for 45–64 year olds, and for residents of rural counties than residents of urban counties.
Conclusions: As heat response plans are developed, they should incorporate findings on climate effects for both mortality and morbidity. While forecast-triggered heat health warning systems are essential to mitigate the effects of extreme heat events, public health preparedness plans should not ignore the effects of more persistently observed high environmental temperatures like those that occur throughout the warm season in North Carolina.

1. Introduction

Public health practitioners have become increasingly aware of the health effects of heat waves and other periods of high ambient temperature. This is due in large part to the occurrence of major heat waves over the past decade, including in western Europe in 2003 (Kosatsky, 2005), western North America and Europe in 2006 (Gershunov et al., 2009; Fouillet et al., 2008), the Southeast United States in 2007 (Fuhrmann et al., 2011), southern Australia in 2008 and 2009 (Karoly, 2009; Mayner et al., 2010) and eastern Europe in 2010 (Barriopedro et al., 2011). Many public health agencies have begun to incorporate extreme heat preparedness plans into their overall natural disaster readiness strategies (Bernard and McGeehin, 2004). Most of these extreme heat response plans have been devised based on findings from studies examining the effect of temperature on *mortality*. Fewer studies have examined the effect of temperature on morbidity due to the more limited availability of large-scale hospital admission and emergency department visit surveillance systems.

This study analyzes the association between temperature and heat-related morbidity in North Carolina. North Carolina is the 10th most populous US state and had the 6th highest population growth rate between 2000 and 2010 (18.5%) (Mackun et al., 2011). Due to its humid subtropical climate, topographic variability, large and rapidly growing population, and statewide morbidity surveillance network, North Carolina provides an excellent setting to study patterns of temperature and health outcomes. Prior work examined heat-related deaths in North Carolina between 1977 and 2001 using medical examiner data, but heat-related fatalities are rare and that study encompassed only 161 events (Mirabelli and Richardson, 2005). With the development of the North Carolina

Abbreviations: ICD-9-CM, 9th Revision of the International Classification of Diseases—Clinical Modification.

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Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT; hereafter referred to as "the NC emergency department surveillance data system") (Hakenewerth et al., 2009), state-wide data on emergency department visits in North Carolina are now available.

In this paper we use NC emergency department surveillance data from 2007 and 2008 to describe the incidence of heat-related emergency department visits in North Carolina and investigate the association between temperature and the incidence rate of emergency department visits for heat-related illness, including heat exhaustion, heat stroke, and heat syncope. We also examine variation in the association between temperature and heat-related emergency department visits by age, sex, urbanization, and region. By drawing upon a state-wide surveillance system for emergency department visits, we derive information that allows us to examine geographic variation in this association, including differences between urban and rural populations. Such analyses are not possible in studies that focus on heat-related illness in a single city, or in studies that pool data from several large urban populations. By focusing on emergency department visit data, we are able to study heat-related events that may be less serious than those leading to hospital admission or death. Consequently, our analysis of emergency department visits provides further insight regarding the public health impacts of heat waves and other periods of high ambient temperature.

2. Materials and methods

2.1. Data sources

In 2005 North Carolina mandated the creation of a statewide emergency department surveillance system. All hospitals in North Carolina with 24-h acute care emergency departments must report electronic visit data to the NC emergency department surveillance data system in near-real time via the North Carolina Hospital Emergency Surveillance System. This system provides information on the age, sex, and county of residence of the patient, the date of the emergency department visit, and up to 11 diagnoses at discharge coded to the 9th Revision of the International Classification of Diseases—Clinical Modification (ICD-9-CM) (U. S. Department of Health and Human Services, Centers for Disease Control and Prevention, and the Centers for Medicare and Medicaid Services, 2009). Discharge diagnoses are the *final* diagnoses given by an emergency department practitioner (typically a physician) and coded for billing and reimbursement. The visit date-time recorded in the data system is the earliest date/time documented in the patient's record for the emergency department visit. Data conform to the Data Elements for Emergency Department Systems guidelines (National Center for Injury Prevention and Control, 1997). This system does not provide information on the patient's race or ethnicity. By the end of 2007 the system had reached near full compliance, with essentially all hospitals reporting emergency department visit data in electronic form to the NC emergency department surveillance data system; it is estimated that the system captured data for 92% of all emergency department visits state-wide in 2007 and 99.5% of such visits in 2008 (Hakenewerth et al., 2009; Carolina Center for Health Informatics, University of North Carolina at Chapel Hill, 2010). Analyses of these data that use information on the discharge diagnoses coded to ICD-9-CM cannot be conducted in real-time, since NC hospitals may experience a lag of several months between the emergency department visit and submitting the final ICD-9-CM discharge diagnoses to the NC emergency department surveillance data system. The current project, which commenced in 2010, therefore analyzed emergency department visits with a primary diagnosis of heat effects (ICD-9-CM code 992.xx) reported from January 1, 2007 to December 31, 2008.

County-specific average daily temperature estimates were obtained from records of the State Climatologist. Fahrenheit scale was used for data management and analysis; Celsius conversions are presented here in consideration of non-U.S. readers. Average daily temperatures for 73 of the 100 counties in North Carolina were derived using hourly observations from first-order weather stations maintained by the National Weather Service and Federal Aviation Administration, as well as from stations in the North Carolina Environment and Climate Observing Network. Estimates of average daily temperature for an additional 20 counties were calculated using daily minimum and maximum temperature recorded at stations in the Cooperative Observer network. Seven counties (Camden, Catawba, Gates, Jones, Mitchell, Perquimans, and Tyrrell) had incomplete temperature records and were excluded from this study. Therefore, the current analysis is restricted to people who resided within the 93 counties in North Carolina for which we could derive estimates of average daily temperature from operational weather stations (Fig. 1).

Other temperature metrics such as apparent temperature were considered. However, recent investigations into the sensitivity of temperature-health associations to the selection of temperature metric have concluded that these alternate metrics are highly correlated and, as a result, metric choice has limited impact on temperature-health associations (Barnett et al., 2010; Vaneckova et al., 2011; Yu et al., 2011). Those researchers suggest that metric selection be based on data quality, completeness, and coverage; average daily ambient temperature was chosen because it was available for the largest number of counties.

Certified age- and sex-specific estimates of the population on July 1, 2007 and July 1, 2008 in each of the 93 counties included in this analysis were obtained from the State Demographer at the North Carolina Office of State Budget and Management based on data from the United States Bureau of the Census (North Carolina Office of State Budget and Management, 2011). These Census-based population estimates are used as population denominators in the estimation of crude and stratified incidence rates and incidence rate ratios, and to describe the population-level exposure to temperature levels. We classified counties in North Carolina as urban or rural based on population data provided by the NC Rural Economic Development Center, Inc. (2011). Counties with a population density of less than 250 people per square mile were classified as rural and thus eligible for the center's programs, based on data from the 2000 Census, while other counties were classified as urban. Using this criterion, 15 NC counties were classified as urban (Fig. 1). These counties represented all major metropolitan areas and approximately 51% of the state population. The remaining counties were classified as rural.

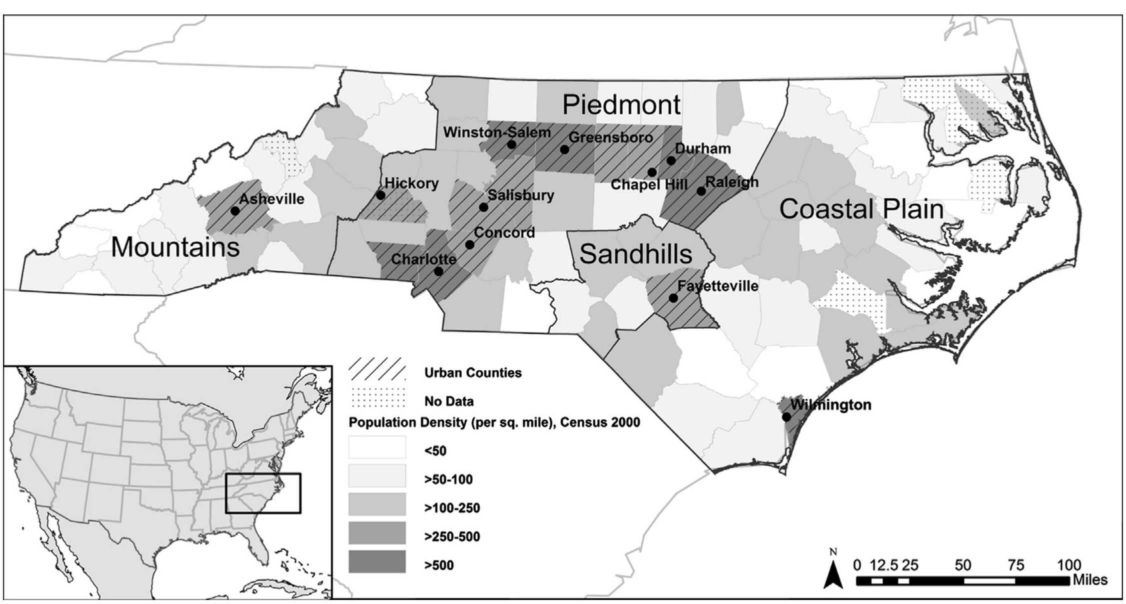

Fig. 1. Map of study area featuring major cities, county and region boundaries, population density (per square mile), and urban/rural classification.