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Did summer weather factors affect gastrointestinal infection hospitalizations in New York State?

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HIGHLIGHTS

- We conducted a time-series analysis to test effects of weather factors on health.
- Summer weather factors will affect gastrointestinal infection hospitalization (GIH).
- Each °C increase in temperature was associated with an increase in daily GIH.
- Bacteria may be a significant cause for GIH in the summer.
- Minority, female and those with bacterial infection are more vulnerable.

GRAPHICAL ABSTRACT

High temperature and precipitation significantly increases the risk of gastrointestinal infection hospitalization.

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ABSTRACT

Background: Gastrointestinal infections, a substantial public health problem worldwide, have been associated with single weather factors but the joint effect of multiple weather factors on gastrointestinal infections remains unclear.

Methods: We conducted a retrospective time-series analysis to investigate effects of weather conditions on hospitalizations for gastrointestinal infections (GIH) in New York State in July and August from 1991 to 2004. Applying generalized additive model (GAM), we evaluated the associations between daily GIH count and multiple weather factors including temperature, humidity, and precipitation (0–10 lag days), adjusting for long term trend, seasonality, and calendar effects.

Results: Maximum temperature, minimum temperature, and maximum universal apparent temperature (UAT) showed that each °C increase in temperature was significantly associated with an increase (0.70–0.96%) in daily GIH count, with the greatest impacts observed at lag 1. Extreme heat (EH: >90th percentile) (3.68% at lag 1) and precipitation (0.31% at lag 4) showed larger impacts on increases of GIH and a clear dose–response relationship for EH. Stratified analyses showed that the impacts of extreme heat on GIH tend to be greater among Hispanics, blacks, females, and those with bacterial infections.

Abbreviations: GIH, gastrointestinal infection hospitalization; **ICD-9**, International Classification of Disease-9; **SPARCS**, Statewide Planning and Research Cooperative System; **UAT**, universal apparent temperature; **EH**, extreme heat; **GAM**, generalized additive model; **CDC**, **C**enters for Disease Control and Prevention; **NYS**, New York State.

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Conclusion: We found that high maximum and minimum temperature, UAT, precipitation, and extreme heat in summer significantly increased the risks of GIH in NYS. Our findings also suggest that bacteria might be a significant cause for GIH in the summer, and minority, female and those with bacterial infection may be more vulnerable to heat's effects on GIH.

1. Introduction

Gastrointestinal (GI) infections are major public health problems worldwide (WHO, 2007). In the United States, the associated social and economic burden of GI infectious diseases is substantial due to high morbidity and potential mortality (Rose et al., 2001). It has been previously reported that in the United States there are 9 million cases of waterborne diseases and 76 million cases of foodborne diseases annually, with 325,000 hospitalizations and 5000 deaths due to foodborne diseases alone per year (Mead et al., 1999). The yearly estimated cost for foodborne illnesses is $51 billion (Scharff, 2012), and over $500 million for waterborne illness (CDC, 2010). Although the pathway/process causing GI infectious diseases are still not totally understood, in most cases the commonly identified pathogens are bacteria, viruses and parasites (Haley et al., 2009; Jagai et al., 2009; Lake et al., 2009; Ruzante et al., 2011; White et al., 2009).

With growing concerns about climate change in recent years, numerous studies have investigated the relationship between weather conditions and risks of gastrointestinal infection hospitalizations (GIH) (Fleury et al., 2006; Drayna et al., 2010; Hall et al., 2011; Onozuka and Hashizume, 2011), Most prior studies of GIH have covered only short periods of time (shorter than 5 years) with small numbers of cases, use only monthly or seasonal weather measurements, and only examine one specific type of GI infection; very few studies examined multiple weather factors simultaneously (Hall et al., 2011). In addition, few existing studies have examined lagged weather effects on GIH, although the differences in lag effects could be substantial (Naumova and Macneill, 2008). In addition, when lag effects are evaluated, the findings are not consistent and varied from days to months (Fleury et al., 2006; D'Souza et al., 2004; Curriero et al., 2001; Drayna et al., 2010). The potential modifying effects of demographic factors on weather-GIH have also not been well studied.

The Northeastern U.S.A. may be especially vulnerable to effects of climate change, in part due to the heat-trapping emissions and heat-island effects in the metropolitan areas (Smargiassi et al., 2008; NECIA Report, 2006; Braga et al., 2002). Additionally, New York State (NYS) has both a diverse socio-demographic makeup, variable climate statewide, and a demonstrated increase in extreme weather events over time (Insaf et al., 2012). We therefore investigated the potential health impacts and lag effects of multiple daily weather factors on GIH, and assess the possible interaction between weather factors and socio-demographic factors in this study.

2. Materials and methods

2.1. Study design and health outcomes

Using generalized additive models (GAM) with a Poisson distribution and log link function, a retrospective time series analysis was conducted to estimate the health effects of multiple weather factors on GI infection daily hospital admission count while controlling for various time-varying factors. The study population consisted of all NYS residents. The health outcomes were all NYS hospitalizations with a principal diagnosis of GI infection in the summer (June–August) from 1991 through 2004. GI infection cases were defined based on the following *International Classification of Diseases*, *Ninth Revision*, *Clinical Modification* (ICD-9-CM) codes: 001–005 and 008 for bacterial infections; 008.6 for viral enteritis; 006–007 for protozoal infections; and 009 for unspecified gastroenteritis.

2.2. Data sources

Information about GIH as described above was obtained from the inpatient database of the New York State Department of Health's (NYSDOH) Statewide Planning and Research Cooperative System (SPARCS). The SPARCS database contains detailed information on more than 95% of all New York State hospital discharges. The data included principal diagnoses and other diagnosis, hospital admission date, date of birth, sex, race, ethnicity, street address, sources of payment, and total charges. Appropriate Institutional Review Board and data approvals were obtained from the NYSDOH. In addition, data from the 2000 U.S. Census at the census block level were used in this study. The data contained race, sex, age, ethnicity, marital status, educational level and occupation.

Meteorological data, including hourly observations for temperature, precipitation, relative humidity, and dew point, barometric pressure, and snowfall were provided by the National Center for Atmospheric Research (NCAR) and linked with the hospital admission data.

2.3. Exposure assessment

According to the National Climate Data Center's NYS climate divisions, we divided NYS into 14 weather regions (Van Zutphen et al., 2012) as described in Appendix A. Based on the meteorological data for 18 first-order airport weather stations obtained from NCAR, we averaged all available airport data for each weather region to generate a daily average value of every meteorological factor under study, including temperature (minimum, mean, and maximum), precipitation, barometric pressure, dew point, wind speed and direction. To define the study population more precisely, the residential address from each hospitalization record was geocoded and assigned a latitude and longitude, using Map Marker Plus (Pitney Bowes Business Insight, Troy, NY). About 94% of residential addresses were geocoded to street level, and 5% to zip code level. Less than 1% of the addresses could not be geocoded. Each geocoded hospitalization was assigned to one of the 14 weather regions, and daily hospitalization counts were summed for each weather region.

The meteorological indicators in this study included minimum temperature (°C), maximum temperature (°C), precipitation (mm), barometric pressure (kilopascals), and daily extreme heat indicator variables such as daily maximum universal apparent temperature, extreme heat (EH), and number of extreme heat days. Universal apparent temperature (UAT) was defined by Steadman's formula, taking into account temperature, vapor pressure, and wind speed (Steadman, 1984). EH was defined as daily maximum temperature > 90th percentile of the temperature distribution for each weather region in the warm season (June–August) from 1991 to 2004 in NYS. The number of EH days was simply defined as the number of consecutive days of EH. The effects of meteorological exposures for lag periods of 0 to 10 days (the number of days prior to the hospital admission) on daily GIH were analyzed.

2.4. Statistical analysis/confounding variables

Based on smoothing techniques and nonparametric regression, GAM relaxes the usual assumption of linearity; therefore GAM enables to uncovering of structure in the relationship between response variables and predictor variables that might otherwise be missed (Terzi and Cengiz, 2009). To examine the effects of multiple weather conditions on GIH, we applied a GAM model assuming a Poisson distribution,