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Weather and gastrointestinal disease in Spain: A retrospective time series regression study

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ABSTRACT

Background: A few studies in high-income countries have investigated the relationship between ambient temperature and/or precipitation and the occurrence of gastroenteritis. In most of the cases, hot temperatures and heavy precipitation events have been related to increases in infections. This is of concern as climate change predictions indicate an increase of those extreme events. Our aim was to evaluate the association between meteorological variables and daily gastroenteritis hospitalizations in Spain for the period 1997–2013.
Methods: We obtained data on all hospitalizations which occurred in Spain for the study period from administrative databases and selected those with gastroenteritis as the main diagnosis. Meteorological data was obtained from the European Climate Assessment & Dataset. Daily counts of hospitalizations were linked to meteorological variables in a retrospective ecological time series study using quasi-Poisson regression models with overdispersion and applying the Distributed Lag Non-linear Model (DLNM) framework.
Results: Both high and cold temperatures increased the risk of gastroenteritis hospitalizations (relative risk (RR) = 1.21, 95% confidence interval (CI): 1.09, 1.34; and RR = 1.07, 95% CI: 1.00, 1.15, respectively), whereas heavy precipitation was found protective for those hospitalizations (RR = 0.74, 95% CI: 0.63, 0.86). Hot temperatures increased hospitalizations for gastroenteritis classified as foodborne or idiopathic but not those in the group of *Others*, which were composed mainly of infections by rotavirus and were associated with cold temperatures.
Conclusions: Our findings suggest an important role of ambient temperatures, especially hot temperatures, in increasing gastroenteritis hospitalizations, while the exposure to heavy precipitation events pose opposite and unexpected effects on these infections.

1. Introduction

Gastroenteritis has a strong burden in morbidity and mortality in the world. The World Health Organization (WHO) estimates that four hundred million diarrhea episodes occur globally every year (Jofre et al., 2009). Gastroenteritis is the second leading cause of preventable illness and one of the leading causes of death in children under 5 years old (Fletcher et al., 2011). Gastroenteritis caused 1.31 million deaths globally in 2015, especially in children under age 5 in low-income countries (Troeger et al., 2017). Even though low and middle-income countries are the most affected, many gastroenteritis outbreaks are also reported in high-income countries like the United States of America (Mac Kenzie et al., 1994; Weniger et al., 1983), Taiwan (Jean et al., 2006), Finland (Kauppinen et al., 2017), the United Kingdom (Nichols et al., 2009) or Spain (Arias et al., 2006).

The cause of gastroenteritis is typically a microorganism or viral agent transmitted by fecal-oral route through ingestion of pathogens found in unsafe drinking-water, contaminated food or unclean hands (Jofre et al., 2009; Prüss-Üstün et al., 2008). Meteorological factors such as temperature and precipitation can have an influence on the risk of gastroenteritis by promoting bacterial growth or through water contamination during flooding events, among other mechanisms. Although there are differences between low-, middle- and high-income countries, rotavirus seems to be the most frequently detected pathogen

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worldwide (Fletcher et al., 2011) and, together with norovirus, they normally have an incidence peak in winter (Lopman et al., 2009).

In high-income countries, the main recognized sources of water contamination are human and animal waste and agricultural activities (Crimmins et al., 2016). However, increases in the presence of fecal microorganisms in surface water have also been found after extreme precipitation events (Kim et al., 2013; Kistemann et al., 2002; Miossec et al., 2000; Shehane et al., 2005; Signor et al., 2005; Tornevi et al., 2014; Tryland et al., 2011). This contamination can be due to, for example, sewer overflows and sewage discharges of untreated (Curriero et al., 2001; Drayna et al., 2010; Hill et al., 2006; Kim et al., 2013; Shehane et al., 2005) or ineffectively treated water from water treatment plants when heavy precipitation events cause a lot of water entering treatment plants and prevent its potabilization (Arias et al., 2006; Britton et al., 2010; Curriero et al., 2001; Drayna et al., 2010; Shehane et al., 2005).

Several studies have found positive associations between heavy precipitation events and gastroenteritis cases and outbreaks. In Sweden, Tornevi et al. uncovered a positive relationship between nurse advice calls related to gastrointestinal diseases and previous heavy precipitation 5–6 days before (Tornevi et al., 2013), while in the United States of America and Canada extreme precipitation and cumulative rainfall were related with higher risks of waterborne disease outbreaks (Curriero et al., 2001; Thomas et al., 2006). Nichols et al., in a study in England and Wales, found that both low rainfall in the three previous weeks (< 20 mm per week) or heavy rainfall in the previous week of the outbreak (> 40 mm in a week) were significantly associated with the risk of drinking water-related outbreaks (Nichols et al., 2009).

In addition, gastroenteritis cases (Hu et al., 2007; Iñiguez et al., 2016; Singh et al., 2001) and outbreaks (Thomas et al., 2006) have been related with high temperatures in several countries, although sometimes cryptosporidiosis (Britton et al., 2010) and Norovirus infections (Lopman et al., 2009) have been associated with cold temperatures. In Valencia (Spain), Iñiguez et al. found increased risk of hospitalizations due to gastrointestinal diseases in days of extreme heat compared to normal days only for short lags (0–1 days) (Iñiguez et al., 2016). It is biologically plausible that warmer temperatures promote bacterial growth, which could be present in water and food, leading to a waterborne or foodborne transmission (Hashizume et al., 2007). The increase of gastroenteritis with cold could be due to the fact that, with cold, people tend to stay indoors and this may increase person-to-person transmission (Onozuka and Hagihara, 2015).

An increase of > 10% in the average global precipitation and a rise between 1.4 and 5.8 °C of ambient temperature is expected in the course of the current century due to climate change (Kim et al., 2013). In Spain, climate change projections predict temperature rises, reductions in precipitations and increases in heavy precipitation events (Fundación Biodiversidad, Oficina Española de Cambio Climático, Agencia Estatal de Meteorología, Centro Nacional de Educación Ambiental., 2013). This can have consequences in the occurrence of gastroenteritis, as food- and waterborne pathogens are known to be sensitive to climatic conditions (European Centre for Disease Prevention and Control, 2012). Knowledge about the links between climate variables and gastroenteritis can help preventing future cases and outbreaks but is also useful to adopt appropriate mitigation and adaptation measures in the context of climate change.

In this study, we examined the effects of precipitation and temperature on hospitalizations by gastroenteritis in Spain during the period 1997–2013. This will contribute to the investigation of the association between weather variables and gastroenteritis in the Mediterranean region, with few previous reports, using a large dataset with countrywide data and long study period. In addition, we conducted separate analyses by diagnostic groups, as different patterns have been reported depending on the specific microorganism involved.

2. Material and methods

2.1. Population

The study included gastroenteritis hospitalizations that occurred in Spain between 1997 and 2013. Spain has 50 provinces plus two autonomous cities (Ceuta and Melilla). Ceuta and Melilla were excluded from the analyses due to their low number of cases (391 and 128 cases in the entire study period, respectively, which represented 0.14% and 0.07% of the cases in the country), while Canary Islands (Las Palmas and Tenerife provinces) were also excluded because they had a different weather pattern from the rest of the Iberian Peninsula.

2.2. Hospitalization data

We obtained data on hospitalizations due to infectious gastroenteritis as the main diagnosis at discharge, according to the 9th Revision of the International Classification of Diseases (ICD-9) codes (codes 001–009), from *Conjunto Mínimo Básico de Datos* (CMBD) of the *Instituto de Información Sanitaria* (Spanish Ministry of Health, Social Services and Equity). Using this registry is compulsory for all hospitals from the National Health System, and the number of private hospitals included has been increasing over the years. Currently, it includes 92% of all hospitalizations and 15.9% belong to private hospitals (Ministerio de Sanidad, Servicios Sociales e Igualdad, 2016). Individual records were obtained, with information on date of hospitalization, sex, age, diagnosis and province. For each province, we derived total daily counts and daily counts by sex, age group (≤1-year-old, > 1– ≤15 years old, > 15– < 65 years old, ≥ 65 years old), climatic region (see below), and diagnostic group according to a classification created a priori by the authors ((1) waterborne: cholera (ICD-9 code 001), typhoid and paratyphoid fever (002), shigellosis (004), amebiasis (006) and protozoa's infections (007); (2) foodborne: salmonellosis (003) and food intoxications (005); (3) other bacteria and viruses causing diarrheas like *Escherichia coli* or Norovirus (008); and (4) idiopathic, which includes ill-defined intestinal infections (009)) (Supplementary material, Table S1). Assigned ICD-9 codes may or may not be based on laboratory results. The system includes a validation process that allows capturing diagnoses of cases that were discharged before the results of in-hospital microbiological tests (García-Basteiro et al., 2011).

2.3. Weather data

The exposures evaluated included total daily precipitation (mm) (including snowfall), heavy precipitation events (binary variable created to indicate when daily precipitation was above the 95th percentile of the province) and daily average temperature (°C), obtained from the European Climate Assessment & Dataset (European Climate Assessment & Dataset, 2016). We also reported associations for extreme heat and cold defined as temperatures above the 95th and below the 5th percentiles, respectively. Meteorological variables were obtained from meteorological stations in the province capital city and those exposures were assigned to all hospitalizations that occurred in the province according to the date of hospital admission.

2.4. Statistical analyses

We conducted a daily time series regression analysis in order to find short-term associations between our exposure variables and the outcome variables. The response variable was the daily number of gastroenteritis hospitalizations in each province, obtained by aggregating the individual hospital records by date and province. As the response variable is composed of counts, we used quasi-Poisson regression models, which can capture overdispersion often present in hospitalization count data (Bhaskaran et al., 2013). We used the Distributed Lag Non-linear Model (DLNM) framework to capture non-linear