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A time-series study of the association of rainfall, relative humidity and ambient temperature with hospitalizations for rotavirus and norovirus infection among children in Hong Kong

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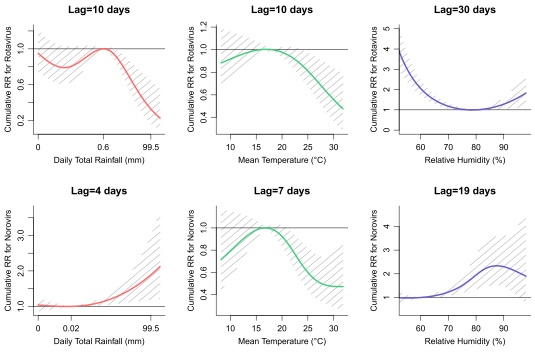
HIGHLIGHTS

- Diarrheal diseases can be attributable to various environmental factors.
- A ten-year time-series with GAMs and DLNMs was used to assess the association.
- Greater rainfall was associated with fewer rotavirus but more norovirus admissions.
- Stronger associations were seen in winter for rotavirus and in summer for norovirus.
- The duration of association with rotavirus was notably longer than norovirus.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Rotavirus and norovirus are infectious pathogens primarily affecting children under 5 years old. The impact of rainfall on diarrheal diseases remains inconclusive. This study aimed to evaluate the association between short-term variation in rainfall, temperature and humidity, and rotavirus and norovirus hospitalizations among young children in Hong Kong.

Methods: Generalized additive negative binomial regression models with distributed lag non-linear terms, were fit with daily counts of hospital admissions due to rotavirus and norovirus infection as the outcomes and daily total rainfall and other meteorological variables as predictors, adjusting for seasonality and trend.

Results: Generally, greater rainfall was associated with fewer rotavirus, but more norovirus hospitalizations. Extreme precipitation (99.5 mm, 99th percentile) was found to be associated with 0.40 (95% confidence interval (CI) 0.20–0.79) and 1.93 (95% CI 1.21–3.09) times the risk of hospitalization due to rotavirus and norovirus infection respectively, relative to trace rainfall. Stronger associations were observed in winter for rotavirus and in summer for norovirus. The duration of association with rotavirus was notably longer than norovirus. Higher temperatures were found to be associated with fewer hospitalizations for both rotavirus and norovirus infection, while higher relative humidity was generally associated with more norovirus, but fewer rotavirus, hospitalizations.

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Conclusions: Both rotavirus and norovirus hospitalizations were strongly associated with recent precipitation variation but in opposite directions. With the introduction of the rotavirus vaccine norovirus is likely to become a greater threat than rotavirus and thus greater precipitation may become more clearly associated with more childhood diarrhea.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) has suggested that aside from other climatic alterations, including temperature elevation, there are more land surfaces where the number of heavy precipitation events has increased than where it has decreased (Intergovernmental Panel on Climate Change, 2014). There has been substantial evidence on the linkage between climate change and both extreme precipitation (O'Gorman, 2015) and drought (Mann & Gleick, 2015), and therefore, the potential impact on both the abundance and quality of ground water has been indicated (Taylor et al., 2013).

Diarrhea is one of the top three leading causes of children's mortality globally (GBD 2013 Mortality and Causes of Death Collaborators, 2015; Lozano et al., 2012). In Hong Kong, rotavirus has been the most common pathogen causing diarrhea among children under 5 (Biswas et al., 1996). Evidence has shown that rotavirus and norovirus were the most common viruses introducing diarrheal hospitalizations among children under 18, of which 87% were children aged 0–5 years (Li et al., 2009). In an investigation of epidemics of acute viral gastroenteritis from 2001 to 2005 in Hong Kong, of all gastroenteritis patients, norovirus-positive cases accounted for 25%, among which 40% were under-five children (Ho et al., 2006). However, the noro-positive rate had decreased to 9.9% in 2013, 10.7% in 2014, and 10.8% in 2015, according to the Centre for Health Protection (Centre for Health Protection, 2016).

Diarrheal diseases can be attributable to various environmental factors (Chou et al., 2010; Hashizume et al., 2007; Phung et al., 2015; Wu et al., 2014). Of all the existing evidence, two meta-analyses, one covering the tropics and the other focused on Southeast Asia, examined the seasonality of rotavirus infection and concluded that 1 cm increase in mean monthly rainfall was associated with 1% and 0.3% reduction in the incidence, respectively (Jagai et al., 2012; Levy et al., 2009). Several observational studies, from the United Arab Emirates (Ijaz et al., 1994a), India (Sumi et al., 2013), Venezuela (Gonzalez Chavez, 2015) and Hong Kong (Mitui et al., 2011), found that more rotavirus cases occurred during seasons in which there was less rainfall, however these studies did not assess associations with rainfall independent of seasonality and other meteorological variables. Two studies employing time-series regression, one from Spain (Hervas et al., 2014) and one from Great Britain and The Netherlands (Atchison et al., 2010), found no evidence of an independent association between rain and rotavirus disease. More consistent results have been reported for norovirus infection. A systematic review of the global seasonality of norovirus (Ahmed et al., 2013) reported a positive association between norovirus outbreaks and average rainfall in the wettest months. And both higher incidence of norovirus outbreaks and higher loads of microbial in beach waters have been observed with heavy antecedent rainfall in studies from Australia (Bruggink & Marshall, 2010), Norway (Eregno et al., 2016) and Louisiana, USA (Wang & Deng, 2016). Nonetheless, except for the study in Australia reporting a 90-day lag between peak average rainfall and norovirus epidemic (Bruggink & Marshall, 2010), the delayed effect of precipitation on both rotavirus and norovirus remains unclear. Other meteorological factors investigated previously include temperature and relative humidity (RH). Generally, cool and dry weather conditions were associated with higher rotavirus incidence while the association between temperature and norovirus infection remains inconclusive. Studies from England and Wales (Lopman et al., 2009) and Toronto, Canada (Greer et al., 2009) found every 1 °C increase in air temperature was statistically significantly associated with a 15% reduction and an 8% increase in the risk of norovirus infection, respectively.

The present study aimed to explore possible associations of rainfall as well as ambient temperature and RH with both rotavirus and norovirus infection and their lag dependencies in a subtropical Chinese city, Hong Kong.

Table 1
Descriptive summary for children hospitalizations of rotavirus (2002−2011) and norovirus (2007–2011) infection and daily total rainfall in Hong Kong.

	Mean(SD)	Min.	P(3rd)	P(25th)	Median	P(75th)	P(97th)	Max.
Rotavirus								
Year-round	2.3(3.4)	0	0	0	1	3	10	32
Summer	0.6(0.8)	0	0	0	0	1	2	6
Winter	4.0(4.0)	0	0	1	3	6	14	32
Norovirus								
Year-round	1.7(1.8)	0	0	0	1	2	6	13
Summer	1.2(1.3)	0	0	0	1	2	4	8
Winter	2.1(2.1)	0	0	1	2	3	8	13
Rainfall (mm)								
Year-round	6.2(20.7)	0	0	0	0.01	1.4	55.9	307.1
Summer	10.8(26.9)	0	0	0	0.01	8.1	79.3	307.1
Winter	1.6(9.3)	0	0	0	0	0.01	12.2	237.4
Temperature (**°C**)								
Year-round	23.4(5.1)	8.2	13.0	19.4	24.6	27.8	30.0	31.8
Summer	27.5(2.0)	18.7	23.7	26.2	27.8	29.1	30.4	31.8
Winter	19.3(3.8)	8.2	11.9	16.9	19.4	21.9	25.9	27.8
Humidity (%)								
Year-round	78.0(10.3)	31.0	54.0	73.0	79.0	85.0	94.0	98.0
Summer	79.8(8.0)	45.0	63.0	75.0	80.0	85.0	94.0	98.0
Winter	76.2(11.8)	31.0	50.0	70.0	78.0	85.0	94.0	97.0