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Impact of meteorological factors on mumps and potential effect modifiers: An analysis of 10 cities in Guangxi, Southern China

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ABSTRACT

Background: In the current context of global climate change, understanding the impact of climate on respiratory infectious diseases such as mumps and the potential modified factors is crucial, especially in developing countries. However, research on the climate-related incidence of mumps is rare, inconsistent and mainly limited to a single city or region.

Methods: Daily mumps cases and meteorological variables of 10 cities in Guangxi, Southern China were collected for 2005–2017. Two-stage analyses were performed to assess the relationship between meteorological factors and mumps incidence during two time-periods: 2005–2012 and 2013–2017, separately. First, a Poisson regression model that allows over-dispersion was used to estimate the city-specific climate-related morbidity after controlling for temporal trends, day of week, and national statutory holidays. Then, we used a multivariate meta-analytical model to pool the city-specific effect estimates and conducted subgroup analyses. Multivariate meta-regression was applied to detect potential effect modifiers.

Results: Non-linear relationships were observed among mean temperature, wind speed, and mumps incidence in 2005–2012. The impact of high temperature on mumps incidence was short and rapid, whereas the impact of low temperature was long and slow. The total cumulative relative risk (RR) associated with hot temperature was 1.18 [95% Confidence Interval (CI): 0.93, 1.48], which was calculated by comparing the incidence of mumps above the 90th percentile of temperature with its incidence at the median temperature at lag of 0–30 days. Meanwhile, the RR associated with cold temperature was calculated to be 1.50 (95% CI: 1.08, 2.10) by comparing the incidence of mumps below the 10th percentile of temperature with its incidence at the median temperature. Similarly, the RRs associated with windless and windy conditions for the total population were 1.23 (95% CI: 1.04, 1.46) and 0.83 (95% CI: 0.67, 1.02), respectively. Effects based on extreme temperature and wind speed conditions were more prominent in males than in females. Compared with children and adults, adolescents (5–14 years old) were more sensitive to extreme weather conditions. Geographical latitude, Population density, GDP per capita, Number of health institutions, Highly educated population and Inoculation rate were considered the most likely associated modifiers. In addition, the correlation between meteorological factors and the incidence of mumps and modification of socioeconomic factors after 2013 showed similar curves compared with results in 2005–2012, but the cumulative effect was not statistically significant.

Conclusions: Meteorological factors, such as temperature and wind speed, exert a significant impact on the incidence of mumps. The relationship varies depending on gender and age. Socioeconomic factors such as vaccination, GDP, geographical latitude, etc. may substantially affect the weather-related mumps incidence.

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1. Introduction

Mumps is an acute respiratory infection caused by a virus of the paramyxovirus family and is characterized by unilateral or bilateral swollen and painful parotid gland, accompanied by fever, headache, nausea, and vomiting (Hviid et al., 2008). Although the symptoms of the disease are mild and the mortality rate is low, the disease can cause a series of serious complications, such as meningitis, oophoritis, and neurological deafness (Yung et al., 2011). Direct contact is the main route for mumps transmission, and the average incubation period of the disease is 19 days (12–25 days) (Cui et al., 2014). The incidence of mumps has been under control since the introduction of a mumps vaccine in the expanded program on immunization (EPI) in 2008, and children between the ages of 18 and 24 months can receive a free dose of the measles–mumps–rubella vaccine; however, outbreaks on cyclical mumps have frequently occurred in the past 10 years, and this phenomenon has also been observed in many other countries worldwide (Barskey et al., 2009; Cui et al., 2014; Fpl, 2008; Sane et al., 2014; Vandermeulen et al., 2009). China, as the most populous country in the world, always have a higher incidence of mumps compared with other countries. The number of reported mumps cases in China was estimated to rank the highest worldwide in 2016 (accounting for approximately 30.01% of the total) (WHO, 2016). Meanwhile, children in most parts of China are only vaccinated with one dose of mumps vaccine, while studies suggested that three doses of mumps vaccination can enable people to obtain stable immunity (Marin et al., 2018; Webber et al., 2017). This suggests that the mumps epidemic may continue to outbreak as the continuous attenuation of the body's antibody level and the accumulation of susceptible population. As a result, mumps prevention and control has become one of the main public health issues that the Chinese government must confront. The incidence of mumps shows a clear seasonal pattern in China, with most cases occurring between April and July, with another small peak in November and December (Cui et al., 2014). However, the seasonal pattern between the northern and southern parts of China differ, showing a double-peak distribution (May–June and December–January) in Jinan but a single-peak distribution (May–June) in Guangzhou (Li et al., 2017; Yang et al., 2014). This observation suggests that the incidence of mumps is influenced by climatic conditions in different regions.

Weather plays an important role in death (Guo et al., 2016), preterm delivery (Basu et al., 2017), waterborne diseases (Herrador et al., 2015) and vector-borne diseases (Zhang et al., 2016). However, few studies have investigated the impact of meteorological factors on respiratory infectious diseases, especially mumps, despite the existence of published reports demonstrating that climatic factors can promote viral infections through different mechanisms, such as increasing viral survival, influencing viral climate-dependent life cycle processes, or modulating the pediatric population's immune response (Nenna et al., 2017; Paynter et al., 2015; Tang and Loh, 2014). However, experiments with animal models and clinical studies do not always support this simple interpretation. A study conducted in Taiwan showed that the number of mumps cases increases at 20 °C and then declines at temperatures higher than about 25 °C, producing an inverted V-shaped curve (Ho et al., 2015). Another study performed in Jining, China found that meteorological factors exert a threshold effect on the incidence of mumps, showing an approximately linear correlation when the meteorological variables exceed a certain value (Li et al., 2016). A Japanese study found that temperature and humidity could increase the risk of mumps, and the risk tended to increase with age; this result is consistent with the results obtained in Guangzhou, China (Onozuka and Hashizume, 2011; Yang et al., 2014). Hu et al. found that the incidence of mumps was related to all the included meteorological factors in a study of four cities in Fujian, while they did not combine the results of the four cities (Hu et al., 2018). Previous studies on the relationship between meteorological factors and mumps incidence were mainly based on a single city or a region such as Taiwan (China). Multi-city studies on this topic have yet to be conducted. Those studies also usually followed different study designs and model specifications, which limit the ability to compare results across cities. In addition, the research results are unstable largely because of the poorly understood heterogeneity across cities due to differences in climate, socioeconomic factors, and behavioral lifestyles. Thus, further evidence is needed to assess the health impacts of different weather indicators from large geographical areas and determine possible sources of heterogeneity.

In this study, 10 cities in Guangxi, Southern China were included to estimate the effects of meteorological factors on the incidence of mumps on the basis of a two-stage analysis. These cities not only suffer from severe epidemics but also show uneven economic development. Since they are located in the subtropical monsoon region, they are susceptible to experiencing extreme weather conditions. Meanwhile, few studies have explored the relationship between the incidence of mumps and meteorological factors after 2013 in China. Previous studies on the climate-related mumps incidence conducted in Guangzhou, Jining and Fujian limited the time period to 2005–2012, 2009–2013 and 2005–2013, respectively. However, the epidemic trend of mumps after 2013 is quite different from the past, which suggests the urgency of the study for this time period. Therefore, we analyzed the data of the two periods: 2005–2012 and 2013–2017, simultaneously.

Our objective was to define the overall cumulative exposure response and the lag response and explore the potential sources of heterogeneity. This study could provide useful information to formulate effective intervention policies for the prevention and control of infectious diseases.

2. Materials and methods

2.1. Study area

The Guangxi Zhuang Autonomous Region, located in the southwestern part of China, is the only coastal autonomous prefecture, and it is inhabited by many different ethnic groups (geographical coordinates: 20°54'–26°24' N, 104°26'–112°04' E, Fig. 1a). It covers a land area of 236,700 km^2, and its total population was 47.96 million in 2015. A total of 14 cities are under the jurisdiction of Guangxi, and 10 of these were selected as research areas for this study, considering data availability. Guangxi is located in a typical subtropical monsoon climate zone. Most parts of the region have a warm climate with abundant heat and rainfall, clear wet and dry periods, and no apparent seasonal changes. The winter is short, dry, and warm, whereas the summer is long, wet, and hot.

2.2. Data collection

Daily data on the incidence of mumps between 2005 and 2017 were obtained from the Infectious Disease Reporting System of the Guangxi Center for Disease Prevention and Control. The system was utilized in 2004 and includes an established network between local medical institutions through modern means of communication. It forms part of an information networking system for disease prevention and control, connecting institutions at the national, provincial, municipal, and county levels. The information network also extends to towns and urban communities, and forms a unified, efficient, fast, and accurate reporting system for infectious disease epidemics. The increasing internet big data integration and cloud storage capabilities can provide certain guarantees for this real-time reporting system (Hossain et al., 2017; Memos et al., 2017). A total of 39 infectious diseases are currently included in the reporting system, and mumps is listed as a Category C infectious disease in China. Health departments require that infected patients and patients with suspected infection or infectious pathogen carriers classified under this category must be reported online within 24 h once diagnosed or be reported by means of a network report card filled out by trained health personnel and sent within 24 h if the