



The association between human perceived heat and early-stage syphilis and its variance: Results from a case-report system



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HIGHLIGHTS

- The risk of early-stage syphilis was positively related to perceived temperature.
- People in developed areas, especially the elderly, tended to be more sensitive.
- The risk elevated at potential comfortable times or under excessive hot conditions.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: The relationship between temperature and syphilis is poorly understood despite clues and suggestions from previous studies. We examined the association between human perceived temperature (humidex) and the relative risk of early-stage syphilis in the most affected area of China, as well as its variance across social-economic status and age groups.

Methods: Information regarding early-stage (primary and secondary) syphilis cases reported to the China Case Report System between 2005–2013 from Guangdong province was analyzed in this study. Weather data were obtained from the National Meteorological Information Center. Distributed lag nonlinear models were applied to assess the relationship between humidex and the relative risk of early-stage syphilis. Results were further stratified by social-economic status and age groups.

Results: The relative risks of early-stage syphilis mainly increased with increased humidex, and were elevated when the humidex was around 30 or greater than 38. The humidex-RR association for the 15–40 age group was similar to the scenario pooled across the age groups, particularly in the Pearl-River Delta Region. The relative risk of syphilis in the elderly for the non-Pearl-River Delta Region did not show a clear change with humidex, whereas that in the Pearl-River Delta Region substantially increased, particularly when humidex was above 25.

Conclusions: Human perceived temperature was positively related to the relative risk of early-stage syphilis. People in the Pearl-River Delta Region tended to be more sensitive, with relative risk elevated at potential

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comfortable times or under excessively hot conditions. The vulnerability of the elderly in the Pearl-River Delta Region is concerning.

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1. Introduction

In 2013, Tan et al. detected a significant annual oscillating trend in the incidence of adult syphilis in Guangdong, the largest and most affected province in South China (Tan et al., 2014). The periodic trend was similar to the seasonality of temperature, suggesting a potential association between syphilis incidence and temperature. Another study from Jiangsu found similar spatial patterns for syphilis and temperature, also suggesting that temperature might be a “supporting variable” for the transmission of syphilis (Cheng et al., 2012). Despite these clues and speculations, few studies have assessed the potential impact of temperature on the risk of syphilis.

Previous studies have also suggested that developed areas more likely to be affected by sexually transmitted diseases such as syphilis, because those areas tended to be more densely populated, with better socio-economic status as well as more social interactions among citizens (Tan et al., 2011; Yang et al., 2010; Zhang et al., 2015). In addition, people of different ages differ as a function of testosterone level and sexual behaviors. Normally, citizens between 14 and 40 years old are more sexually active than those from other age groups (Butler and Lewis, 2002; Kalra et al., 2011). However, little is known whether the vulnerability of citizens to syphilis is varying across demographic subgroups of the population.

China presents a unique opportunity to examine these knowledge gaps, which are particularly important for devising syphilis prevention and control strategies. Although syphilis had been eliminated from China in the 1960s by making free screening and treatment available to all, it has made a precipitous resurgence and now ranks among the top three reported notifiable diseases in China, particularly in Guangdong (Chen et al., 2000; Chen et al., 2007; Tucker and Cohen, 2011). Guangdong is one of the most affected areas in China, and the single province of Guangdong reported more syphilis cases than all of the countries in the European Union combined in 2008 (Yang, 2009).

Using information from this severely affected area, the present study aimed to assess the association between temperature and early-stage syphilis incidence. We also aimed to evaluate possible differences in this association across demographic subgroups, including social-economic status and age groups.

2. Materials and methods

2.1. Study setting

Guangdong is one of the biggest provinces in Southern China, with a population up to 104 million (based on 2010 census data). According to the characteristics of the natural landscape and social-economic development, Guangdong province can generally be divided into two parts: The Pearl River Delta Region (9 cities) and the Non-Pearl River Delta Region (12 cities). According to Statistical Yearbooks for Guangdong, the Pearl River Delta Region has a higher level of social-economic development, accounting for 80% of the GDP (Gross Domestic Product) in Guangdong Province, with <50% of the population (Statistics Bureau of Guangdong Province, 2015).

2.2. Data acquisition

Two major types of data were used for this research: (1) Early-stage syphilis data as the health outcome; (2) Temperature data as the predictor of interest. We set 2005/1/5 as the starting day of the first week of

the study period, defined a sequence of weeks from 2005/1/5 through 2013/12/31 (469 weeks totally), and matched the weekly number of cases to the weekly average of the predictor.

- (1) Early-stage syphilis data: Syphilis data were obtained from China Case Report System (CRS) developed by the China CDC (Center for Disease Control and Prevention) (Health, 2014). According to the Diagnostic criteria for syphilis as established by the Ministry of Health, China (Health, 2014), early-stage (primary and secondary) syphilis cases were defined as positive for both treponemal and non-treponemal tests in addition to clinical manifestations and sexual risk history. Information including age, ZIP (Zone Improvement Plan) code, onset times and case type (stage) was entered into the CRS. Early-stage syphilis cases who were 15 years or older were included in this study, as they were more likely to be related to recent exposure and transmission (Zhang et al., 2015). In this study, cases were grouped by regions (the Pearl River Delta Region/the Non-Pearl River Delta Region) and age groups ($15 < \text{Age} \leq 40$ / $40 < \text{Age} \leq 65$ / $\text{Age} > 65$). Weekly number of cases was calculated overall as well as for each subgroup.
- (2) Temperature data: Daily meteorological data were obtained from the National Meteorological Information Center (<http://cdc.nmic.cn/>). Data from meteorological stations of the same region (i.e., the Pearl-River Delta/Non-Pearl-River Delta regions in stratified analyses and the whole province when analyzed as a whole) were then averaged to regional levels. Regional level daily data were then averaged out of weeks. According to previous studies, the same temperature can generate substantially different effects on human feelings, behaviors or even activity of pathogens under different humidity conditions (Cakmak et al., 2007; Chebana et al., 2013; Masterton et al., 1979; Zhang W. et al., 2016a, 2016b, 2016c; Zhang Z. et al., 2016d). In the current study, we used a new indicator, humidex, instead of the conventionally used temperature indicators. Humidex combines the effects of humidity and temperature and might be particularly applicable to related research in highly-humid subtropical regions such as Guangdong. It is unitless but equivalent to dry temperature in degrees Celsius. For example, if the temperature is 30 °C, and the calculated humidex is 40, this indicates that the humid heat feels approximately like a dry temperature of 40 °C (Wikipedia). In the present study, humidex was calculated on the basis of relative humidity and temperature using a calculator provided by CSGNetwork (<http://www.csgnetwork.com/>) in California, USA.

2.3. Statistical analysis

The nonlinearity of associations between temperature and human health outcomes is well documented (Chen et al., 2014; Huang et al., 2013; Zhang W. et al., 2016a, 2016b, 2016c; Zhang Z. et al., 2016d). Similarly, we can assume nonlinear relationships between relative risk of syphilis and humidex in the present research. In addition, incubation of early-stage syphilis, which normally lasts a few weeks or even a few months, makes the quantification of delayed humidex effects necessary for exploring the relationship between them (Cheng et al., 2016; Fraga et al., 2011).

Therefore, in this study, distributed lag nonlinear models with quasi-Poisson distribution were applied to evaluate the association between humidex and syphilis, with weekly number of syphilis cases as the

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