Short-term effects of ambient temperature and relative humidity on the risk of COVID-19 and SARS in Guangzhou, China: A time-series analysis

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Research Article

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Abstract

Coronavirus infection has exerted a severe disease burden on the world, especially the newly emerged SARS-CoV-2 that has caused worldwide pandemic. It is possible meteorological factors can influence the transmission of coronavirus. The aim of this study was to evaluate the effect of meteorological factors on COVID-19 and SARS, and to provide evidence for disease control and prevention. Data of COVID-19 and SARS cases and daily mean temperature, relative humidity and other meteorological factors in Guangzhou in 2003 and 2020 were collected. Using a distributed lag non-linear model approach, we assessed the relationship between ambient temperature, relative humidity and the risks of COVID-19 and SARS. The numbers of cases for COVID-19 and SARS during the study period were 347 and 1072, respectively. There was a dome-shaped relation between mean temperature and COVID-19, with a threshold of 14.50°C (RR=1.48, 95%CI: 1.01, 2.16) and the optimal range was 12.40-16.40°C. A similar association was found between mean temperature and SARS occurrence, with a threshold of 18.40°C (RR=1.02, 95%CI: 1.00, 1.04), and the optimal range was 15.30-19.30°C. Besides, there were non-linear negative relationships between both RH and COVID-19, SARS. In addition, the largest overall effect of RH on COVID-19 and SARS were obtained at 52% and 45%, yielding relative risk of 7.47 (95%CI: 1.66, 33.55) and 47.56 (95%CI: 11.49, 196.95), respectively. The optimal ranges were below 77.00% and below 82.70%, respectively. Meteorological parameters should be taken into consideration while developing early warning systems and risk strategies for controlling and preventing coronavirus infection.

Introduction

In November 2019, a novel coronavirus (SARS-CoV-2) has emerged in Wuhan, and was widespread across mainland China in next few weeks [1]. By the 6th March 2020, a total of 80,151 Coronavirus Disease 2019 (COVID-19) cases have been detected and confirmed in Mainland China. On the 30th January 2020, the World Health Organization (WHO) declared the novel coronavirus “2019-nCoV” outbreak as a global public health emergency. Internationally, as of the 7th May 2020, there were more than 3.5 million additional cases confirmed with 250 thousands deaths reported [2]. Although many coronaviruses are pathogenic to humans but present with mild clinical symptoms, SARS-CoV-2 is the 2nd highly pathogenic coronavirus which had severely struck China in the past 2 decades. The first outbreak was SARS firstly emerged in Guangdong province of China. In total, there were 8098 cases of SARS with 774 deaths across 26 countries in 2002-2003[3]. According to what has been reported, the SARS-CoV-2 shared 79.5% identity with the SARS-CoV[4]. Similar epidemic patterns were observed of the two coronavirus with both the outbreaks occurred during the spring festival. Without vaccines and antiviral medicines, understanding the influential factors for the occurrence and transmission of the SARS-CoV-2 will help deploy contain measures.

Accumulating evidence suggests that meteorological factors, in particularly temperature and humidity might be important environmental factors favoring the transmission of the respiratory infectious disease [5]. For example, a previous study from Hong Kong has shown that during the epidemic, the risk of increased daily incidence of SARS was 18.18-fold higher in days with a lower air temperature than in days with a higher temperature [6]. Liu [7] and Zhang [8] explored the associations of temperature with H7N9 human cases. They both reported that temperature contributed significantly to human infection with H7N9, and the effects of temperatures were nonlinear. Studies from temperate and subtropical climates have demonstrated that low temperature and humidity increased the risk of influenza [9,10]. It is plausible SARS-CoV-2 can remain viable and infectious in aerosol for multiple hours and on surfaces up to days[11], and some experimental studies as well as animal models have shown that low specific humidity favored virus survival and aerosol transmission[12-14]. Moreover, Salah et al. revealed that breathing cold air would slow mucociliary clearance and thereby encouraged viral spread within the respiratory tract [15].

Despite the research advance, only a few studies have explored environmental parameters of coronavirus infection. The association between temperature, humidity and the occurrence of coronavirus has remained unclear. As Guangzhou and Wuhan sharing similar climate patterns were both severely attacked by the SASR and COVID-19, are there any environmental factors facilitating the COVID-19 and SARS outbreak in China? The objective of the present study was to examine the relations between temperature, humidity and the risk of coronavirus infections in a subtropical climatic zone, Guangzhou. We collected the COVID-19 and SARS cases information reported in 2020 and 2003 in Guangzhou. Our hypotheses were that there were significant associations between mean temperatures (MT), relative humidly (RH) and coronavirus infection and the relationships were non-linear.

Results

Basic information in SARS and COVID-19

Between Jan 2nd and May 11th 2003, a total of 1072 SARS cases aged 2 month to 92 years were reported. Of the 1072 cases, 475 were male and 597 were female, with a male-to-female sex ratio1:1.26. There was an average of 7.68 daily SARS cases, and the mean level of daily MT and RH were 18.77°C and 76.95% at the same time. COVID-19 cases were first reported at Jan 21st 2020, the date was very close to the first SARS case in Guangzhou 17 years ago. Between Jan 21st and Mar 6th 2020, a total of 347 COVID-19 cases aged 3 months to 90 years were reported. Of the 347 cases, 167 were male and 180 were female, with a male-to-female sex ratio 1:1.08. There was an average of 9.35 daily COVID-19 cases and the mean level of daily MT and RH were 15.69°C and 78.78%, respectively (Table1). Fig.1 shows the trends of reported cases and meteorological variables during the period of study. Visually, there was a similar trend observed in the association between COVID-19 cases, SARS cases and meteorological factors.

Estimation of Separate effects of MT, RH on COVID-19 and SARS

Fig.2 shows the three-dimensional relationship between MT, RH and COVID-19 as well as SARS cases within 5 lag days, taking the median values as the reference. The largest separate effects of MT on COVID-19 and SARS were obtained at 13.70°C and 11.10°C, although the effects were not significant.

And the largest separate effects of RH on COVID-19 and SARS were obtained at 52.00% and 45.00%, yielding relative risk of 2.28 (95%CI: 1.30, 3.98) and 3.73 (95%CI: 2.38, 5.85) respectively.(Seen in Table 2)

Estimation of Overall effects of MT, RH on COVID-19 and SARS

Fig. 3 shows the overall effects of MT and RH within 5 lag days, taking the median values as references. The overall cumulative association analyses suggested non-linear relationship between MT, RH and COVID-19 as well as SARS. There was a dome-shaped relation between MT and COVID-19, with a threshold of 14.50°C(RR=1.48，95%CI: 1.01, 2.16) and the optimal range was 12.40-16.40°C. There was a similar association between MT and SARS occurrence, with a threshold of 18.40°C (RR=1.02, 95%CI: 1.00, 1.04), and the optimal range was 15.30-19.30°C. Besides, there were negative relationships between COVID-19, SARS and RH. The largest overall effect of RH on COVID-19 and SARS were obtained at 52.00% and 45.00%, yielding relative risk of 7.47 (95%CI: 1.66, 33.55) and 47.56 (95%CI: 11.49, 196.95), respectively. The optimal ranges were below 77.00% and below 82.70%, respectively.

Discussion

Coronavirus infection has become global public health threat that causes severe respiratory disease with a high case fatality [17]. In this study, we analyzed the relationships between the epidemics of COVID-19, SARS and MT as well as RH using the DLNM. Results suggested that COVID-19 and SARS exhibited similar trend of RR curves with the largest overall effects at similar MT (14.5°C, 18.4°C respectively) and RH (52%,45%) in Guangzhou.

The overall effects of MT on COVID-19 as well as SARS exhibited dome -shaped curves. Specifically, the risks of COVID-19 and SARS rose along with MT up to certain points with largest effects and then subsequently decreased with increasing MT. The finding was similar to a previous study on SARS that ambient temperate was negatively associated with SASR outbreaks in Hong Kong [18]. Whereas, our results were less consistent with a recent published study on COVID-19. By collecting the cumulative number of confirmed cases from 224 cities in China, Yan et al. found that ambient temperature has no significant impact on the transmission ability of SARS-CoV-2. These discrepancies can be explained by different modeling approaches, controlling efforts and also medical resource. In addition, the response to meteorological factors of coronavirus infection may be varied with the different climate environments [18,19]. Thus, more studies from different climate zones are needed to expand our knowledge of this relationship. What is worth noticing, our study, for the first time found that RH was negatively correlated with the occurrence of COVID-19 and SARS. Our results were also similar to previous reports where MERS-CoV cases increased with lower MT and RH. For instance, Gardner et al found that lowest temperature (OR=1.27; 95% CI: 1.04-1.56) and humidity (OR=1.35; 95%CI: 1.10-1.65) were associated with increased risk of MERS-CoV infection [20]. These findings combined with previous studies suggested that cold and dry weather conditions may facilitate an optimal environment for the occurrence and transmission of respiratory infectious disease caused by coronavirus.

Temperature and relative humidity have been shown to exert significance on causing viral respiratory infectious disease [21,22]. Jaakkola has conducted a cross-over study in a cold climate [23]. They found that every 1°C decrease in temperature and 0.5g decrease per m^3 in absolute humidity increased the estimated risk by 11% and 58%, respectively. Soebiyanto et al. have reported that influenza activity was negatively associated to temperature [24,25]. This kind of associations were also observed in H5N1 and H7N9 with the highest frequency in a temperature range of 5-10°C and 10-15°C, respectively[26]. Multiple mechanisms may contribute to the relationships between the meteorological factors and coronavirus infection. It has been reported that the coronavirus can survive in the environment, and be transmitted through close contacts [27]. A laboratory study has reported infectious virus persisted for as long as 28 days at 4°C, and the lowest level of inactivation occurred at 20% RH [28]. Chan et al. observed that virus viability was rapidly lost at higher temperatures and higher relative humidity (e.g., 38∘C, and relative humidity >95%) [29]. Additionally, Chin demonstrated that low temperature enhanced the survivability of viruses and provides more suitable conditions for transmission [30]. Other explanatory factors including alterations in host susceptibility (e.g. immunity), viral mutations, as well as the effects of weather on social contact patterns during the wintertime can also partly explained the association between MT, RH and coronavirus infection. For instance, in low-humidity environments, immune defense system is impaired and the risk of infectious diseases rises [31].

There were several limitations in our study. First, in the COVID-19 and SARS model, a limited timespan for dataset in our study might influence the relationships between the occurrence of coronavirus infection and meteorological factors. Second, we only adjusted the concomitant variable of meteorological factors in the study. Other factors such as host susceptibility, prevention and control efforts might have effects on the associations between meteorological factors and coronavirus infection. All of these will be considered in a more comprehensive model in the future. Given the gap in knowledge, our results provided a good starting point and a priori hypothesis for further studies.

In conclusion, our study suggests that both low MT and RH were associated with the occurrence of coronavirus infection during wintertime in subtropical climate. The finding may partly clarify the reason that the SARS-CoV and SARS-CoV-2 caused extensive outbreak in southern China where the climate were characterized as subtropical climate and the MT and RH reached the lowest between November to February in the next year. And also our research highlights that governments should take meteorological parameters into consideration while developing early warning systems and risk strategies for controlling and preventing coronavirus infection. Further studies are still needed to explain the relationships and confirm causality between temperature, humidity and coronavirus infection.

Methods

Study location

Guangzhou，the capital of Guangdong Provinces located in Southern China (112°57 E to 114°3 E and 22°26 N to 23°56 N) which is the third largest city of China, with a permanent resident population of approximately 14.90 million at the end of 2019. It has a humid subtropical climate with comparatively longer summers and shorter winters (Lu et al., 2009).

Study design and Data collection

A retrospective study to investigate the relationship between COVID-19, SARS cases and meteorological factors were carried out. Daily count of reported COVID-19 cases in Guangzhou from 21st Jan 2020 to 8th Mar 2020 was obtained from the China Information System for Disease Control and Prevention (CISDCP). And the daily count of reported SARS cases in Guangzhou from 2nd Jan 2003to 11th May 2003was obtained from the archives of SARS in Guangzhou center for disease control and prevention. In this study, all the COVID-19 and SARS cases were all laboratory confirmed. Daily meteorological factors including MT, RH and wind velocity (WV) corresponding to the case report in 2003 and 2020 were obtained from Guangzhou meteorological bureau.

Statistical analysis

Mean±standard deviation (x±s) and percentile were used to describe the distribution of cases and meteorological factors. As daily count of COVID-19 and SARS cases typically follow a quasi-Poisson distribution, a quasi-Poisson generalized linear regression combined with a distributed lag non-linear model (DLNM) was applied to quantify the effect of MT and RH on COVID-19 and SARS. In this study, we found the effect of MT and RH was negligible for lags above 5 days, so a maximum lag of 5 days was used to explore the lag associations. To adjust for potential effects of meteorological conditions, we used a smooth function of the natural cubic spline in the DLNM for wind velocity. In all cases, the Minimum Akaike Information Criterion (AIC) was adopted to choose the degree of freedom (df) for meteorological factors, lag and time trend. The model was specified as:

$$\text{Log}[E(Y_t)] = a + cb(\textit{temperature/relative humidity}) + ns(\textit{humidity\_lag2/temperature\_lag2}, df) + ns(\textit{wind velocity\_lag2}, df) + ns(time, df)$$

In the model, *Yt* is reported daily COVID-19 /SARS cases on day t; *a* is the intercept; *cb*(MT/RH) indicates the cross-basis function, which is obtained by DLNM to model non-linear and distributed lag effects of temperature/humidity. The "*ns*" means a smooth function based on natural cubic spline. *Humidity_lag2 /temperature_lag2 /wind velocity_lag2* are humidity, temperature and wind velocity with two-day lag .*Time* controls the time trend. All the analyses were carried out using the "dlnm" and "spline" packages in R software (version 3.6.2).

Declarations

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Author contributions

TG Li designed the study. H Wang and C Chen performed data analysis, and wrote the study. QX Lin contributed to the data and performed data analysis collection. All authors assisted in writing the manuscript.

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Conflict of interest

The authors have no other conflicts of interest or funding to disclose

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Tables

Table 1. Descriptive statistics for daily COVID-19, SARS cases and MT, RH variables in Guangzhou 2003 and 2020

	Year	Variable	Mean	SD	Min	P25	Median	P75	Max
COVID-19	2020	Cases	9.35	10.73	0.00	1.00	4.00	16.00	38.00
		MT	15.69	3.89	9.40	11.82	16.40	18.80	21.70
		RH	78.78	11.48	52.00	72.75	80.50	86.5	98.00
SARS	2003	Cases	7.68	9.18	0.00	2.00	4.00	9.50	41.00
		MT	18.77	4.48	11.10	15.15	19.30	22.25	26.80
		RH	76.95	10.59	45.00	72.00	78.00	84.00	97.00

SD: Standard Deviation; Cases: daily reported cases; MT: daily mean temperature; RH: daily relative humidity

Table 2. The largest separate and overall effects of meteorological factors values of COVID-19 and SARS in Guangzhou

riable		Reference value	Separate effect			Overall effect	
			Maximum RR (95%CI)	Variable value	lag	Maximum RR	Variable value
D-	MT	16.40℃	1.08 (0.90,1.30)	13.70℃	0	1.48 (1.01,2.16)	14.50℃
	RH	80.50%	2.28 (1.30,3.98)	52.00%	0	7.47 (1.66,33.55)	52.00%
	MT	19.30℃	1.03 (0.93,1.14)	11.10℃	3	1.02 (1.00,1.04)	18.40℃
	RH	78.00%	3.73 (2.38,5.85)	45.00%	3	47.56 (11.49,196.95)	45.00%

MT: daily mean temperature; RH: daily relative humidity

Figures

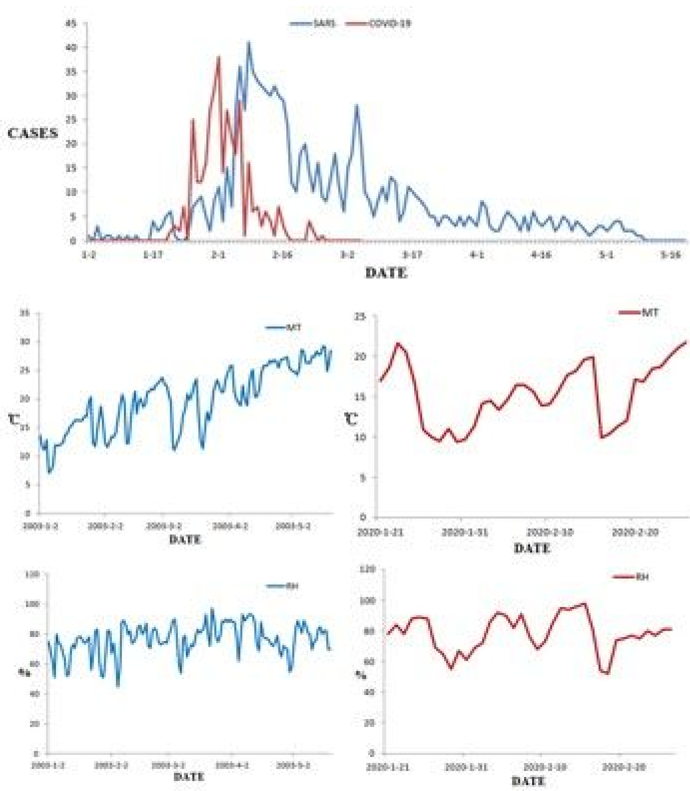

Figure 1

Time series distribution of daily COVID-19 case count, SARS cases count and meteorological variables during the study period.

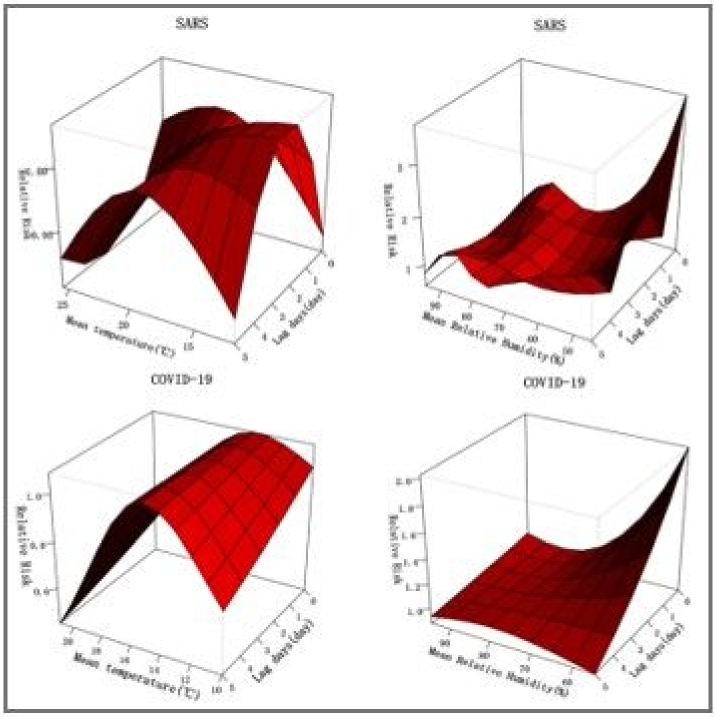

Figure 2

3D plots of relative risk of MT and RH on COVID-19 and SARS within 5 lag days

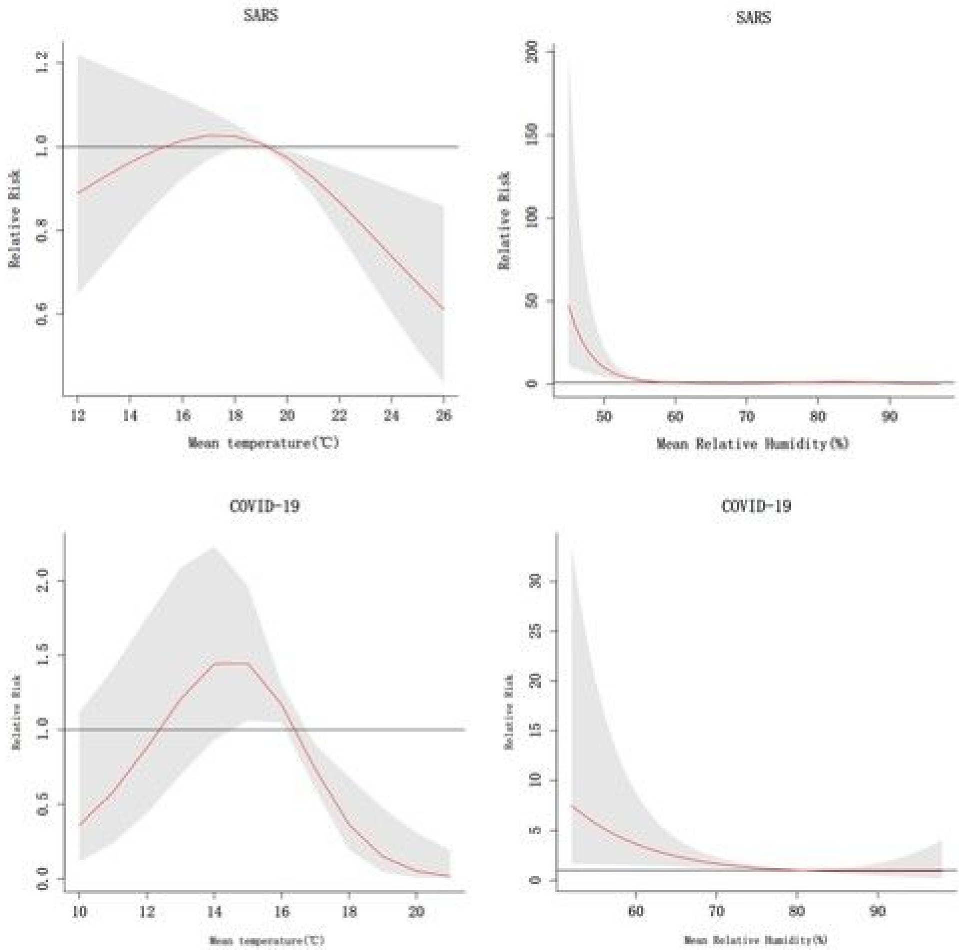

Figure 3

Overall effects of MT and RH on COVID-19 and SARS within 5 lag days. The median values of meteorological factors was selected as references