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ORIGINAL ARTICLE

Association between apparent temperature and hypertension hospital admissions: a case study in rural areas in western China

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Abstract

Introduction and Objective. Although it has previously been shown that temperature is associated with cardiovascular disease, no investigations exploring the association between apparent temperature (AT) and hypertension in farmers in Zhangye and Longnan, Gansu Province, China, have been undertaken. As hypertension is a commonly known risk factor for cardiovascular disease, the relationship between apparent temperature (AT) and hypertension is examined in Zhangye and Longnan to provide advice to local governments on preventive measures.

Materials and method. Daily data and weather conditions were collected in Zhangye and Longnan from 2014–2015. The Poisson generalized linear model and the distributed lag nonlinear model (DLNM) were combined to investigate the relationship between AT and hypertension in hospital admissions in the study areas.

Results. A non-linear relationship between AT and hypertension in hospital admissions in both Zhangye and Longnan were recorded. The cold effects were stronger in Zhangye than that in Longnan for both study group and subgroups. The heat effects were more deleterious for the entire study group, female subgroup and adult subgroup in Longnan, but stronger for the male subgroup and elderly subgroup in Zhangye.

Conclusions. This investigation indicates that AT has adverse impacts on hypertension hospital admissions in Zhangye and Longnan, especially under low AT exposure levels. The results from this study may promote the formulation of further prevention measures for hypertension disease.

Key words

hypertension, impact, hospital admission, apparent temperature

Abbreviations

AT – Apparent Temperature; **DLNM** – Distributed Lag Nonlinear Model; **RR** – Relative Risk

INTRODUCTION

In recent years, the adverse impact of extreme temperatures on human health due to climate change has been examined on a global scale [1, 2, 3, 4, 5, 6, 7], with findings indicating that extreme temperature has a significant association with morbidity and mortality [8, 9, 10]. Among these investigations, the association between temperature and cardiovascular disease has been widely reported. Previously, a non-linear relationship with U, J or V-pattens between temperature and cardiovascular disease have been documented [11, 12, 13]. In addition to ambient temperature, the diurnal temperature range has been selected as a temperature indicator for investigation; for example, Sharafkhani et al. reported high diurnal temperature ranges increased mortality in Tabriz, Iran [14]. In Beijing, China, a significant association between four major causes of emergency room admissions and elderly people were indicated by Wang et al. (2013) [15]. In Jinchang, a city located in northwestern China, Zheng et al. (2020) [16] recorded that diurnal temperature ranges were significantly associated with blood pressure.

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Although previous studies have examined the adverse impacts of ambient temperature or diurnal temperature range on cardiovascular disease, the comprehensive impact of meteorological factors on human health has not been taken into account with these indicators. Therefore, apparent temperature (AT), an indicator combining ambient temperature, wind velocity and relative humidity, has been shown to have a better performance in representing physiological experiences than temperature alone [17].

Studies incorporating AT as the temperature exposure indicator were carried out by Yi et al. (2019) [18], who explored the association between AT and schizophrenia in Hefei, China. In addition, Niu et al. (2020) investigated the effect of AT on mental and behavioural disorders by analyzing daily emergency visits in Beijing. Similar research by Min et al. (2019) in Yancheng examined the association between AT and mental and behavioural disorders on daily emergency admissions [17, 19]. However, few investigations have used AT to analyze associations with cardiovascular disease [20, 21, 22].

Hypertension is a common chronic disease, being an important risk factor for cardiovascular disease [23, 24]. In China, 270 million people suffer from hypertension, resulting in this disease having a high prevalence [25, 26] and the financial burden of hypertension accounting for 6.61% of total health costs [27]. Previous investigations indicate that air pollution, noise and outdoor temperature have an adverse impact on hypertension [23, 24, 28]. For example, Lin et al., (2021) recorded short-term $PM_{2.5}$ exposure to be positively correlated with increased outpatient clinic visits for hypertension in Guangzhou [23]. Hu et al., (2021) observed that low temperatures could increase blood pressure, thereby increasing hypertension prevalence in Guangdong province [24]. In addition, lifestyle, such as alcohol and salt intake, as well as adiposity, are factors associated with increases in blood pressure [29].

Zhangye and Longnan are two regions in Gansu province characterized by different climatic conditions. Unlike previous investigations, the current study focused on farmers in the two regions. To the best of the knowledge of the authors, previous investigations exploring the association between AT and hypertension in farmers in Zhangye and Longnan have not been undertaken. The aim of this study, therefore, is to investigate the relationship between AT and hypertension hospital admissions in farmers in the two regions. By quantifying impacts, a constructive reference for the formulation of local preventive measures and medical insurance policies may be proposed.

MATERIALS AND METHOD

Study area. For this study, two cities in Gansu Province characterized by different climatic conditions were selected. Zhangye (37° 28′–39° 57′ N, 97° 20′–102° 12′ E), located in the west of Gansu Province, has a cold, arid temperate, characterized by a semi-arid and semi-humid climate; Longnan (32° 35′–34° 32′ N, 104° 01′–106° 35′ E), located in the southeast of Gansu Province, has a north subtropical, warm temperate climate. The total area of Zhangye and Longnan is 40,874 square kilometers and 27,923 square kilometers, respectively.

Data collection. Hypertension hospital admission data for Zhangye and Longnan, spanning 1 January 2014 – 31 December 2015, was collected from the New Rural Cooperative Medical Scheme. Meteorological data for both cities were collected during the same period from the Gansu Meteorological Bureau. Meteorological data included daily mean temperature (°C), relative humidity (%), barometric pressure (hPa), sunshine duration (h), rainfall (mm) and wind velocity (m/s). AT was calculated as [17]:

$$AT=T+0.33*e-0.70*WS-4.00$$
$$e=RH/100*6.105*\exp(17.27*T/(237.7+T))$$

T – daily mean temperature; e – water vapor pressure; WS-s wind speed; RH – relative humidity.

Statistical analysis. Non-linear and delay relationships between temperature and human health outcomes have been previously examined using empirical studies [7, 12, 30]. In the current study, the Poisson generalized linear model and the distributed lag nonlinear model (DLNM) were combined to evaluate the relationship between AT and hypertension hospital admissions, calculated as:

$$Log[E(Y_t)] = \alpha + \beta(AT_{t,l}) + ns(Time,\ df{=}7) + ns(sunshine,\ df = 3) + ns(humidity,\ df = 3) + DOW + PH$$

where, $E(Y_t)$ denotes the expected value of the hospital admission on day t; α is the intercept of the model; β is the vector of the coefficient for $AT_{t,l}$; AT is the cross-basis matrix of the apparent temperature in the DLNM; df is the degree of freedom; and $Time$ represents long-term trend effects.

The 7 df for *Time* was chosen in order to remove long-term trend effects; the 3 df was selected for sunshine and humidity to control the influence of the sunshine and the relative humidity, and *DOW* and *PH* were considered in the model to control the effects of the day of the week and public holidays. In accordance with previous investigations, the maximum lag days up to 21 days was set to capture all adverse impacts [31, 32].

It has been previously shown that a lower AIC value represents a better model fit [17], in this analysis the AIC (Akaike Information Criterion) value was checked; and finally, we chose the 3 df natural cubic spline for AT and the 3 df natural cubic spline for lag. Relative risks (RRs) with 95% confidence interval (CI) were evaluated by using the reference AT of 27.9 °C and 31.6 °C, with the admission risk lowest in Zhangye and Longnan, respectively.

Cold effects were defined as cumulative RRs associated with 5th percentile of AT, and heat effects were defined as cumulative RRs associated with 95th percentile of AT. Stratified analysis was conducted by gender and age group (<65 years, ≥ 65 years). All analysis was performed using R software (version 3.6.3) with the 'dlnm' package.

Sensitive analysis was performed by changing the maximum lag days from 20 to 22, and altering the df of variables: time (df=6–8), sunshine (df=3–5), relative humidity (df=3–5). Results indicated that the model was robust (Fig. S1, Fig. S2).

RESULTS

Between 1 January 2014 – 31 December 2015, 9,588 and 14,622 hospital admissions for hypertension were recorded in Zhangye and Longnan, respectively (Tab. 1). Daily mean

Table 1. Summary statistics for hypertension hospital admissions in Zhangye and Longnan, respectively

	Mean	Min	P25	Med	P75	Max
Zhangye						
All	13	0	9	13	16	155
Gender						
Male	5	0	3	5	7	58
Female	8	0	5	8	10	97
Age						
Adult	7	0	4	7	10	96
Elderly	6	0	4	5	7	59
Longnan						
All	20	0	13	19	26	94
Gender						
Male	9	0	5	8	12	37
Female	11	0	7	10	14	57
Age						
Adult	11	0	7	10	15	56
Elderly	9	0	6	8	12	38

Mean, Min, Max, P25, P75 - mean, minimum, maximum, 25th percentile, 75th percentile and median of variables, respectively.

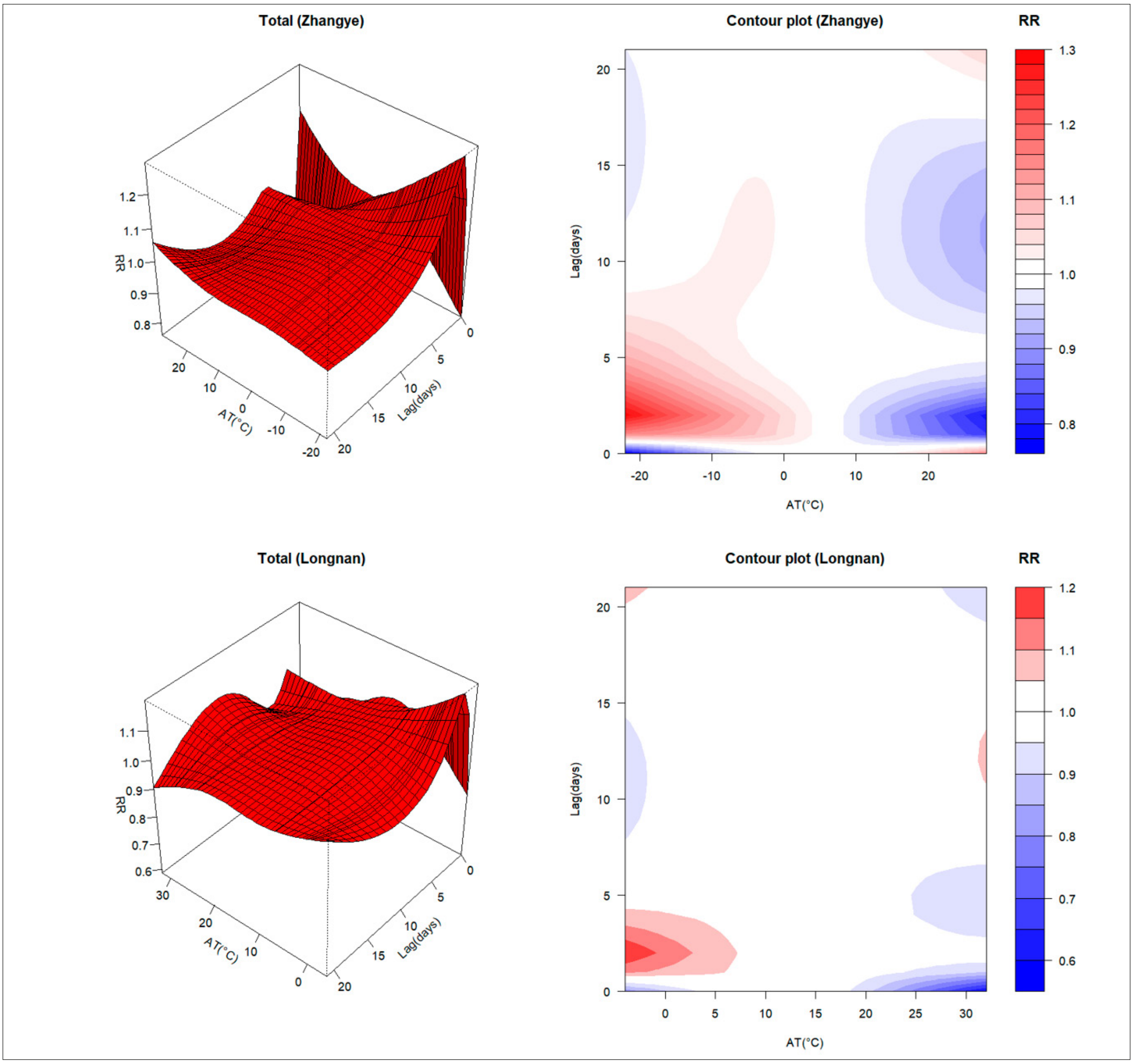

Figure 1. Three-dimensional plot and its contour plot for Zhangye and Longnan.

hospital admissions in Zhangye and Longnan were 13 and 20, respectively. Male patients accounted for 38.5% and 45% of the total number of hospitalizations in Zhangye and Longnan respectively, with adults accounting for 53.8% and 55% of the total number of hospitalizations in Zhangye and Longnan, respectively. The proportions of CVD cases were higher in females and adults, than in males and the elderly.

Daily meteorological variables in the two regions, including temperature, AT, relative humidity, barometric pressure, rainfall, windspeed and sunshine duration, are shown in Table 2. In summary, daily mean temperature was 8.61 °C and 15.71 °C in Zhangye and Longnan, and AT ranged from -21.57 °C to 27.93 °C and from -3.67 °C to 31.64 °C, respectively.

The three-dimensional plot (left side) and its contour plot (right side) for Zhangye and Longnan are shown in Figure 1; the median value of AT (6.07 °C and 15.08 °C, respectively) was designated as the reference value. Results indicate that the relationship between AT and hypertension hospital admissions was non-linear in both regions. In Zhangye, cold temperature effects showed protective effects and immediately reached the maximum at about lag 2 days, then attenuated along lag days; high temperatures initially recorded adverse effects, then became protective effects, and finally the adverse occurred at about lag 20 days. Results in Longnan recorded obvious cold effects at about lag 1 day, persisting for about 3 days, then recording protective effects from lag 8 days to lag 14 days, the adverse effect occurred again at lag 20 days. Heat effects only occurred at about lag 10 days and persisted for 2 days.

Overall cumulative effects of AT on hypertension hospital admissions in the two regions are shown in Figure 2, by comparing with the reference AT of 27.9 °C and 31.6 °C (AT with minimum hospital admission risk) in Zhangye and Longnan, respectively. Here, the dashed blue and orange lines represent cold effects (5th percentile of the AT range) and heat effects (95th percentile of the AT range), respectively. In general, the impact of AT on hypertension hospital

Table 2. Summary statistics for meteorological variables in Zhangye and Longnan, respectively

	Temperature(°C)		Apparent Temperature(°C)		Relative Humidity(%)		Pressure(hPa)		Rainfall(mm)		Windspeed(m/s)		Sunshine(h)	
	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan
Mean	8.61	15.71	4.66	14.08	45.45	53.52	853.84	893.53	0.35	1.29	2.83	1.64	8.57	5.32
Min	-15.80	0.50	-21.57	-3.67	10.00	22.00	837.90	877.70	0.00	0.00	0.90	0.30	0.00	0.00
P25	-1.50	9.20	-6.59	6.09	32.25	45.00	850.00	889.20	0.00	0.00	2.10	1.10	7.13	1.10
Med	10.45	16.60	6.07	15.08	44.00	53.00	853.50	893.00	0.00	0.00	2.70	1.50	9.05	6.00
P75	18.70	22.38	16.32	22.23	58.00	61.00	857.40	897.78	0.00	0.30	3.30	2.00	10.90	8.60
Max	29.50	30.50	27.93	31.64	96.00	85.00	871.80	912.00	13.80	52.60	8.00	5.10	13.90	12.10

Note: Mean, Min, Max, P25, P75, Med represented the mean, minimum, maximum, the 25th percentile, the 75th percentile and median of variables, respectively

Table 3. Cumulative effects of low AT for entire study group and subgroups along the lag days in Zhangye and Longnan, respectively

	Total		Male		Female		Adult		Old	
	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan
Lag 0	0.741 (0.495, 1.108)	1.458 (1.102, 1.930)	1.133 (0.592, 2.166)	1.860 (1.226, 2.823)	0.562 (0.336, 0.940)	1.182 (0.809, 1.726)	0.959 (0.561, 1.642)	1.551 (1.064, 2.262)	0.523 (0.285, 0.962)	1.354 (0.891, 2.057)
Lag 0-3	2.008 (1.348, 2.990)	2.395 (1.825, 3.142)	2.541 (1.334, 4.839)	2.335 (1.558, 3.498)	1.703 (1.026, 2.829)	2.449 (1.697, 3.534)	2.319 (1.362, 3.949)	2.744 (1.903, 3.958)	1.656 (0.908, 3.021)	2.040 (1.361, 3.058)
Lag 0-5	2.490 (1.662, 3.731)	3.125 (2.364, 4.131)	3.071 (1.592, 5.925)	3.190 (2.111, 4.819)	2.155 (1.290, 3.602)	3.073 (2.103, 4.490)	3.128 (1.819, 5.379)	4.014 (2.752, 5.856)	1.844 (1.004, 3.387)	2.307 (1.525, 3.491)
Lag 0-7	2.831 (1.818, 4.411)	3.421 (2.496, 4.690)	3.562 (1.733, 7.325)	3.836 (2.409, 6.109)	2.428 (1.383, 4.261)	3.114 (2.026, 4.785)	3.793 (2.093, 6.876)	4.635 (3.024, 7.106)	1.931 (0.992, 3.757)	2.360 (1.478, 3.767)
Lag 0-14	5.180 (3.100, 8.657)	2.042 (1.382, 3.019)	6.345 (2.748, 14.655)	2.590 (1.449, 4.628)	4.496 (2.345, 8.619)	1.721 (1.014, 2.921)	5.816 (2.915, 11.605)	2.292 (1.356, 3.874)	4.482 (2.078, 9.668)	1.784 (0.993, 3.204)
Lag 0-21	5.141 (2.849, 9.277)	2.562 (1.596, 4.111)	4.903 (1.879, 12.791)	2.907 (1.440, 5.869)	5.176 (2.446, 10.957)	2.382 (1.256, 4.519)	5.691 (2.582, 12.546)	3.341 (1.770, 6.304)	4.526 (1.860, 11.008)	1.874 (0.922, 3.809)

Table 4. Cumulative effects of high AT for entire study group and subgroups along the lag days in Zhangye and Longnan, respectively

	Total		Male		Female		Adult		Old	
	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan	Zhangye	Longnan
Lag 0	0.938 (0.826, 1.064)	1.211 (1.112, 1.317)	1.016 (0.828, 1.247)	1.294 (1.141, 1.466)	0.889 (0.757, 1.045)	1.149 (1.024, 1.288)	1.006 (0.849, 1.191)	1.251 (1.116, 1.402)	0.856 (0.707, 1.035)	1.164 (1.026, 1.320)
Lag 0-3	1.095 (0.973, 1.232)	1.263 (1.157, 1.379)	1.091 (0.901, 1.321)	1.266 (1.111, 1.442)	1.096 (0.944, 1.273)	1.262 (1.121, 1.421)	1.014 (0.866, 1.187)	1.332 (1.183, 1.500)	1.205 (1.009, 1.439)	1.186 (1.042, 1.350)
Lag 0-5	1.114 (0.988, 1.255)	1.338 (1.224, 1.464)	1.073 (0.884, 1.304)	1.263 (1.107, 1.442)	1.138 (0.978, 1.324)	1.403 (1.242, 1.586)	1.037 (0.884, 1.217)	1.464 (1.296, 1.654)	1.216 (1.016, 1.456)	1.202 (1.053, 1.372)
Lag 0-7	1.129 (0.992, 1.286)	1.365 (1.237, 1.505)	1.086 (0.879, 1.340)	1.262 (1.093, 1.458)	1.155 (0.980, 1.361)	1.456 (1.273, 1.665)	1.081 (0.908, 1.286)	1.509 (1.320, 1.724)	1.191 (0.981, 1.447)	1.210 (1.047, 1.397)
Lag 0-14	1.300 (1.133, 1.492)	1.126 (1.014, 1.250)	1.332 (1.064, 1.668)	1.182 (1.012, 1.381)	1.281 (1.076, 1.525)	1.091 (0.947, 1.257)	1.267 (1.052, 1.527)	1.111 (0.965, 1.280)	1.344 (1.095, 1.650)	1.147 (0.981, 1.341)
Lag 0-21	1.253 (1.102, 1.425)	1.214 (1.093, 1.349)	1.180 (0.957, 1.455)	1.284 (1.099, 1.502)	1.300 (1.104, 1.530)	1.170 (1.015, 1.348)	1.160 (0.976, 1.379)	1.251 (1.086, 1.441)	1.379 (1.138, 1.672)	1.179 (1.008, 1.378)

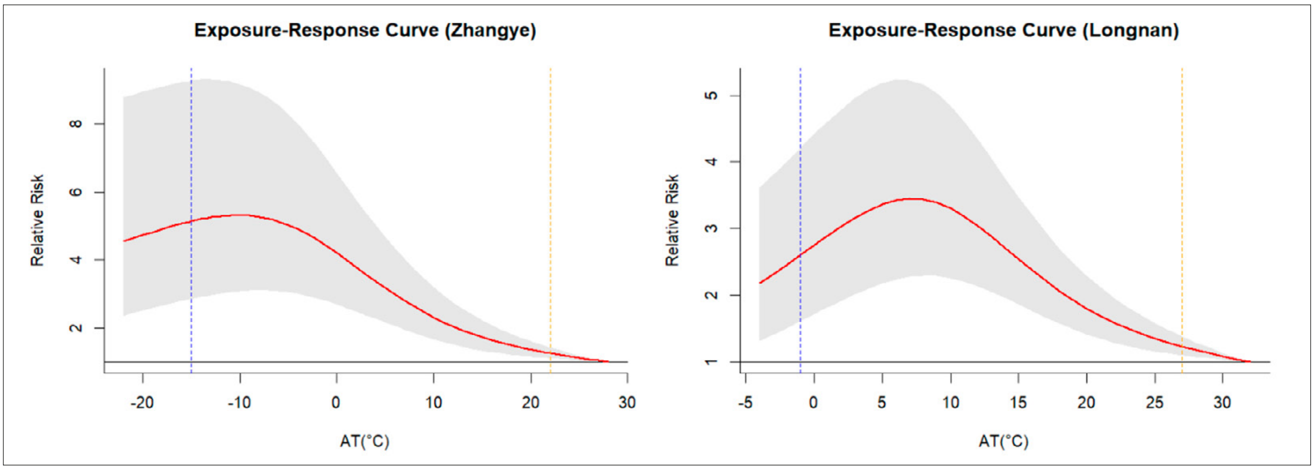

Figure 2. Overall cumulative effects of AT on hypertension hospital admissions in Zhangye and Longnan

admissions presented similar patterns in the two regions, recording an initial increase before a decrease, with the cold effects being stronger in Zhangye than Longnan.

Figure 3 presents the overall cumulative effects of AT on the gender subgroup (male and female) and age subgroup (<65 years old and ≥ 65 years old), by comparing with the reference AT of 27.9 °C and 31.6 °C (AT with minimum hospital admission risk) in Zhangye and Longnan, respectively. The exposure response curves of each subgroup in the two regions presented a tendency to increase at first, and then decreased along the lag days. The curves in Zhangye were relatively flat compared to Longnan, but the cold effects of each subgroup were stronger in Zhangye than in Longnan.

Cumulative RRs of cold effects associated with the 5th percentile of the AT range compared with the AT with minimum hospital admission risk in the two regions for the entire study group and subgroups along 21 lag days are shown in Table 3. For the entire study group, RRs peaked at lag 0–14 with value of 5.180 (95%CI:3.100, 8.657) in Zhangye, and at lag 0–7 with the value of 3.421 (95%CI:2.496, 4.690) in Longnan. Results for the cold effect were higher in Zhangye than in Longnan. For the male subgroup, the RRs peaked at lag 0–14 with the value of 6.345 (95%CI:2.748, 14.655) in Zhangye, and at lag 0–7 with the value of 3.836 (95%CI:2.409, 6.109) in Longnan. For the female subgroup, the RRs peaked at lag 0–21 with the value of 5.176 (95% CI:2.446, 10.957) in Zhangye, and at lag 0–7 with the value of 3.114 (95%CI:2.026, 4.785) in Longnan. For adult subgroup, the RRs peaked at lag 0–14 with the value of 5.816 (95%CI:2.915, 11.605) in Zhangye, and at lag 0–7 with the value of 4.635 (95%CI:3.024, 7.106) in Longnan; for the elderly subgroup, the RRs peaked at lag 0–21 with the value of 4.526 (95%CI:1.860, 11.008) in Zhangye, and at lag 0–7 with the value of 2.360 (95%CI:1.478, 3.767) in Longnan. The cold effects were stronger in Zhangye than that in Longnan for both either study group or subgroups.

Cumulative RRs of heat effects associated with the 95th percentile of the AT range compared with the AT with minimum hospital admission risk in the 2 regions for the entire study group and subgroups along 21 lag days are shown in Table 4. For the entire study group, RRs peaked at lag 0–14 with value of 1.300 (95%CI:1.133, 1.492) in Zhangye, and at lag 0–7 with the value of 1.365 (95%CI:1.237, 1.505) in Longnan. Results for the cold effect were higher in Zhangye than in Longnan. For the male subgroup, the RRs peaked at lag 0–14 with the value of 1.332 (95%CI:1.064, 1.668) in Zhangye, on the current day (lag 0) with the value of 1.294 (95%CI:1.141, 1.466) in Longnan; for female subgroup, the RRs peaked at lag 0–21 with the value of 1.300 (95%CI:1.104, 1.530) in Zhangye, and at lag 0–7 with the value of 1.456 (95%CI:1.273, 1.665) in Longnan; for adult subgroup, the RRs peaked at lag 0–14 with the value of 1.267 (95%CI:2.915, 11.605) in Zhangye, and at lag 0–7 with the value of 1.509 (95%CI:1.320, 1.724)

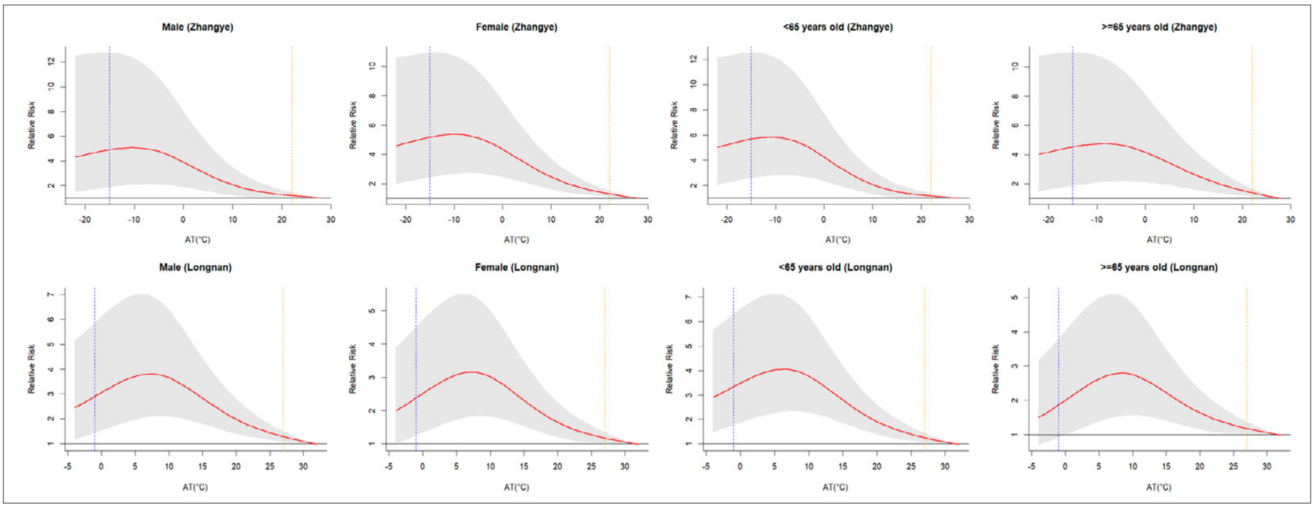

Figure 3. overall cumulative effects of AT on gender and age subgroups.

in Longnan. For the elderly subgroup, the RRs peaked at lag 0–21 with the value of 1.379 (95%CI:1.138, 1.672) in Zhangye, and at lag 0–7 with the value of 1.210 (95%CI:1.047, 1.397) in Longnan. The heat effects were more deleterious for the entire study group, female subgroup and adult subgroup in Longnan, but stronger for male subgroup and elderly subgroup in Zhangye.

DISCUSSION

This study mainly examined the relationship between AT and hypertension hospital admissions in Zhangye and Longnan, 2 regions recording different climatic conditions in Gansu, China. The nonlinear relationship was reported with reference AT values of 6.07 °C and 15.08 °C in Zhangye and Longnan, respectively. Cold effects in Zhangye were recorded to be more harmful for hypertension than in Longnan, but the heat effects were stronger in Longnan for entire study group.

The relationship between temperature and hospital admissions for cardiovascular disease has been previously highlighted [3, 32, 33]. For example, Guo et al., (2020) found a nonlinear relationship between ambient temperature and acute coronary syndrome emergency hospitalization [32]. A similar finding was reported by Mohammadi et al., (2018) in Tehran, Iran; their results indicated that a non-linear relationship existed between temperature and acute myocardial infarction [3]. Although few studies have explored the AT impact on hypertension, the results obtained in the current study indicate a non-linear relationship between AT and hypertension, and was evident in both Zhangye and Longnan.

The adverse impact of cold AT in the study areas was in accordance with previous findings investigating the association between temperature and hypertension. For example, Meng et al., (2020) reported that cold waves have significant impacts on hypertension hospital admission in Jinchang, a region geographically close to Zhangye [27]. Hu et al., (2021) also reported low temperatures increased blood pressure and an incidence of hypertension [24]. Similarly, Su et al., (2014) indicated that lower outdoor temperatures had a strong association with higher blood pressure and hypertension prevalence in rural China [29]. Compared with Longnan, the cold effect was more deleterious in Zhangye, with some potential factors possibly being responsible for differences between the two regions. Firstly, Zhangye is located to the north of Gansu Province, and is characterized by an arid cold temperate climate; Longnan is located to the south of Gansu Province, with a north subtropical, warm temperate climate. Winter temperatures in Zhangye are lower than those in Longnan, resulting in local residents being exposed to more risks associated with these lower temperatures. Secondly, indoor heating has becoming an effective way to cope with cold temperatures. Although a study conducted in Harbin indicated that indoor heating is a good way to control blood pressure [34], differences between indoor and outdoor temperatures may play an important role in triggering an increase in blood pressure when people leave their homes, thereby inducing hypertension.

Finally, eating habits, such as salt and alcohol intake, lifestyle choices, income and educational level, may also be factors influencing hypertension; results obtained by Lewington et al., (2016) indicted that hypertension counter-measures were less effective for people with lower levels of education and income [35].

Findings from the current and from previous investigations have shown that cold temperatures have an adverse impact on hypertension. Potential mechanisms that may explain this phenomenon include exposure to cold stimulation, whereby the sympathetic nervous and renin angiotensin systems are activated which inevitably result in elevated blood pressure levels [36]. Additionally, an increase in blood pressure can also be triggered by an increase in the secretion of catecholamine due to cold temperatures, thereby elevating heart rates and peripheral vascular resistance [37].

The current study indicates that heat AT effect was more pronounced and prolonged in Longnan than Zhangye, the potential factor may have contributed to the result. The AT in Longnan was higher than Zhangye.

This study focused mainly on the rural population who may experience more outdoor activities than indoor, which means they would face a higher AT risk; thus, the impact on the inhabitants of Longnan was more deleterious than in Zhangye. Similar to the current findings, Zheng et al., (2021) indicated that the impact of outdoor temperature on both systolic blood pressure and diastolic blood pressure was bigger in summer than in other seasons in Jinchang; the elevated blood pressure was regarded as the critical factor to trigger the hypertension [38].

Hypertension hospital admissions caused by AT were recorded as being different between Zhangye and Longnan, indicating that climate conditions between the study regions, such as temperature and relative humidity, influence hypertension morbidity. Similarly, Ge et al., (2018) indicated that hot temperatures rather than low temperatures could increase the risk of rheumatic heart disease hospital admissions in Shanghai [39]. By examining the association between extreme temperature and cardiovascular disease in Beijing and Shanghai, Wang et al., (2015) indicated that the adverse impact of cold and hot temperatures on cardiovascular disease was stronger in Beijing than in Shanghai [40].

However, previous studies examining the association between temperature and cardiovascular disease in different areas reported inconsistent findings. For example, a study conducted in Qingdao (Zhai et al., 2020) recorded low temperatures having a stronger cumulative effect and high temperature effects were acute, having a short persistence time [41]. Another study in Tehran, Iran (Mohammadi et al., 2018) reported cold temperature effects being delayed and lasting longer than hot temperature effects [3]. Therefore, the results from the current study and those of previous studies highlight that climatic conditions have a modifying effect on cardiovascular disease.

Differences between the gender and age subgroups in the two regions under heat conditions were highlighted using subgroup analysis. Results revealed that males and the elderly were more vulnerable to heat exposure in Zhangye, while the female and adult in Longnan suffered more heat exposure risk. The discrepancies in these results may be due to certain circumstances, for example, temperatures were higher in the warm season in Longnan than in Zhangye. Although the aimed of the current study was to investigate the differences between the agricultural populations in the regions, some people may have been employed in the other industries. The findings by Robert and Brook (2017) revealed that loud noises could also increase blood pressure and the risk of hypertension [42]. Hypertension risk can therefore be associated with occupation, possibly accounting for some differences recorded between the two regions. Other factors such as dietary structure and preference, daily activities could also have influenced the results. In addition, air pollution has an impact on hypertension, but the current study did not take into account the confounding effects of air pollution, which may responsible for the discrepancies and deserves further investigation.

Strengths and limitations of the study. The first important strength is that to the best of the authors' knowledge, this is the first study to investigate the relationship between AT and hypertension in Zhangye and Longnan. Secondly, as AT is a more objective and comprehensive indicator than temperature, AT was used instead of other temperature indicators to examine differences between two regions. Thirdly, as hypertension is a type of cardiovascular disease with a potential impact on a significant proportion of the population in China, the obtained may contribute to the identification of vulnerable populations and the formulation of prevention measures.

Despite the advantages perceived in the study, some limitations exist. Firstly, as meteorological data used was collected from fixed monitoring stations, it was therefore limited in reflecting individual exposure. Secondly, potential confounding factors, such as living standards, eating habits, education levels, etc. were not considered in this study due to a lack of information. Thirdly, although Zhangye has two climate types and Longnan has three climate types, the same exposure level was used in each region, which possibly resulted in inaccuracies. Finally, the mixed effect of gender and age was not controlled in the study, which should be undertaken in further investigations.

CONCLUSIONS

The results obtained in Zhangye and Longnan indicate that a low AT impact was stronger in Zhangye while the heat effects were more deleterious in Longnan for entire study group. The impact of low AT was stronger in Zhangye than in Longnan for both the gender and age subgroups, whereas the impact of high AT was stronger in Longnan for the female and adult subgroup. Our findings indicate that both low and high AT are risk factors triggering hypertension morbidity, and could possibly promote the formulation of further prevention measures for hypertension disease.

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