Effects of Ambient Temperature and Fall Related Injuries in Ma'anshan, Anhui Province, China: A Distributed Lag Non-linear Analysis

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Research Article

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Abstract

Despite the significant economic cost of falls and injuries to individuals and communities, little is known about the impact of meteorological factors on the incidence of fall-related injuries (FRIs). Therefore, a time-series study was conducted to explore the effects of meteorological factors on FRIs in Ma'anshan City, East China. Injury data from 2011 to 2017 were collected from the National Injury Monitoring Station in Ma'anshan City. Meteorological data were obtained from the National Meteorological Information Center. A distributed lag nonlinear model was used in this study to evaluate the correlation between ambient temperature and fall injuries. The results showed a significant exposure-response relationship between temperature and FRIs in Ma'anshan City. There was an asymmetric U-shaped relationship between ambient temperature and injuries, if the lowest risk temperature (4°C) was used as the reference temperature. The high temperatures increases the risk of FRIs (RR = 1.110, 95%CI:1.005–1.225). Sensitivity to ambient temperature varied by different ages and genders, and the ≥ 60 years subgroup seemed to be more sensitive in low temperature (RR = 1.071, 95%CI:1.024–1.120). The cumulative result is similar to the single-day effect. This study would help the establishment of fall-related injury prediction and provide evidence for the formulation and implementation of preventive strategies and measures in the future.

Introduction

The 2017 global burden of disease (GBD) study showed that disability-adjusted life-year (DALY) of fall-related injuries (FRIs) were the first among all unintentional injuries in the world (GBD 2017 DALYs and HALE Collaborators, 2018). According to the World Health Organization (WHO) report, 37.3 million FRIs occur every year in the world, causing more than 17 million DALY losses, and 646,000 patients will lose their lives (WHO, 2018). While falls and injuries cause serious health consequences, they also increase the burden on the emergency department of the hospital (Murray et al., 2011) and the potential long-term sequelae (Stevens et al., 2007). FRIs are also one of the most important sources of occupational injuries and cause huge economic losses (Davis et al., 2010; Heinrich et al., 2010).

FRIs represent a major health and safety concern for people of all ages. A study by Verma et al. found that middle-aged and young adults living in the community accounted for 35.3% and 32.3% of all fall-related injuries in the population (Verma et al., 2016). There are many studies on risk factors leading to fall injuries (Nahit et al., 1998; Peeters et al., 2009), but fewer studies that emphasize the effects of meteorological factors. Lin et al. examined seasonal variations in FRIs, population-based data from Taiwan of China, and found a significant correlation between winter and the occurrence of hip fractures in older adults (Lin and Xiraxagar, 2006). Turner et al. investigated people over the age of 70 and found that lower mean temperatures were significantly associated with higher fall-related hip fracture hospitalizations (Turner et al., 2011). Hussain et al. reported that heat waves can greatly increase the risk of unintentional falls in children (Hussain et al., 2007). Gevitz et al. study showed that rainfall was associated with an increase in the number of emergency department visits for fall-related fractures, but the temperature effect results were not statistically significant (Gevitz et al., 2017). The above studies have shown that the actual effect of meteorological factors on fall related injuries has not been fully revealed and the results are inconsistent across populations.

Previous studies have shown that the effect of meteorological factors is time-dependent and is not linear in most cases (Gasparrini et al., 2012). Such lagged effect might be related to the indirect effect of meteorological factors on immunity and thermoregulatory capacity (Ma et al., 2016). At present, the short-term effects of ambient temperature on mortality have been found by many studies worldwide (Huang et al., 2015). Zhang et al. found a lag relationship between meteorological factors and injuries in traffic accident types (Zhang Y. et al., 2020). Liao et al. conducted a fall injury study of the elderly in Guangzhou of China, and found that there is a correlation between FRIs and temperature after lag three days (Liao et al., 2018). These research results indicated that meteorological factors might also have a lag effect on FRIs.

China has a very high health burden for FRIs (WHO, 2018), and FRIs are one of the main causes of unintentional injuries in Anhui Province (Xing et al., 2016). Using distributed lag nonlinear model (DLNM) approach, which has function to explore the relationship between potential lag and nonlinear effects in time-series data (Gasparrini et al., 2010), this study conducted a time-series study to explore the relationship between ambient temperature and the risk of FRIs in Ma'anshan city, China. The results of the study will provide a scientific basis for intentional injury prevention and intervention.

Materials And Methods

Study Setting

Ma'anshan City is one of two Chinese national injury monitoring cities in Anhui Province. It is located in eastern China, downstream of the Yangtze River (longitude 117° 53'-118° 52'E, latitude 31° 24'-32° 02'N). The Yangtze River flows from east to west in the region. It has a northern subtropical humid monsoon climate with warm and humid seasons.

Injury data

Injury cases collected from January 1, 2011 to December 31, 2017 at the National Injury Surveillance Station in Ma'anshan city were provided by the Chinese Center for Disease Control and Prevention. The data included general information on injury cases (age, sex, occupation, and education level), basic information on injury events (time, cause, location of injury, activity at the time of injury, and whether the injury was intentional), and clinical information on the injury.

This study was approved by the ethics committee from the Chinese Center for Disease Control and Prevention Institute for Environmental Health and Related Product Safety (201606).

Meteorological data

Meteorological data for the study period were extracted and accumulated from the National Meteorological Information Center (http://data.cma.cn). Specific meteorological data included mean temperaturee (°C), relative humidity (%), precipitation (mm), atmospheric pressure (hPa), snow depth (mm), and sunshine time (hour).

Statistical analysis

The study explored exposure-lag-response associations through modeling. Daily FRIs are considered as small probability events, and this study used Poisson generalized linear model (PGLM) with distributed lag nonlinear model to estimate the nonlinear and lagged effects of ambient temperature on daily FRIs s (Dai et al., 2018; Rosenberg et al., 2018).

We first investigated the correlations between FRIs and meteorological factors with Spearman's correlation analysis. According to the results of correlation analysis, there is a correlation between the mean temperature and the incidence of injuries ($p < 0.001$).

And according to the relevant analysis results, this model would incorporate meteorological factors such as atmospheric pressure ($p=0.001$), snow depth ($p < 0.001$) , sunshine time ($p=0.002$), and adjust their influence by changing the degrees of freedom (*df*) (Hao et al., 2019; Min et al., 2019; Rosenberg et al., 2018).

The DLNM is based on the definition of a "cross-basis", a bi-dimensional space of functions, which describes both the shape of the relationship along the space of predictors and the lag dimension in which it occurs (Gasparrini et al., 2010). By performing the quasi-Poisson Akaike information criteria (Q-AIC) to select the optimal degrees of freedom. The model used in the study to quantify the relationship between ambient temperature and FRI is as follows:

$$Y_t \sim \text{Poisson}(\mu_t)$$

$$\text{Log}(\mu_t) = \alpha + \beta(TEM_t, 4) + ns(PRS_t, 1) + ns(SNOW_t, 1) + ns(SUN_t, 3) + ns(time_t, 9/year) + \eta DOW_t + v Holiday_t$$

where Y_t refers to the number of FRI occurring on day t; α is the intercept of the model; TEM_t, 4 represents the temperature on day t with 4 *df*s; β is the matrix coefficient of the temperature and a natural cubic spline function used to estimate the lag effects of temperatures; ns () is smoothing function of independent variables in mgcv package in R software. PRS in the model represents the atmospheric pressure, SNOW represents the snow depth, SUN represents the sunshine time. Using a natural cubic spline curve with an annual degree of freedom 9 to control the time trend. DOW means the day of the week, with a reference day of Friday. Public holidays during the study period are also accounted for using the categorical variable holiday due to the potential holiday-effects.

According to the combination of AIC criteria and references provided by related literature, we chose 30 days as the maximum lag period in the model. In the case of a nonlinear relationship (Min et al., 2019; Yi et al., 2019), we calculated the relative risk (RR) with a 95% confidence interval (CI) of specific temperatures on daily FRIs. The temperature with the lowest risk of total FRIs as the reference. RR was used to quantify the effect of temperature on the number of fall injuries, meaning the risk of FRI caused by changes in ambient temperature. Further analysis of the population of interest was performed by stratifying by age and gender groups. Sensitivity analysis in this study was performed by changing the *df* for time trend (*df* = 7-11), atmospheric pressure (*df* =1-3), snow depth (*df* =1-3), and sunshine time (*df* = 2-5).

All statistical analyses were performed using R (Version 3.6)software.

Results

Data description

As shown in Table 1, from 2011 to 2017, the Ma'anshan injury monitoring system recorded a total of 36,723 cases of fall-related injuries, with a maximum of 49 cases in a single day. Of the total cases, 21,447 males while 15,276 cases were female. 11,533 cases <20 years of age, 8,045 cases 20-39 years of age, 9,404 cases 40-59 years of age, and 7,741cases 60 years of age and older. Figure 1 showed the time series distribution of daily injury cases in Ma'anshan from 2011 to 2017. Detailed meteorological factor information over the study period could be found in Table 2.

Relationship between ambient temperature and FRIs

Figure 2 shows the exposure-response relationship between daily mean temperature and FRIs, which showed a significant nonlinear association in the results.

The temperature at the lowest risk of FRIs (4.0°C) was used as the reference dimension in this study to compare the single-day and cumulative lagged effects of high and low temperatures on FRIs in Ma'anshan, respectively. Detailed RRs and effect intervals are shown in Tables 3 and 4. We used the 10.0 (3.0°C) and 90.0 (27.9°C) percentile of ambient temperature in the Ma'anshan city as the prescribed high and low temperatures (Min et al., 2019; Zhang et al., 2019). Figure 3 showed the dose-response relationships for FRIs at different lag days (1-30) at different mean temperatures.

Table 3 showed the single-day effects of high and low temperatures on FRIs. The effect of temperature in the results showed an asymmetric U-shape. In terms of the single-day lag effect, the lag effect of high temperature appeared earlier and was more pronounced for the general population. At lag0, high temperature significantly increased the risk of FRIs (RR=1.110, 95%CI: 1.005-1.225). The lag effect appeared again at lag10 (RR=1.032, 95%CI: 1.003-1.063) and increased day by day, and then gradually remained stable after lag25 (RR=1.077, 95%CI: 1.045-1.110). The cumulative lag effect is shown in Table 4. The cumulative effect began to show a significant lag effect at lag1 (RR=1.175, 95%CI: 1.002-1.378), and it appeared for the second time after lag15 (RR=1.632, 95%CI: 1.042-2.556). In the general population, no statistically significant results of low temperature on FRI were found, whether single-day effect or cumulative effect.

Subgroup analysis

The different subgroup effects of temperatures on FRIs were shown in figure 4. In terms of the single-day lag effect, the lag effect of high temperature appeared in the male group after lag15 (RR=1.042, 95%CI: 1.006-1.079), and it increased day by day. In comparison, the female group might be more sensitive to high temperature. The lag results of female group appeared the first time at lag1 (RR=1.105, 95%CI: 1.018-1.200) and the second time is after lag15 (RR=1.085, 95%:1.041-1.132).

In the high temperature results of different age groups, the single-day lag effect of the group < 20 years old appeared at lag15 (RR=1.058, 95%:1.009-1.110). The results were similar for the 20-39 and 40-59 years groups, with an immediate significant effect of high temperature on FRIs. It is worth noting that the effect of temperature on FRIs in the ≥60 years group was different from the other groups. There was a significant association and lag effect with FRIs in the ≥60 years group at low temperature (RR=1.017,95%CI:1.004-1.031, lag0; RR=1.003,95%CI:1.000-1.007, lag25).

For the cumulative lag effect, the result is similar to the single-day lag effect. The low temperature showed a significant effect on FRIs for group ≥ 60 years of age.

Sensitivity analysis

Sensitivity analysis was performed by varying the degrees of freedom of time trend (*df* = 7-11), atmospheric pressure (*df* =1-3), snow depth (*df* =1-3), and sunshine time (*df* =2-5). The results are shown to be robust. The non-linear lag relationship between the mean temperature and FRIs after used alternative cut-off points (5th and 95th percentile) is presented in Table A1 and A2. For the high temperature (95th percentile), the results did not change significantly. However, there was a significant increase in the risk of FRIs in the total population, the female group, and the group ≥60 years of age at lower temperatures (5th percentile). Also the duration of the lagged effect was longer. This suggests that for lower temperatures, the results may be more statistically significant.

Discussion

Fall-related injurie is a major public health problem (Hartholt et al., 2011). These injuries could lead to chronic pain, incapacitation, increased health care needs, and even increased risk of mortality (Tinetti et al., 1988). If the burden of related injuries will further increase, it will have a huge health, social and economic impact on society and the country. Although previous studies have explored the risk factors for FRIs, few studies have focused on the effects of ambient temperature on FRIs in different populations.

In this study, we found a non-linear effect of ambient temperature on FRIs through a time series study, and there is also a short-term lag influence of this effect. This certainly compensates for the limitation of previous related linear model research. Compared with the reference temperature, high temperature increased the risk of FRIs, while the lagged effect of low temperature on FRIs was significant for people aged 60 years or older in Ma'anshan.

Above conclusion is consistent with previous studies. Turner's study (2011) investigated whether there was an association between fall-related fracture hospitalizations and ambient temperature at the daily level, and after considering autocorrelation and seasonal trends, they found an increased incidence of hip fractures in people over 75 years of age when the temperature decreased. Stevens' seasonal study on injuries showed that the average incidence of fatal falls in older adults was 9.1% higher in colder climates (Stevens et al., 2007). Some studies have also found that the incidence of fall-related injury among children increased during the high temperature season (Morrison et al., 1999; Parslow et al., 2005). Hussain thought this is because parents of children open windows for ventilation due to the high temperature, which increased the risk of children from heights (Hussain et al., 2007).

Age, drug use, physical condition and environmental condition are generally considered to be the main causes of fall injuries (Gillespie et al., 2012). Because of this, few studies have been published previously on the correlation between ambient temperature and injury. This study is the first to examine the epidemiological relationship between ambient temperature and FRIs in the eastern Chinese city of Ma'anshan. Although the exact biological mechanism remains to be further explored, previous studies on injury could provide some hypotheses.

Studies on occupational injuries has shown that excessively high temperatures could lead to individual negligence, fatigue, decline in cognitive function and athletic ability (Nindl et al., 2013; Otte im Kampe et al., 2016). For high temperatures, causing dehydration and heat cramps in individuals over the thermoregulatory system will impair the ability to work (Cohn and Rotton, 1997). Ambient temperature also affects people's activity level, and a suitable temperature would increase the amount of activity and expand the scope of activity (Morency et al., 2012; Sumukadas et al., 2009), and the risk of FRIs would increase.

The lag effects of FRIs in this study might be related to the long- and short-term effects of temperature on physiology and state of mind. Anderson et al. found that the effect of cold on mortality usually lasts for a long time (Anderson and Bell, 2009). Extreme temperatures may trigger a series of reactions in people who are already weak, and this process is not completed in an instant (Basu, 2009; Bhaskaran et al., 2013). Studies have found that after the heat wave, the hospitalization rate of patients with underlying diseases such as asthma and heart disease will also increase significantly (Khalaj et al., 2010).

The occurrence of such underlying diseases will undoubtedly increase the risk of falling in related patients. Similar to the results of our study, Lee found that injury by fall significantly increased at high temperatures in South Korea (Lee et al., 2020). They also used the DLNM model to explore the lag effects of injury, although they did not further differentiate the risks of different populations (Lee et al., 2020). These studies show that a few days after the temperature reaches a certain temperature, it still affects people's risk of falling.

This study showed that the FRIs of the elderly is significantly different from other populations for temperature changes. Especially when we alternative cut-off points and compare with the reference temperature, the low temperature effect would more obvious. The reasons for the fall of elderly are also different from other population. Outdoor activities of the elderly in extreme temperature would significantly reduce (Collins et al., 1977), thereby reducing the possibility of exposure to fall risk factors, which is a reason for the reduction of FRIs in the elderly in high temperature. Studies have shown that FRI in the elderly in winter is related to walking on wet and slippery roads (Xu et al., 2012). Low temperature caused lower body temperature, decreased flexibility, slower reaction speed, changes in physiological processes (Keatinge et al., 1984; Riley and Cochran, 1984), and wearing heavy clothes, all of which would increase the risk of falls for elder (Lin et al., 2015).

As far as we know, this is the first study reported the lag and nonlinearity of FRIs and ambient temperature in the eastern China. We provided scientific evidence of the lag-exposure-response relationship between ambient temperature and FRIs, and adjusted meteorological factors including atmospheric pressure, snow depth and sunshine time. Our results indicated that the long-term cumulative effect of ambient temperature should cause greater concern.

Several limitations also need to be acknowledged. First of all, this time series analysis directly uses the data of the injury monitoring site, which may not be able to avoid the ecological fallacy of the research in terms of methodology. But the research time span is as long as 7 years. According to previous research, these ecological fallacies will not affect our inferences about the results. Second, this study cannot distinguish where the injury occurred, which may obscure the true relationship between temperature and FRI. For further investigations, more complete information still needs to be collected for further analysis. Third, since our temperature is estimated based on fixed monitoring points, there may be exposure measurement errors. If this exposure measurement error occurs in this study, it may lead to bias against the null hypothesis, thereby underestimating the true association. But this will not significantly change our conclusion.

Conclusion

This study showed that there is a lag and non-linear relationship between temperatures and FRIs. Different age groups have different risk outcomes. The results of the study will help establish an early warning system for injury and reduce the burden of FRI, especially among high-risk groups.

Declarations

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Conflict of interest

There is no conflict of interest that exists in this manuscript and it is approved by all authors.

Ethics approval and consent to participate:

Not applicable.

Consent for publication

There is no conflict of interest that exists in this manuscript and it is approved by all authors.

Availability of data and materials

Not applicable.

Competing interests

There is no conflict of interest.

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Authors' contributions

Mingming Liang: Data curation, Writing, Original draft preparation, Software. *Xiuxiu Ding*: Conceptualization, Methodology. *Zhenhai Yao*: Data curation and Writing- Reviewing. *Leilei Duan*: Writing- Reviewing and Editing. *Xiuya Xing:* Supervision and Editing. *Yehuan Sun*: Supervision, Writing- Reviewing and Editing.

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Tables

Table 1 Characteristics of daily fall-related injury from 2011 to 2017.

Group	Total	Mean	Standard Deviation	Minimum	Maximum	Percentiles（%）		
						25	50	75
Injury	36723	14.36	8.285	0	49	8	13	19
Male	21447	8.39	4.963	0	32	5	8	11
Female	15276	5.97	4.184	0	25	3	5	8
<20	11533	4.51	3.666	0	24	2	4	6
<40	8045	3.15	2.323	0	15	1	3	4
<60	9404	3.68	2.558	0	16	2	3	5
≥60	7741	3.03	2.437	0	19	1	2	4

Table 2 Descriptive statistics of daily meteorological variables in Ma'anshan, China from 2011 to 2017.

Group	Mean	Standard Deviation	Minimum	Maximum	Percentiles（%）						
					5	10	25	50	75	90	95
Pressure (Pa)	1007.0	9.1	985.0	1033.3	993.6	995.	999.1	1007.1	1014.2	1019.4	1021.6
Mean temperature (°C)	16.6	9.1	-7.0	35.4	1.8	3.0	8.7	17.8	23.9	27.9	30.5
Relative humidity (%)	71	17	24	99	41	47	59	72	84	93	97
Precipitation (mm)	3.49	10.84	0	148.20	0	0	0	0	2.00	9.34	18.48
Snow depth (mm)	0.10	0.93	0	21.00	0	0	0	0	0	0	0.10
Sunshine(h)	5.17	5.45	0	12.0	0	0	0	5.4	8.7	10.5	11.2

Table 3. Single relative risk of the ambient temperature on FRIs in Ma'anshan, China

oup	Relative risk and 95% CI of multi-day								
	lag1	lag5	lag10	lag15	lag20	lag25	lag30		
	3.0°C	0.994(0.986,1.003)	0.997(0.992,1.003)	1.001(0.998,1.005)	0.999(0.997,1.001)	0.999(0.997,1.001)	0.999(0.997,1.001)	1.001(0.999,1.003)	1.003(0.999,1.006)
C	1.110(1.005,1.225)*	1.059(0.995,1.127)	0.992(0.955,1.031)	1.032(1.003,1.063)*	1.060(1.027,1.093)*	1.073(1.042,1.104)*	1.077(1.045,1.110)*	1.076(1.030,1.124)*	
	3.0°C	0.992(0.982,1.002)	0.995(0.989,1.001)	0.999(0.996,1.003)	1.000(0.997,1.002)	1.000(0.997,1.002)	1.000(0.997,1.002)	1.000(0.997,1.002)	1.000(0.996,1.004)
C	1.060(0.947,1.187)	1.028(0.958,1.104)	0.988(0.946,1.032)	1.019(0.986,1.053)	1.042(1.006,1.079)*	1.057(1.023,1.092)*	1.067(1.031,1.104)*	1.074(1.022,1.128)*	
le	3.0°C	0.997(0.986,1.008)	1.001(0.994,1.007)	1.004(1.000,1.009)	0.999(0.997,1.002)	0.998(0.995,1.001)	0.999(0.997,1.002)	1.002(1.000,1.005)	1.007(1.002,1.011)*
C	1.187(1.042,1.352)*	1.105(1.018,1.200)*	0.999(0.949,1.051)	1.053(1.012,1.094)*	1.085(1.041,1.132)*	1.096(1.054,1.139)*	1.092(1.048,1.137)*	1.080(1.019,1.145)*	
	3.0°C	0.980(0.966,0.994)	0.989(0.980,0.997)	1.003(0.998,1.009)	1.000(0.997,1.003)	0.998(0.995,1.002)	0.999(0.996,1.002)	1.001(0.997,1.004)	1.003(0.998,1.009)
C	1.039(0.894,1.208)	1.014(0.923,1.115)	0.990(0.934,1.050)	1.030(0.985,1.077)	1.058(1.009,1.110)*	1.075(1.028,1.124)*	1.084(1.035,1.136)*	1.090(1.019,1.165)*	
	3.0°C	0.991(0.976,1.007)	0.995(0.985,1.004)	1.000(0.994,1.006)	0.999(0.995,1.002)	0.999(0.995,1.003)	1.000(0.997,1.003)	1.002(0.998,1.006)	1.004(0.998,1.010)
C	1.239(1.044,1.470)*	1.137(1.021,1.266)*	0.994(0.930,1.063)	1.037(0.987,1.090)	1.067(1.012,1.125)*	1.080(1.028,1.135)*	1.082(1.028,1.139)*	1.078(1.000,1.162)*	
	3.0°C	0.991(0.979,1.004)	0.995(0.987,1.002)	1.000(0.996,1.005)	1.000(0.997,1.003)	0.999(0.996,1.002)	0.999(0.996,1.002)	0.999(0.996,1.002)	0.999(0.994,1.004)
C	1.206(1.035,1.405)*	1.120(1.017,1.233)*	0.994(0.936,1.055)	1.024(0.979,1.072)	1.048(0.998,1.099)	1.061(1.015,1.109)*	1.067(1.019,1.118)*	1.070(1.000,1.145)	
	3.0°C	1.017(1.004,1.031)*	1.012(1.004,1.020)*	1.001(0.996,1.006)	0.999(0.995,1.002)	0.999(0.995,1.002)	1.000(0.997,1.004)	1.003(1.000,1.007)*	1.007(1.001,1.012)*
C	0.980(0.833,1.154)	0.974(0.879,1.079)	0.989(0.928,1.054)	1.039(0.990,1.091)	1.068(1.014,1.126)*	1.079(1.028,1.133)*	1.078(1.025,1.134)*	1.071(0.996,1.151)	

.05, the 4.0 °C as the reference

Table 4. Cumulative relative risk of the ambient temperature on FRIs in Ma'anshan, China

Subgroup	Relative risk and 95% CI of multi-day								
lag0	lag1	lag5	lag10	lag15	lag20	lag25	lag30		
Total	3.0°C	0.994(0.986,1.003)	0.992(0.978,1.005)	0.995(0.976,1.015)	0.996(0.970,1.023)	0.991(0.958,1.025)	0.987(0.947,1.028)	0.988(0.942,1.036)	0.999(0.945,1.055)
27.9°C	1.110(1.005,1.225)*	1.175(1.002,1.378)*	1.180(0.921,1.510)	1.279(0.905,1.807)	1.632(1.042,2.556)*	2.272(1.300,3.971)*	3.274(1.693,6.329)*	4.732(2.214,10.111)	
Male	3.0°C	0.992(0.982,1.002)	0.987(0.971,1.002)	0.980(0.958,1.003)	0.978(0.948,1.009)	0.976(0.939,1.014)	0.974(0.930,1.020)	0.973(0.922,1.027)	0.973(0.914,1.036)
27.9°C	1.060(0.947,1.187)	1.090(0.909,1.307)	1.059(0.799,1.403)	1.093(0.737,1.620)	1.288(0.773,2.144)	1.656(0.880,3.119)	2.251(1.067,4.749)*	3.172(1.343,7.494)*	
Female	3.0°C	0.997(0.986,1.008)	0.998(0.981,1.015)	1.015(0.989,1.041)	1.020(0.985,1.057)	1.010(0.967,1.056)	1.002(0.950,1.057)	1.007(0.946,1.072)	1.033(0.961,1.110)
27.9°C	1.187(1.042,1.352)*	1.312(1.063,1.619)*	1.386(1.001,1.919)*	1.615(1.023,2.550)*	2.309(1.273,4.185)*	3.604(1.715,7.570)*	5.653(2.349,13.604)	8.492(3.087,23.361)	
<20	3.0°C	0.980(0.966,0.994)	0.969(0.948,0.990)	0.971(0.940,1.003)	0.977(0.935,1.020)	0.971(0.920,1.025)	0.964(0.904,1.029)	0.965(0.894,1.041)	0.976(0.894,1.065)
27.9°C	1.039(0.894,1.208)	1.054(0.827,1.343)	1.012(0.694,1.476)	1.086(0.640,1.845)	1.372(0.688,2.736)	1.917(0.811,4.531)	2.832(1.024,7.830)*	4.312(1.336,13.916)*	
<40	3.0°C	0.991(0.976,1.007)	0.986(0.962,1.010)	0.981(0.946,1.017)	0.976(0.930,1.025)	0.970(0.914,1.029)	0.967(0.900,1.039)	0.973(0.895,1.057)	0.989(0.899,1.088)
27.9°C	1.239(1.044,1.470)*	1.409(1.069,1.856)*	1.513(0.990,2.313)	1.663(0.921,3.003)	2.188(1.019,4.698)*	3.153(1.221,8.144)*	4.672(1.523,14.336)*	6.862(1.882,25.024)*	
<60	3.0°C	0.991(0.979,1.004)	0.986(0.966,1.006)	0.983(0.955,1.013)	0.983(0.945,1.024)	0.980(0.932,1.030)	0.974(0.916,1.035)	0.968(0.901,1.040)	0.963(0.886,1.046)
27.9°C	1.206(1.035,1.405)*	1.350(1.055,1.728)*	1.440(0.984,2.110)	1.522(0.893,2.595)	1.845(0.924,3.684)	2.426(1.027,5.731)*	3.326(1.206,9.173)*	4.642(1.443,14.939)*	
≥60	3.0°C	1.017(1.004,1.031)*	1.030(1.009,1.051)*	1.046(1.014,1.079)*	1.042(0.998,1.087)	1.034(0.980,1.090)	1.032(0.967,1.101)	1.042(0.966,1.124)	1.069(0.979,1.168)
27.9°C	0.980(0.833,1.154)	0.954(0.733,1.242)	0.874(0.580,1.318)	0.967(0.544,1.719)	1.284(0.608,2.710)	1.854(0.732,4.696)	2.717(0.907,8.133)	3.880(1.101,13.680)*	

*P<0.05, the 4.0 °C as the reference

Figures

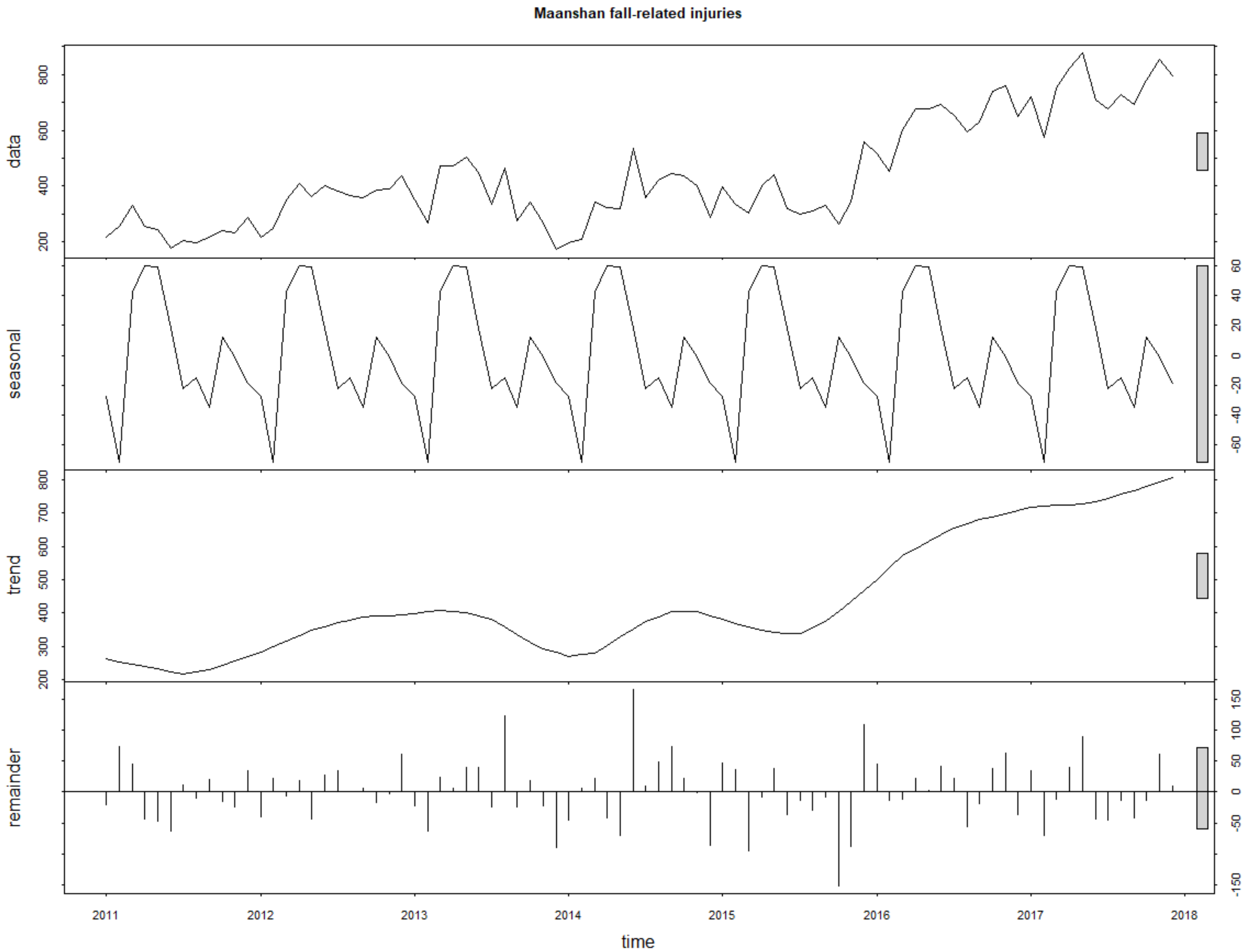

Figure 1

The time-series distribution of daily fall-related injury cases in Ma'anshan, 2011–2017.

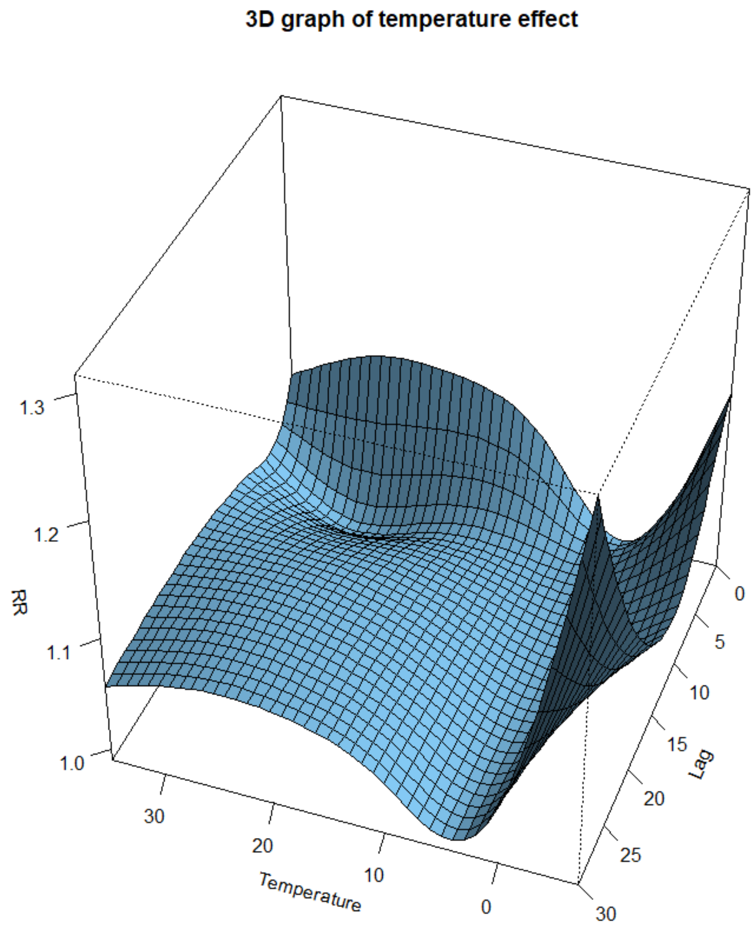

Figure 2

Three-dimension plot for relative risk (RR) of ambient temperature on FRIs in Ma'anshan, China, 2011–2017

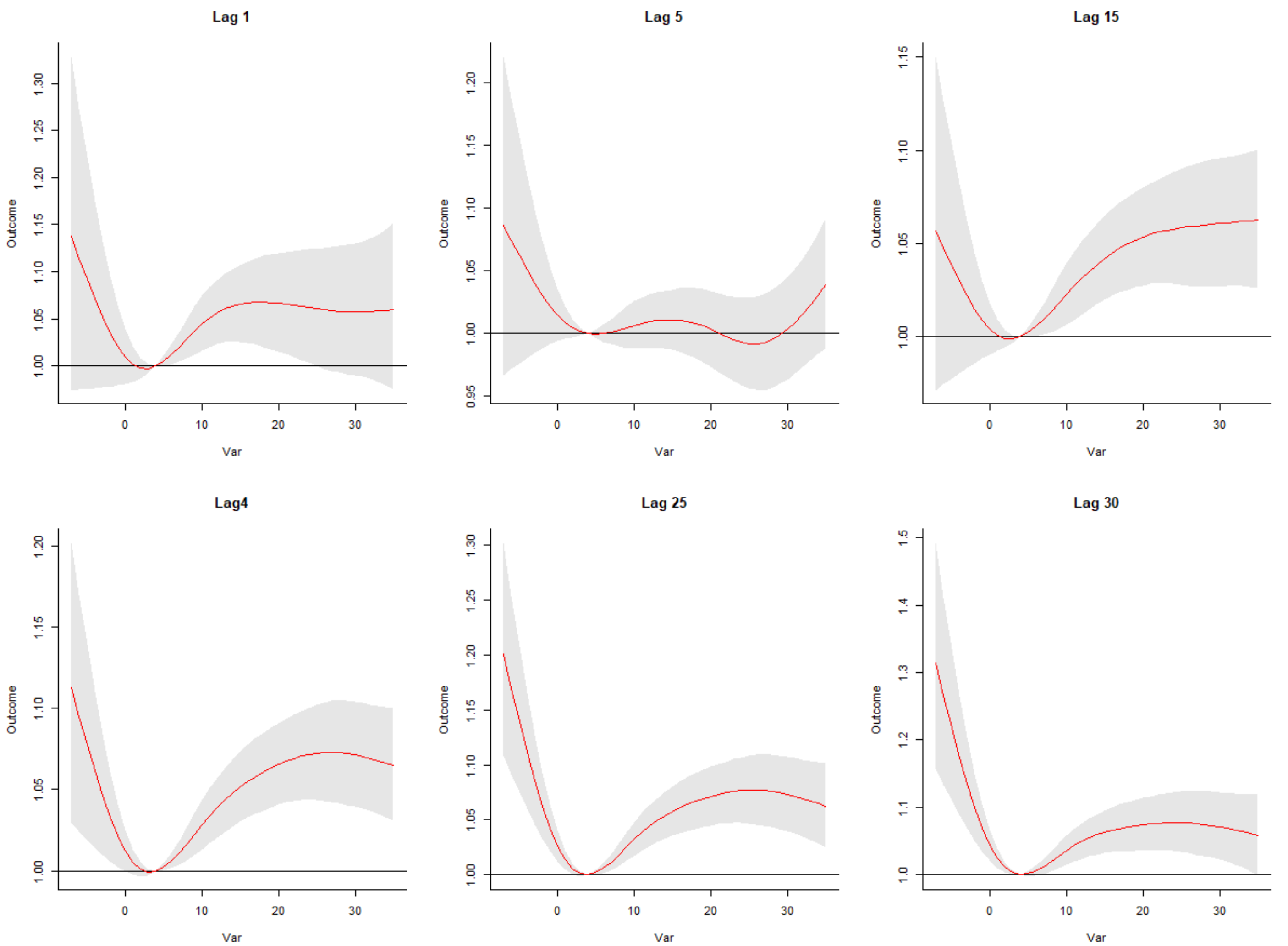

Figure 3

Lag effects of ambient temperature at different lag days on FRIs in Ma'anshan, China, 2011–2017.

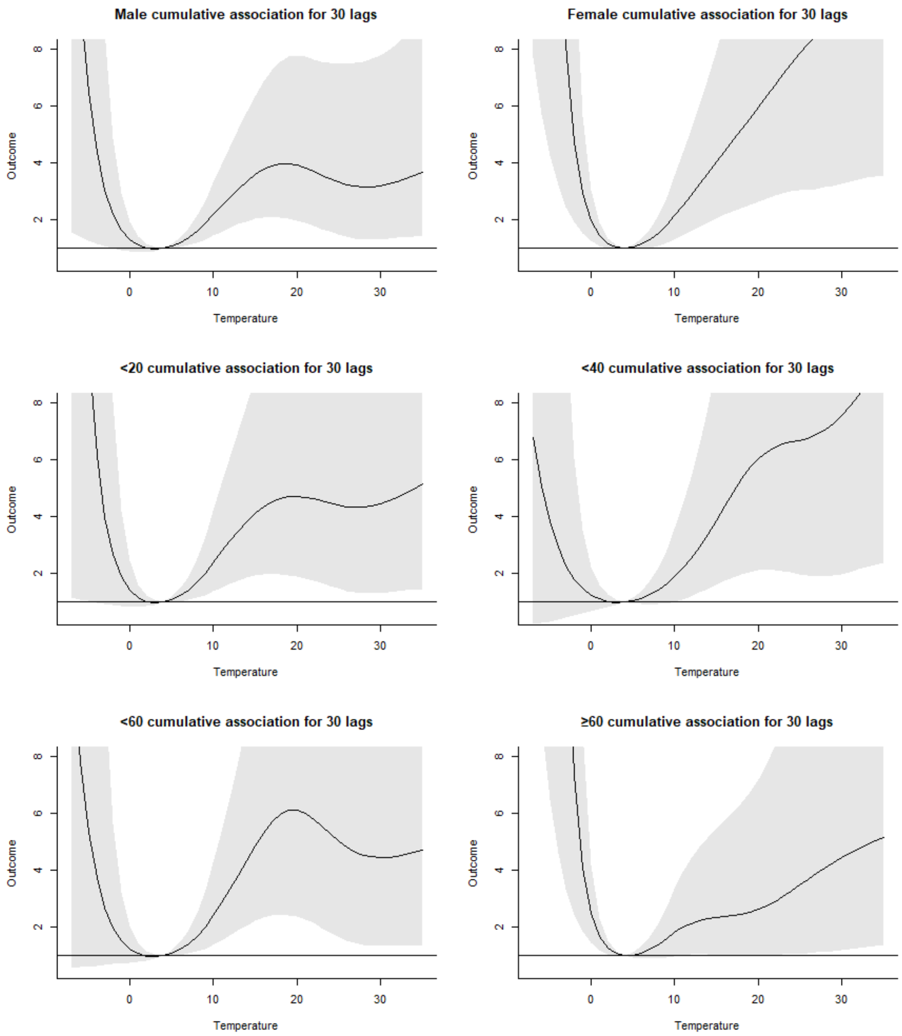

Figure 4

The cumulative effects of ambient temperature on FRIs in different gender and age groups

Supplementary Files

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- TableA1andA2.docx
- responsetoeditorcomments.docx