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Association between ambient temperature and economic burden of unintentional injury

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Title page

Title: Association between ambient temperature and economic burden of unintentional injury

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Abstract

Objective Unintentional injuries constitute an important global public health issue with significant social and economic costs. Previous evidence suggests ambient temperatures are associated with unintentional injury occurrences. However, the impacts of ambient temperature on the economic burden of unintentional injury have received little research attention. The objective of the study was to assess the temperature-attributable economic burden of unintentional injury.

Design Time-stratified case-crossover study.

Setting This study was performed at Tianjin Hospital, the largest trauma center in Tianjin, by applying a hospital-based time-stratified case-crossover study.

Participants The 12 241 patient data who were admitted with unintentional injuries and meteorological data were collected in Tianjin, China in 2021.

Primary and secondary outcome The association between ambient temperature and unintentional injury hospitalization was evaluated with a distributed lag nonlinear model, further temperature-attributable economic burden of unintentional injuries was quantified, and adjusted for demographic characteristics, injury mechanism and injury location of injury.

Results Low temperatures (below 11.5 °C) were significantly associated with the increased risk of unintentional injury hospitalization in Tianjin, 2021. The effect was maximized on the current day. The low temperature was responsible for 25.441% (95% CI: 13.74, 33.092) of unintentional injury patients, and was associated with the number of unintentional injury patients (3114, 95%CI: 1608, 4036). The low temperature was associated with the excess economic burden for unintentional injury (197.521 million RMB, 95%CI: 101.995, 256.003; about 27.095 million dollars), accounting for 26.493% total economic burden. The cold temperatures generally had greater impacts on males (136.455 million RMB, 95%CI: 83.277, 172.415; about 18.667 million dollars) and the elderly (74.347 million RMB, 95%CI: 14.869, 102.137; about 10.244 million dollars).

Conclusion The low temperature was associated with approximately 3000 unintentional injury patients and 200 million RMB (27 million dollars), accounting for 26% total economic burden in Tianjin, 2021.

Keywords Ambient temperature, Unintentional injury, Economic burden, Health effect

Strengths and limitations of this study

- This article confirms the relationship between low temperature and the economic burden of unintentional injury.
- This is a single-city study with one year, which limits the generalizability of the findings to other regions and times.
- Some factors, such as cold waves, occupation status, public accident, and loss of productivity after discharge and intangible costs, etc., that might confound the associations between ambient temperature and unintentional injury were not controlled.

INTRODUCTION

Unintentional injuries as a major public health issue increase disability and death, and also represent great economic costs[1, 2]. As defined by the WHO, unintentional injuries occur in the absence of predetermined intent. It has been estimated that more than 5 million people die each year due to injuries, and nearly 80% of injury deaths are due to unintentional injuries[3]. Most of the unintentional injury cost estimates have been conducted in high-income countries. A study from the United States estimated unintentional injuries in the home to cost USD 217 billion annually[4]. Cost estimates for fall-related hospitalizations varied across regions of the world and within countries[4], including Sartini et al. in Italy ($7,945)[5], Roudsari et al. in the United States ($17,483)[6], and Stevens et al. in the United States ($7,355)[7].

It is widely recognized that increasing episodes of extreme weather are the phenomena associated with climate change and are currently accelerating[8]. Ambient temperature is of great interest as a major environmental health risk factor[9, 10]. Previous studies determined the association between temperature and injuries associated with traffic accidents[11], and the number of total injury admissions[12]. Liying Luo found that hot extremes were associated with increased unintentional injury mortality risk in China[13]. Hyewon Lee found that unintentional injury morbidity was significantly associated with ambient temperature in Seoul, Korea[2]. There have been separate efforts to determine the association between ambient temperature and injury incidence. Nevertheless, relationships between ambient temperature and economic burden of unintentional injury have not been comprehensively investigated.

The current study used data of patient admitted with unintentional injury and meteorological data to evaluate the association between ambient temperature and unintentional injury hospitalization, applying a case-crossover design with a distributed lag nonlinear model (DLNM), and further quantify temperature-attributable economic burden of unintentional injuries. The findings will draw a comprehensive picture of the health impacts of temperature on unintentional injury hospitalization in Tianjin, China.

MATERIALS AND METHODS

Study area and data collection

Tianjin was a megacity located in northern China with a population of approximately 13.8 million inhabitants and covered 11946.88 km^2, which was administratively equivalent to a province. Tianjin (117.2°E, 39.1°N) experienced a warm temperate monsoon continental climate with four distinct seasons, including a hot and wet summer (due to monsoons), and a cold and relatively dry winter (due to vast Siberian anticyclones)[14]. Given that Tianjin had a large population and undergoes a relatively wide range of ambient temperatures, it was an appropriate location for evaluating the association between ambient temperature and unintentional injury hospitalization with adequate statistical power.

This study was performed at Tianjin Hospital, the largest trauma center in Tianjin. It was a level 2 trauma center, and its emergency department (ED) provided 124,009 consultations per year. A retrospective study of all patients admitted with unintentional injuries (International Classification of Diseases, 10th Revision [ICD-10] codes: V00-X59) to Tianjin trauma center from ED was conducted based on the electronic medical record system from January 1 through

December 31, 2021. Information on patients included the date of onset, age, gender, injury mechanism, injury location, hospital length of stay and hospitalization cost. Furthermore, daily meteorological data for Tianjin in 2021 were obtained from the China Meteorological Data Sharing Service System (http://data.cma.cn/) issued by the National Meteorological Information Center of China Meteorological Administration.

Outcome of interest

In the present study, the outcome of interest was the daily number of patients admitted with unintentional injuries. Data were collapsed by date to create time series of the daily number of patients admitted with unintentional injuries, and were stratified by gender, age, injury mechanism and injury location. Three age groups were considered (i.e., < 18 years, 18-64 years, and ≥ 65 years). The injury mechanism and injury location were coded based on ICD-10. Unintentional injury was divided into road traffic injury (V00-V99), falls (W00-W19), mechanical injury exposure to mechanical forces (W20-W64) and other injury (W65-W99, X00-X59). Injury locations were divided into head and neck (S00-S19), thorax (S20-S29), abdomen (S30-39), upper extremity (S40-S69), hip and thigh (S70-79), lower extremity (S80-S99), multiple locations in the body (T00-T14) and unspecified (T08-T14, T20-T35, T66-T88, T90-98). The diagnosis was verified by the emergency department physician.

Exposure assessment

Daily meteorological data included daily mean temperature, max temperature, min temperature, barometric pressure, relative humidity, precipitation, average wind velocity, rain day and snow day in climate stations across Tianjin in 2021. We averaged the daily available weather conditions measurements of climate stations to represent the exposure in the target populations in Tianjin area. To control for the effect of potential confounding factors, The data for other meteorological variables were also obtained.

The holidays, day of the week, calendar time and the number of confirmed cases of Coronavirus disease 2019 (COVID-19) as the epidemic indicator were considered as short-term covariates. Weekends were defined as Saturday and Sunday, and weekdays were from Monday to Friday. Holidays were defined as weekends and the Chinese statutory holidays (29 days per year), including New Year, Spring Festival, Qing Ming Festival, Labor Day, Dragon Boat Festival, Mid-Autumn Festival and Chinese National Day, and non-holiday as the other days.

Assessing the association between ambient temperature and unintentional injury admission

A time-stratified, case-crossover design was applied to investigate the association between ambient temperature and unintentional injury. This case-crossover design is useful for controlling for time-invariant characteristics and for slowly varying factors, as each patient serves as his/her own control. In the present study, each ED visit day of patients admitted with unintentional injuries was matched to all control days within a stratum, defined as a three-way interaction term (Year × Month × Day of the week). For instance, if a patient visited an ED with unintentional injuries on Thursday, July 1, 2021, all other Thursdays in July 2021 were

138 selected as control days.

139 Daily mean temperature and the number of patients admitted with unintentional injuries were linked by date. A quasi-Poisson distributed lag nonlinear model (DLNM) was employed to investigate their associations. Because the daily number of patients admitted with unintentional injuries typically followed an over-dispersed Poisson distribution, a model of quasi-Poisson was applied. In order to flexibly account for the potential lagged and nonlinear effect of mean temperature on the number of patients admitted with unintentional injuries, mean temperature was incorporated as a "cross-basis" function using DLNM. We empirically decided on a maximum lag of up to 21 days according to previous large studies[15, 16]. A number of covariates were also incorporated as follows:

$$Log[E(Y_t)] = \alpha + cb(T_t) + \beta\, CW_t + \gamma\, DOW_t + s(DOY_t, 7/year) + \sum_{i=1}^{i} ns(W_{i,t}, df = 3)$$

149 Where t was the day of the observation; Y_t was the count of patients admitted with unintentional injuries on day t; α represents the intercept of the model; $cb\ (T_t)$ was a cross-basis of mean temperature; CW_t was a binary variable for holidays (1 if day t was classified as part of a holiday, 0 otherwise); DOW_t represented the day of the week which was modeled with six indicator variables through a dummy parameterization; β and γ were the vectors of regression coefficients; $s\ ()$ was a smooth function; DOY_t represented the day of the year specified through a natural cubic spline with 7 df per year to account for seasonality and long-term trends. $W_{(i,t)}$ meant covariates in meteorological variables without co-linear relationship on day t, including relative humidity, precipitation, average wind velocity, the number of COVID-19 confirmed cases, rain

day and snow day, which was controlled by using natural cubic spline (*ns*) with 3 degrees of freedom (*df*) determined by the Akaike Information Criterion (quasi-likelihood for Akaike's information criterion, Q-AIC).

The relative risks (RRs) of extreme temperature (eg., 10th temperature percentile and 25th temperature percentile) were calculated compared with the referent temperature, i.e., the temperature with the minimum counts of patients admitted with unintentional injuries. The lag structures in the effects of extreme temperature over lags of 0-21 days were also explored. Subgroup analyses were conducted to assess whether the associations between low temperature and unintentional injuries differed by demographic characteristics (age and gender), mechanism of injury and location of injury.

Calculating economic burden of unintentional injuries due to ambient temperature

The attributable fraction (AF) and attribute numbers (AN), and their 95 % confidence intervals (CIs) were calculated using the following formulas[17, 18]:

$$AF_t = 1 - \exp\left(-\sum_{l=l_0}^{L} \delta_{t-l}, l\right)$$

$$AN_t = n_t * AF_t$$

where AF_t referred to the attributable fraction of unintentional injury hospitalization due to ambient temperature on *t* day; we considered that the risk at day *t* was the cumulative effect of the previous period (t-l_0, ..., t-L) of exposure; L was the maximum lag time for the exposure factor; $\delta_{(t-l)}$ referred to the effect parameters of *Beta* at day *t*-*l*; AN_t referred to the count of patients admitted with unintentional injuries attributable to ambient temperature on *t* day; n_t

was the total number of patients with unintentional injuries in the population at day *t*.

The economic burden of the unintentional injury admissions associated with ambient temperature was further assessed by the Cost of Illness (COI) method. Economic burden was defined by the direct cost and indirect cost due to unintentional injury during hospital length of stay[19]. The direct cost relates to hospitalization costs, and indirect cost was estimated by lost productivity during hospital length of stay in this study[20]. Economic burden was shown as below[21]:

$$C_i = H_i * AN_i + (GDP' * T_i) * AN_i$$

Where C_i denoted the economic burden of subgroup *i*; H_i was the average hospital cost of subgroup *i*; AN_i referred to the count of patients admitted with unintentional injuries attributable to the ambient temperature of subgroup *i*; H_i referred to the hospitalization cost; $H_i * AN_i$ referred to the direct cost; *GDP'* referred to the daily GDP per capita per day; T_i was the average length of stay in hospital (days) of subgroup *i*; $(GDP' * T_i) * AN_i$ referred to the indirect cost. According to the *Tianjin Statistical Yearbook*, the GDP per capita per day was RMB 101614 in 2020[22].

Sensitivity analysis

In addition, we conducted sensitivity analyses to confirm whether main findings were robust to different model specifications by changing the lag period of 21 days for the lag-response association to 14 or 28 days.

Statistical analysis

Statistical analysis was performed using R software (version 4.2.1). Spearman's correlation coefficients were used to summarize the similarities in daily meteorological variables. When the correlation coefficient between two variables was greater than 0.8, it indicated that there was a co-linear relationship between the two variables. R packages of "dlnm" were used for the DLNM model to explore the relationship between ambient temperature and unintentional injury hospitalization, and "spline" was used for the natural spline function to investigate the non-linear relationship between them. All statistical tests were two-sided, and values of $P < 0.05$ were considered statistically significant.

RESULTS

Descriptive analysis for meteorological variables and unintentional injury admission

Descriptive statistics for daily meteorological variables in Tianjin (2021) were summarized in Table S1. The median daily mean temperature was 14.200 °C, with temperatures ranging from -14.200 °C to 30.300 °C. The median daily maximum and minimum temperatures were 20.500 °C and 9.200 °C, respectively. There were 114 (31.233%) rainy days and 8 (2.192%) snowy days. There were high correlations among these three temperature measurements (Spearman r = 0.920 to 0.978). These temperature measurements were strongly correlated with barometric pressure (Spearman r = 0.796 to 0.850) (Table S2). Since the mean temperature was a better predictor of population health than barometric pressure, maximum or minimum temperatures, we selected the daily mean temperature as the exposure indicator of ambient temperature[23]. The epidemiology of patients admitted with unintentional injuries by gender, age, injury mechanism and injury location were summarized in Table S3. A total of 12 241 patients with unintentional injuries were admitted to Tianjin Hospital from ED in 2021. Among these, 7 360 (60.126%) were males, and 4 881 (39.874%) were females. For each age group (< 18, 18-64, and ≥ 65 years old), the numbers of patients with unintentional injuries by age were 1 118 (9.133%), 7 827 (63.941%) and 3 296 (26.926%), respectively. Injury mechanisms were road traffic injury (1 571, 12.834%), falls (7 521, 61.441%), mechanical injury (2 830, 23.119%), and others (319, 2.606%). The most common injury locations were upper extremity (4 375, 35.741%) lower extremity (3 373, 27.555%), and, hip and thigh (2 828, 23.103%). The leading diagnosis was fracture (9 969, 81.439%). The hospitalization cost was 60 907.117 RMB per capita for unintentional injury patients. The daily counts of patients admitted with unintentional injuries during the study period were presented in Figure S1.

Association between ambient temperature and unintentional injury admission on the current day

The impact of ambient temperature on the risk of hospital admission for unintentional injury was maximized on the current day (lag0). The relationship between ambient temperature and hospitalization for all unintentional injury followed a L-shaped curve on the current day (Figure 1A). Increased risks were found during cold days, with higher risks during more cold extreme temperatures. Significant effects of cold were observed among all unintentional injury patients, with an estimated *RR* at the 25th percentile (5 °C) of 1.175 (95% CI: 1.076-1.282) and the 10th percentile (-1 °C) of 1.337 (95% CI: 1.178-1.518) (Figure S2A and Figure 3A). The risk of hospital admission for all unintentional injury was statistically significant when the temperature was below 11.5 °C.

Results revealed that the risk was present for both males and females, with similar temperature-admission curves (Figure 1B). Females tend to be more sensitive to cold weather than males. The *RR* at the 25th percentile on the current day (lag0) was 1.171 (95% CI: 1.044-1.314) for males and 1.180 (95% CI: 1.060-1.312) for females (Figure S2B), and the RR at the 10th percentile was 1.310 (95% CI: 1.122-1.529) for males, compared with 1.376 (95% CI: 1.157-1.637) for females (Figure 3B).

For age groups, the highest risks were found among people aged ≥ 65 years old at 1.915 (95% CI: 1.219-3.009), followed by people aged 18-64 years old at 1.869 (95% CI: 1.414-2.471) on the current day (lag0) at the lowest temperature (Figure 1C). RRs for the ＜ 18 years old group were not statistically significant. The *RR* at the 25th percentile on the current day (lag0) was 1.153 (95% CI: 1.059-1.255) for people aged 18-64 years old and 1.205 (95% CI: 0.985-1.474) for people aged ≥ 65 years old (Figure S2C). And the RR at the 10th percentile was 1.313 (95% CI: 1.148-1.501) for people aged 18-64 years old, compared with 1.371 (95% CI: 1.062-1.771) for people aged ≥ 65 years old (Figure 3C). The risk of hospital admission for unintentional injury for people aged ≥ 65 and 18-64 years old was statistically significant when the temperature was below 3.5 °C and 11°C, respectively.

For injury mechanisms, only the risk of falls increased at low temperatures (Figure 2A). RR at the 25th percentile (5 °C) was 1.282 (95% CI: 1.141-1.439) and the 10th percentile (-1 °C) was 1.548 (95% CI: 1.308-1.833). For injury locations, the risks of thorax, upper extremity, hip and thigh, and lower extremity injuries increased at low temperatures (Figure 2B). Significant effects of cold were observed in fracture patients, with an estimated RR at the 25th percentile (5 °C) of 1.229 (95% CI: 1.109-1.361) and the 10th percentile (-1 °C) of 1.441 (95% CI: 1.248-1.663). When the temperature was below 12°C, the risk of hospitalization for fracture was statistically significant.

Cumulative associations between ambient temperature and unintentional injury admission over lag days

Figure 3 depicted the cumulative associations between 10th temperature and unintentional injury over 0-21 lag days. The effects of low temperatures on the risk of hospital admission for unintentional injury were presented to be acute (lasting for approximately 5 days), maximized on the lag0 day (Figure 3A). As the lag increased, the RR of unintentional injury moved close to 1. When stratified by gender and age, the results revealed significant risks lasting for less than 9 days in males, 3 days in females, 4 days in people aged 18-64 years old and 6 days in people aged ≥ 65 years old (Figure 3B and 3C). For injury mechanisms, significant risks lasted for 7 days for falls (Figure 4A). For injury locations, significant risks of thorax, upper extremity, hip and thigh, and lower extremity injury lasted for less than 4, 0, 7 and 3 days. The risk of fracture lasted for less than 6 days. Figure S2 and Figure S3 show the overall cumulative 25th temperature-injury associations over 0-21 lag days. The sensitivity analysis is conducted by changing the lag period of 21 days for lag-response association to 14 or 28 days. It did not alter the main results (Table S4-S7).

Economic burden of unintentional injuries attributed to low temperature

Low temperature was responsible for 25.441% (95% CI: 13.74, 33.092) of all unintentional injury patients during the study period, with higher AF for males (30.366%, 95%CI: 18.274, 37.767) than that for females (15.537%, 95%CI: -13.685, 29.406) (Table 1). For age groups, the highest AF was found among people aged ≥ 65 years old (31.261%, 95%CI: 6.783, 42.478), followed by people aged 18-64 years old (21.184%, 95%CI: 4.146, 30.871). For injury mechanisms, the highest AF was observed for falls (31.653%, 95%CI: 14.765, 40.615. For injury locations, the AF of the hip and thigh (39.915%, 95%CI: 19.789, 49.704) was higher than others. The AF of the fracture was 27.614% (95%CI: 15.843, 35.634).

Short-term cold exposures were associated with the number of unintentional injury patients (3114, 95%CI: 1608, 4036) for several specific subgroups, accounting for 2235 (95%CI: 1364, 2824) for males, 1658 (95%CI: 443, 2445) for people aged 18-64 years old, 1030 (95%CI: 206, 1415) for people aged ≥ 65 years old, 2381 (95%CI: 1143, 3135) for falls, 1129 (95%CI: 527, 1411) for the hip and thigh injuries, 2753 (95%CI: 1449, 3626) for fractures attributable to cold (Table 1).

Short-term cold exposures were responsible for 197.521 million RMB (95%CI: 101.995, 256.003; about 27.095 million dollars) of all unintentional injury patients during the study period, accounting for 26.493% total economic burden, and were associated with the excess economic burden of unintentional injury for several specific subgroups, accounting for 136.455 (95%CI: 83.277, 172.415; about 18.667 million dollars) million RMB for males, 104.616 (95%CI: 27.952, 154.274; about 14.337 million dollars) million RMB for people aged 18-64 years old, 74.347 (95%CI: 14.869, 102.137; about 10.244 million dollars) million RMB for people aged ≥ 65 years old, 155.001 (95%CI: 74.408, 204.086; about 21.374 million dollars) million RMB for the falls, 93.239 (95%CI: 43.522, 116.528; about 12.880 million dollars) million RMB for hip and thigh injury, 185.386 (95%CI: 97.575, 244.174; about 25.503 million dollars) million RMB for fracture attributable to cold (Table 1 and Table S7).

DISCUSSION

In the current study, 12 241 patients admitted with unintentional injuries were analyzed using a time-stratified case-crossover design with a DLNM. One interesting finding is that the risk of unintentional injury significantly increased at low temperatures. Females were more vulnerable to cold weather than males, but the effect on males persisted longer. Low temperatures were linked to an increased risk of unintentional injury in adults, more sensitive in the elderly. The mechanism-specific analyses showed that the risk of falls was significantly associated with low temperatures. The location-specific analyses showed that the risks of thorax, upper extremity, hip and thigh, and lower extremity injuries were significantly associated with low temperatures. The excess economic burden of unintentional injury associated with low temperature was approximately 200 million RMB, and fracture accounting for 185 million RMB. The findings have provided a deeper insight into evidence that ambient temperature was associated with risks of unintentional injury admission. The findings have important implications for unintentional injury prevention and control in northern China.

Unintentional injuries increased at low temperatures

According to this research, unintentional injury risk was significantly associated with low temperatures, which were consistent with several studies. For example, a study conducted in Seoul, South Korea from 2008 to 2016 reported that patients with unintentional injuries who had visited emergency departments increased significantly at low temperatures[2]. Another study conducted between 2015 and 2016 in Shenzhen of China found that high RR was for traffic accident injuries during cold exposure. However, other studies found that an increase in temperature was only associated with a relatively high risk of injury[12]. Therefore, the effect of low temperatures has been inconsistent and has not been observed as extensively. This discrepancy could be attributed to differences according to various geographical locations, temperature distribution, social factors and patients' characteristics[2]. For example, Tianjin has four distinct seasons with a freezing winter, and the minimum temperature during winter is below 0 ℃, which increases the risk of unintentional injury. Besides, the effect of high temperatures on the unintentional injuries was not significant, likely owing to the small sample size.

Differences in relationship between unintentional injury risk and low temperatures in subgroups

The findings showed that cold temperatures generally had greater impacts on the elderly, which is in line with those of previous studies[13, 24-26]. The reason for the results may be that the elderly are more susceptible to injury, associated with their osteoporosis due to calcium loss, and their gradually weakening ability of balance[2, 27, 28], although older groups were positive associated factors of personal cold protection behaviors[29]. The study also observed people aged 18-64 years old were also more likely to suffer from unintentional injury. In addition, the increased risk of hospital admission for unintentional injury for people aged ≥ 65 and 18-64 years old is statistically significant when the temperature is below 3.5 °C and 11°C, respectively. Young and middle-aged people are more likely and more frequently exposed to outdoor working conditions in around 10 °C of spring and autumn [30, 31]. While older people are more likely to fall in winter when the temperature is below 0 °C. Therefore, in order to alleviate the injury burden of low temperatures, policymakers need to account for the specific susceptible populations to unintentional injury when formulating targeted adaptation plans and priority protection.

As determined in this study, the increased risk of unintentional injury at low temperatures seems related to falls injuries. This finding supports evidence from previous observations. [32]. Hassi et al. and Bell et al. both found an increase in slipping and falling injuries at low-temperature conditions[33]. Therefore, it is likely that the increase in injuries observed, which are associated with low temperatures, is caused by one's physical environment, such as snow or ice on the ground, freezing rain, and freezing temperatures, during the winter[34].

Moreover, in the present study, the risk of fracture increased at low temperatures. A study conducted in Tokyo, Japan over a 3-year period also found that fractures risk was the highest in the winter for some individuals[35]. José María Tenías found that the weather series showed a positive tendency, with a greater occurrence of fracture cases in the autumn and winter months[36]. Aviram M. Giladi, in their study of the population of the US, observed that the risk of distal radius fractures was higher in winter months[37]. In particular, the risks of thorax, extremity, hip and thigh injury increase at low temperatures in this study. Hip fractures among the elderly represent an important public health problem[38], both because of their high incidence and the serious consequences that derive from them: increased mortality, morbidity, and high consumption of medical resources, especially considering the aging trend of the population in China.

As determined in the study, the effects of low temperatures on the risk of hospital admission for unintentional injury present lasted for approximately 5 days, and the risk decreased as the lag days decreased, which is consistent with other evidence that has consistently noted that the effects of low temperatures on the injury risk present are acute[39]. The lag days could be attributed to the following: (i) Patient factors (e.g., the time from onset to diagnosis); (ii) Meteorological factors (e.g., icy ground). These findings suggest that low-temperature warnings for trauma centers may need to last for approximately 5 days to prepare for additional service demand pressures.

Economic burden of unintentional injuries increased at low temperatures

Previous studies have mainly focused on the economic burden of air pollution[40]. To the best of our knowledge, little is known about the economic burden of low temperatures on intentional injury. The findings highlight that, short-term cold exposures were associated with the hospital admission (more than 3000 patients admitted with unintentional injuries) and economic burden (approximately 200 million RMB; 27 million dollars) for unintentional injury, especially susceptible groups in males, aged ≥ 18 years old, the falls, the hip and thigh injury and fractures. The economic impacts of cold weather on males tend to be greater than on females. The reason for the results is the influence of cold weather on males for a longer period than on females, because they are more likely and more frequently exposed to outdoor working conditions[31]. Though 83% of houses had central heating in winter in Tianjin, and the majority of the population was potentially protected from the outdoor weather. Extremely cold days still posed some increased risks[23]. The following prevention measures may be necessary to decrease substantial economic burden: (i) Stratified analyses by gender and age identify vulnerable subgroups and warning temperatures. Public health agencies should consider using these warnings to trigger initiation of injury prevention strategies. (ii) Public health initiatives focused on injury prevention through fall prevention, bike helmets, sport impact policy changes and other public safety measures. (iii) In addition to standard calendar-related factors, incorporating weather into resource planning models can improve the daily allocation of resources and staff of hospital. (iv) The personalized health education is needed in order to inform better prevention practices among vulnerable population and sensitive diseases group[3].

Limitations

The major limitations of this study need to be acknowledged. First, temperature effects could be modified by many factors, and this is a single-city study with one year, which limits the generalizability of the findings to other regions and times. Second, temperature data from fixed sites were used rather than individual exposures. Third, the effects of immediate cold waves and possible interventions by a cold warning system were not considered in this study. Fourth, some factors, such as occupation status and public accident, etc., that might confound the associations between ambient temperature and unintentional injury were not controlled. Fifth, COVID-19 pandemic may have had some impact on the results in 2021. Finally, considering the loss of productivity after discharge and intangible costs, the costs of unintentional injury admission attributed to low temperatures were underestimated in this research.

CONCLUSIONS

This study assessed the association between ambient temperature and economic burden of unintentional injury, and identified characteristics of population and diseases with high risks. Research results suggest that the risk of hospitalization for unintentional injury increased when it was below 11.5 °C in Tianjin, China. The low temperatures risk to unintentional injury were presented to be acute and the highest in the absence of the delay effect. Low temperature was responsible for approximately 3000 unintentional injury patients, and the economic burden attributable to cold exposures was up to approximately 200 million RMB (about 27 million dollars), approximately accounting for 26% total economic burden in Tianjin, 2021. People with male, aged above 18 years old, falls, hip and thigh injuries, and fractures were identified as particularly susceptible groups and sensitive diseases to low temperature. The findings may clarify the health impacts of temperature on unintentional injury economic burden. It is helpful for informing effective targeted public health interventions to prevent and control unintentional injury, and to increase resilience in response to climate change.

Declarations

Acknowledgments

Not applicable.

Author contributions

Yue Li: Conceptualization, Methodology, Writing-Original draft preparation. **Chao Yuan:** Resources, Data Curation, Writing-Original draft preparation. **Tao Liu:** Methodology, Software. **Zhao Yang:** Resources, Data Curation. **Fangguo Li:** Resources, Data Curation. **Ji Li:** Software, Validation. **Haojun Fan:** Funding acquisition, Supervision, Writing-Original draft preparation. **Chunxia Cao:** Funding acquisition, Writing- Reviewing and Editing.

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Conflict of interest

None.

Ethical Aspects

The study protocol was approved by the ethics committee of Tianjin Hospital (2021-175). Data were analyzed at the aggregate level, as agreed by the Ethical Committee, and no participants were contacted.

Informed consent statement

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available

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Figure Legends

Figure 1 Association between daily mean temperature and admission for unintentional injury according to age or gender on the current day

Figure 2 Association between daily mean temperature and unintentional injury among subgroups according to injury mechanism and injury location on the current day

Figure 3 Cumulative associations between 10th temperature and unintentional injury over 0-21 lag days according to age or gender

Figure 4 Cumulative associations between 10th temperature and unintentional injury over 0-21 lag days according to injury mechanism or injury location

Table Legends

Table 1 Attributable fractions (AF%), attribute numbers (AN) and hospitalization cost of unintentional injuries attributed to low temperature across lag0 21 day by age, gender, mechanism, location and diagnosis

TABLE 1 Attributable fractions (AF%), attribute numbers (AN) and economic burden of unintentional injuries attributed to low temperature across lag 21 day

	AF（%）	AN	Direct cost (million RMB)	Indirect cost (million RMB)	Economic burden (million RMB)
Total	25.441 (13.74, 33.092)	3114 (1608, 4036)	189.665 (97.939, 245.821)	7.856 (4.057, 10.182)	197.521 (101.995, 256.003)
Gender					
Male	30.366 (18.274, 37.767)	2235 (1364, 2824)	130.668 (79.745, 165.103)	5.787 (3.532, 7.312)	136.455 (83.277, 172.415)
Female	15.537 (-13.685, 29.406)	758 (-698, 1430)	48.96 (-45.084, 92.364)	1.836 (-1.691, 3.464)	50.796 (-46.775, 95.829)
Age					
＜18 years	30.485 (-23.66, 45.62)	341 (-308, 501)	12.914 (-11.665, 18.974)	0.71 (-0.641, 1.042)	13.624 (-12.305, 20.016)
18-64 years	21.184 (4.146, 30.871)	1658 (443, 2445)	100.358 (26.815, 147.995)	4.258 (1.138, 6.279)	104.616 (27.952, 154.274)
≥65 years	31.261 (6.783, 42.478)	1030 (206, 1415)	71.705 (14.341, 98.508)	2.642 (0.528, 3.63)	74.347 (14.869, 102.137)
Mechanism					

Road traffic injury	31.378 (-2.019, 43.815)	493 (-62, 668)	42.109 (-5.296, 57.056)	1.765 (-0.222, 2.392)	43.874 (-5.518, 59.448)
Falls	31.653 (14.765, 40.615)	2381 (1143, 3135)	149.618 (71.824, 196.998)	5.384 (2.584, 7.089)	155.001 (74.408, 204.086)
Mechanical injury	-43.07 (-181.517, -1.548)	-1219 (-5001, -22)	-53.731 (-220.434, -0.97)	-3.216 (-13.195, -0.058)	-56.947 (-233.629, -1.028)
Other injury	-71.627 (-3430.241, 37.307)	-228 (-13123, 116)	-9.984 (-574.65, 5.08)	-0.555 (-31.95, 0.282)	-10.539 (-606.599, 5.362)
Location					
Head and neck	-571.079 (-287618.517, 35.592)	-697 (-270310, 39)	-50.8 (-19701.353, 2.842)	-3.305 (-1281.765, 0.185)	-54.105 (-20983.118, 3.027)
Thorax	28.565 (-73.59, 48.994)	171 (-459, 293)	8.49 (-22.789, 14.547)	0.454 (-1.218, 0.777)	8.944 (-24.007, 15.325)
Abdomen	1.364 (-138.84, 38.07)	8 (-959, 209)	0.715 (-85.716, 18.68)	0.029 (-3.477, 0.758)	0.744 (-89.192, 19.438)
Upper extremity	11.473 (-20.906, 26.243)	502 (-910, 1140)	22.546 (-40.869, 51.199)	1.135 (-2.057, 2.577)	23.68 (-42.926, 53.776)
Hip and thigh	39.915 (19.789, 49.704)	1129 (527, 1411)	90.158 (42.084, 112.678)	3.08 (1.438, 3.85)	93.239 (43.522, 116.528)
Lower extremity	23.516 (-6.447, 38.715)	793 (-191, 1290)	48.746 (-11.741, 79.297)	1.824 (-0.439, 2.967)	50.57 (-12.18, 82.264)
Multiple regions	-189.116 (-9038.169, 38.7)	-333 (-18675, 68)	-29.701 (-1665.673, 6.065)	-1.448 (-81.205, 0.296)	-31.149 (-1746.878, 6.361)

Unspecified	-1049.437 (-1113200, 23.565)	-2330 (-3081363, 50)	-133.947 (-177141.298, 2.874)	-6.32 (-8358.091, 0.136)	-140.267 (-185499.389, 3.01)
Diagnosis					
Fracture	27.614 (15.843, 35.634)	2753 (1449, 3626)	178.518 (93.96, 235.128)	6.868 (3.615, 9.046)	185.386 (97.575, 244.174)
Non-fracture	-10.753 (-111.710, 21.512)	-1072 (-9798, 2146)	-46.780 (-427.568, 93.648)	-2.835 (-25.916, 5.676)	-49.616 (-453.484, 99.324)

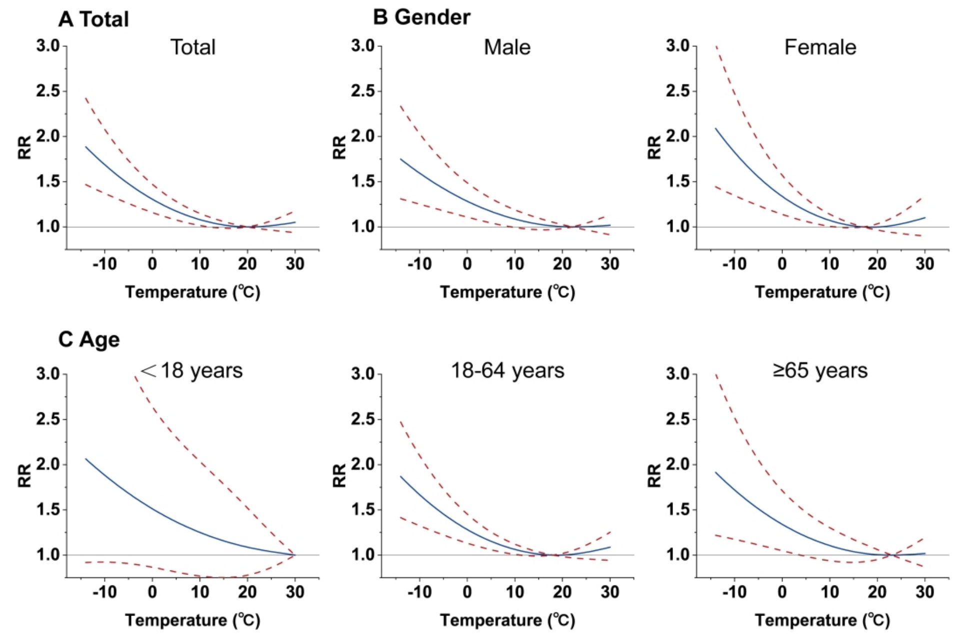

Figure 1 Association between daily mean temperature and admission for unintentional injury according to age or gender on the current day

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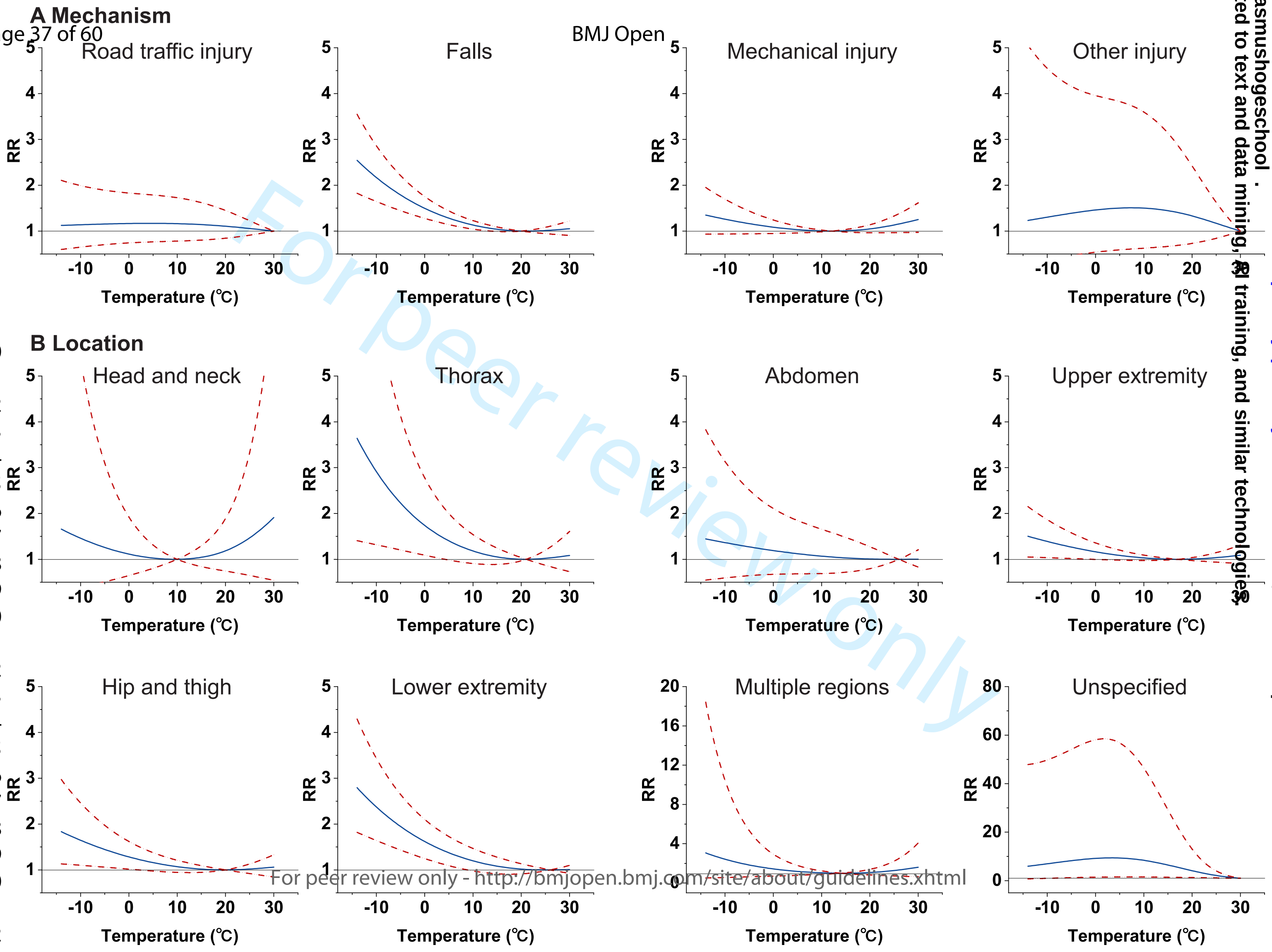

A Mechanism
Road traffic injury
Falls
Mechanical injury
Other injury
B Location
Head and neck
Thorax
Abdomen
Upper extremity
Hip and thigh
Lower extremity
Multiple regions
Unspecified
RR
Temperature (℃)

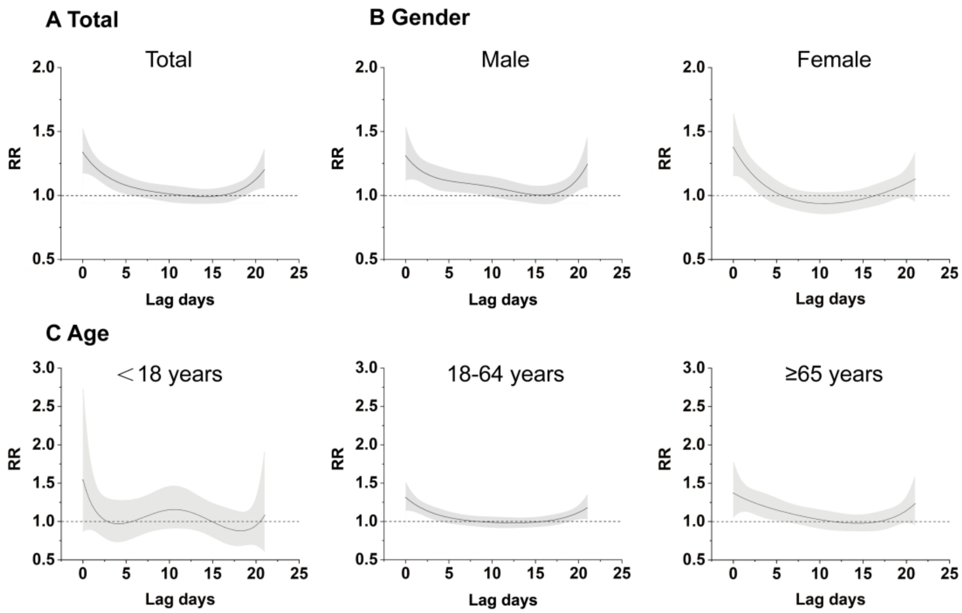
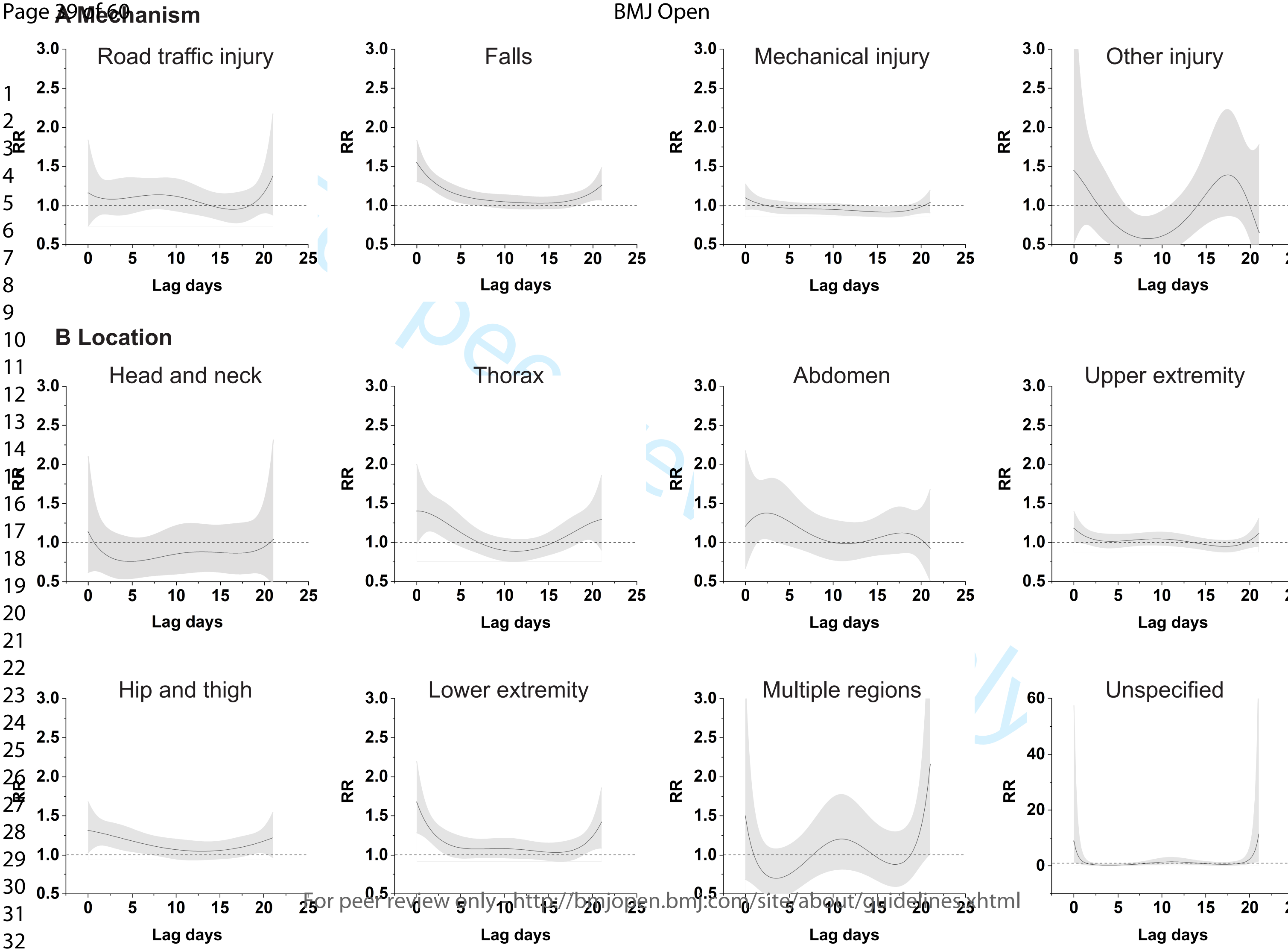


Figure 3 Cumulative associations between 10th temperature and unintentional injury over 0-21 lag days according to age or gender

157x96mm (600 x 600 DPI)


A Mechanism
Road traffic injury
Falls
Mechanical injury
Other injury
RR
Lag days
B Location
Head and neck
Thorax
Abdomen
Upper extremity
Hip and thigh
Lower extremity
Multiple regions
Unspecified
RR
Lag days

Supplemental Figure Legends

Supplemental figure 1 Time series of daily counts of patients admitted with unintentional injuries

Supplemental figure 2 Cumulative associations between 25th temperature and unintentional injury over 0-21 lag days according to age or gender

Supplemental figure 3 Cumulative associations between 25th temperature and unintentional injury over 0-21 lag days according to injury mechanism or injury location

Supplemental Table Legends

Supplemental table 1 Descriptive statistics for daily meteorological variables

Supplemental table 2 Correlations between the meteorological variables

Supplemental table 3 Epidemiology of patients admitted with unintentional injuries

Supplemental table 4 Cumulative associations between 10th temperature and unintentional injury over 0-14 lag days

Supplemental table 5 Cumulative associations between 25th temperature and unintentional injury over 0-14 lag days

Supplemental table 6 Cumulative associations between 10th temperature and unintentional injury over 0-28 lag days

Supplemental table 7 Cumulative associations between 25th temperature and unintentional injury over 0-28 lag days

Supplemental table 1 Descriptive statistics for daily meteorological variables

Meteorological variables	***Min***	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	***Max***
Mean temperature (℃)	-14.200	-1.080	4.900	14.200	23.550	27.000	30.300
Max temperature (℃)	-7.900	4.600	10.950	20.500	28.600	31.640	36.900
Min temperature (℃)	-19.900	-5.820	-0.500	9.200	19.100	22.800	26.500
Barometric pressure (hPa)	994.400	1002.900	1007.600	1016.400	1024.300	1028.700	1044.500
Relative humidity (%)	18.300	30.180	45.400	65.000	75.800	85.200	98.800
Precipitation (mm)	0.000	0.000	0.000	0.000	0.000	3.470	136.600
Average wind velocity (m/s)	0.700	1.400	1.750	2.400	3.100	4.100	8.000

Supplemental table 2 Correlations between the meteorological variables

Weather variables	Barometric pressure	Mean temperature	Max temperature	Min temperature	Relative humidity	Precipitation	Average wind velocity
Barometric pressure	1.000	-	-	-	-	-	-
Mean temperature	**-0.836****	1.000	-	-	-	-	-
Max temperature	**-0.850****	**0.978****	1.000	-	-	-	-
Min temperature	-0.796**	**0.974****	**0.920****	1.000	-	-	-
Relative humidity	-0.245**	0.372**	0.291**	0.479**	1.000	-	-
Precipitation	-0.252**	0.290**	0.214**	0.381**	0.463**	1.000	-
Average wind velocity	-0.144**	0.065	0.045	0.082	-0.370**	0.019	1.000

**: $P \le 0.05$; Bold font: The Spearman correlation coefficients were greater than 0.8.

Supplemental table 3 Epidemiology of patients admitted with unintentional injuries

Variable	n (%)
Total	12 241 (100%)
Gender	
Male	7 360 (60.126%)
Female	4 881 (39.874%)
Age	
< 18 years	1 118 (9.133%)
18-64 years	7 827 (63.941%)
≥ 65 years	3 296 (26.926%)
Mechanism	
Road traffic injury	1 571 (12.834%)
Falls	7 521 (61.441%)
Mechanical injury	2 830 (23.119%)
Other injury	319 (2.606%)
Location	
Head and neck	122 (0.997%)
Thorax	597 (4.877%)
Abdomen	548 (4.477%)
Upper extremity	4 375 (35.741%)
Hip and thigh	2 828 (23.103%)
Lower extremity	3 373 (27.555%)

Multiple regions in the body	176 (1.438%)
Unspecified	222 (1.814%)
Diagnosis	
Fracture	9 969 (81.439%)
Non-fracture	2 272 (18.561%)

Supplemental table 4 Cumulative associations between 10th temperature and unintentional injury over 0-14 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**	**7**	**…**	**14**
Total	1.296 (1.117, 1.504)	1.227 (1.136, 1.325)	1.128 (1.044, 1.219)	1.073 (1.004, 1.146)	1.046 (0.974, 1.123)		0.908 (0.781, 1.056)
Gender							
Male	1.268 (1.070, 1.504)	1.207 (1.106, 1.318)	1.131 (1.035, 1.235)	1.101 (1.022, 1.187)	1.098 (1.013, 1.189)		0.891 (0.749, 1.059)
Female	1.339 (1.088, 1.647)	1.250 (1.121, 1.395)	1.113 (0.998, 1.241)	1.022 (0.930, 1.123)	0.968 (0.875, 1.072)		0.929 (0.754, 1.145)
Age							
< 18 years	1.640 (0.858, 3.135)	1.161 (0.844, 1.597)	0.971 (0.696, 1.356)	1.063 (0.813, 1.389)	1.119 (0.844, 1.483)		1.916 (0.998, 3.678)
18-64 years	1.244 (1.069, 1.448)	1.212 (1.119, 1.313)	1.110 (1.026, 1.202)	1.030 (0.961, 1.103)	1.003 (0.931, 1.080)		0.835 (0.716, 0.974)
≥65 years	1.380 (1.038, 1.835)	1.273 (1.102, 1.472)	1.187 (1.025, 1.375)	1.159 (1.024, 1.312)	1.120 (0.981, 1.279)		0.957 (0.719, 1.275)
Mechanism							

Road traffic injury	1.380 (1.038, 1.835)	1.273 (1.102, 1.472)	1.187 (1.025, 1.375)	1.159 (1.024, 1.312)	1.120 (0.981, 1.279)		0.957 (0.719, 1.275)
Falls	1.582 (1.282, 1.952)	1.353 (1.215, 1.506)	1.169 (1.048, 1.305)	1.133 (1.033, 1.243)	1.123 (1.017, 1.240)		0.925 (0.747, 1.145)
Mechanical injury	1.084 (0.902, 1.303)	1.043 (0.945, 1.151)	0.994 (0.903, 1.094)	0.973 (0.895, 1.057)	0.966 (0.884, 1.055)		0.941 (0.785, 1.129)
Other injury	1.090 (0.335, 3.543)	1.428 (0.812, 2.513)	1.124 (0.632, 2.001)	0.644 (0.404, 1.029)	0.471 (0.284, 0.781)		0.845 (0.264, 2.706)
Location							
Head and neck	1.479 (0.726, 3.016)	0.925 (0.624, 1.372)	0.727 (0.487, 1.084)	0.840 (0.591, 1.192)	0.935 (0.622, 1.405)		1.167 (0.464, 2.934)
Thorax	2.049 (1.196, 3.509)	1.718 (1.290, 2.289)	1.513 (1.141, 2.006)	1.397 (1.086, 1.796)	1.154 (0.878, 1.517)		1.185 (0.690, 2.033)
Abdomen	1.000 (0.978, 1.022)	0.992 (0.981, 1.004)	0.994 (0.984, 1.005)	1.004 (0.994, 1.014)	1.009 (0.998, 1.019)		1.007 (0.986, 1.027)
Upper extremity	1.157 (0.954, 1.402)	1.088 (0.983, 1.203)	1.016 (0.920, 1.122)	1.010 (0.927, 1.100)	1.045 (0.953, 1.145)		0.856 (0.704, 1.041)
Hip and thigh	1.397 (1.007, 1.938)	1.194 (1.013, 1.408)	1.131 (0.954, 1.340)	1.201 (1.043, 1.383)	1.204 (1.036, 1.399)		1.093 (0.783, 1.524)
Lower extremity	1.578 (1.206, 2.065)	1.373 (1.198, 1.575)	1.144 (0.995, 1.316)	1.055 (0.938, 1.187)	1.042 (0.917, 1.183)		0.982 (0.749, 1.288)
Multiple regions	1.448 (0.661, 3.173)	1.029 (0.680, 1.556)	0.764 (0.508, 1.150)	0.790 (0.552, 1.130)	0.943 (0.645, 1.379)		0.880 (0.400, 1.936)

Unspecified	1.920 (0.268, 13.759)	1.571 (0.616, 4.003)	0.569 (0.228, 1.420)	0.273 (0.122, 0.607)	0.333 (0.143, 0.778)		0.344 (0.049, 2.402)
Diagnosis							
Fracture	1.450 (1.231, 1.708)	1.276 (1.173, 1.389)	1.124 (1.032, 1.223)	1.086 (1.010, 1.168)	1.076 (0.995, 1.164)		0.960 (0.813, 1.133)
Non-fracture	1.137 (0.837, 1.545)	0.980 (0.827, 1.161)	0.923 (0.787, 1.082)	0.987 (0.856, 1.137)	1.037 (0.894, 1.203)		1.337 (0.997, 1.792)

Supplemental table 5 Cumulative associations between 25th temperature and unintentional injury over 0-14 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**		**…**	**14**
Total	1.146 (1.035, 1.270)	1.122 (1.066, 1.181)	1.080 (1.024, 1.138)	1.050 (1.005, 1.096)	1.032 (0.985, 1.081)		0.946 (0.853, 1.049)
Gender							
Male	1.139 (1.013, 1.280)	1.117 (1.054, 1.184)	1.079 (1.016, 1.146)	1.059 (1.007, 1.112)	1.055 (1.001, 1.112)		0.925 (0.822, 1.041)
Female	1.160 (1.016, 1.324)	1.127 (1.053, 1.206)	1.071 (1.000, 1.147)	1.027 (0.969, 1.088)	0.993 (0.933, 1.057)		0.975 (0.852, 1.115)
Age							
< 18 years	1.444 (0.800, 2.607)	1.099 (0.823, 1.469)	0.973 (0.721, 1.313)	1.062 (0.835, 1.351)	1.105 (0.859, 1.421)		1.788 (1.000, 3.200)
18-64 years	1.110 (1.012, 1.218)	1.109 (1.058, 1.163)	1.067 (1.017, 1.120)	1.023 (0.983, 1.066)	1.005 (0.963, 1.050)		0.900 (0.819, 0.989)
≥65 years	1.206 (0.972, 1.495)	1.155 (1.039, 1.284)	1.110 (0.995, 1.239)	1.093 (0.999, 1.196)	1.072 (0.974, 1.179)		0.966 (0.779, 1.198)
Mechanism							

Road traffic injury	1.206 (0.972, 1.495)	1.155 (1.039, 1.284)	1.110 (0.995, 1.239)	1.093 (0.999, 1.196)	1.072 (0.974, 1.179)		0.966 (0.779, 1.198)
Falls	1.306 (1.117, 1.526)	1.189 (1.101, 1.284)	1.103 (1.018, 1.195)	1.096 (1.026, 1.171)	1.092 (1.018, 1.171)		0.971 (0.829, 1.136)
Mechanical injury	1.016 (0.926, 1.116)	1.014 (0.966, 1.065)	1.002 (0.955, 1.052)	0.989 (0.950, 1.031)	0.982 (0.940, 1.026)		0.964 (0.878, 1.059)
Other injury	1.429 (0.479, 4.265)	1.312 (0.784, 2.196)	0.913 (0.544, 1.534)	0.644 (0.424, 0.979)	0.560 (0.356, 0.879)		1.056 (0.370, 3.016)
Location							
Head and neck	1.137 (0.855, 1.514)	0.973 (0.833, 1.136)	0.905 (0.771, 1.063)	0.955 (0.831, 1.096)	0.984 (0.839, 1.155)		1.068 (0.741, 1.540)
Thorax	1.433 (1.021, 2.011)	1.337 (1.121, 1.593)	1.266 (1.062, 1.510)	1.198 (1.028, 1.395)	1.061 (0.900, 1.252)		1.193 (0.844, 1.687)
Abdomen	1.009 (0.795, 1.280)	0.912 (0.805, 1.033)	0.930 (0.827, 1.045)	1.040 (0.935, 1.156)	1.095 (0.974, 1.231)		1.089 (0.871, 1.360)
Upper extremity	1.070 (0.953, 1.202)	1.046 (0.986, 1.110)	1.016 (0.957, 1.079)	1.011 (0.962, 1.063)	1.025 (0.971, 1.082)		0.914 (0.812, 1.029)
Hip and thigh	1.225 (0.940, 1.595)	1.075 (0.945, 1.223)	1.049 (0.917, 1.200)	1.131 (1.013, 1.262)	1.150 (1.024, 1.292)		1.134 (0.870, 1.478)
Lower extremity	1.300 (1.065, 1.586)	1.212 (1.098, 1.337)	1.092 (0.986, 1.211)	1.039 (0.956, 1.130)	1.036 (0.947, 1.133)		0.949 (0.778, 1.158)
Multiple regions	1.105 (0.782, 1.563)	1.013 (0.847, 1.213)	0.912 (0.761, 1.093)	0.897 (0.767, 1.049)	0.945 (0.801, 1.115)		0.909 (0.640, 1.291)

Unspecified	2.303 (0.337, 15.737)	1.577 (0.631, 3.941)	0.554 (0.231, 1.330)	0.300 (0.139, 0.647)	0.395 (0.175, 0.891)		0.537 (0.085, 3.381)
Diagnosis							
Fracture	1.225 (1.095, 1.370)	1.146 (1.084, 1.212)	1.075 (1.015, 1.139)	1.058 (1.009, 1.110)	1.052 (0.999, 1.107)		0.980 (0.874, 1.098)
Non-fracture	1.204 (0.794, 1.827)	0.970 (0.770, 1.221)	0.889 (0.716, 1.105)	0.981 (0.809, 1.189)	1.055 (0.862, 1.291)		1.501 (1.006, 2.241)

Supplemental table 6 Cumulative associations between 10th temperature and unintentional injury over 0-28 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**	**7**	**…**	**28**
Total	1.386 (1.229, 1.564)	1.299 (1.195, 1.412)	1.174 (1.103, 1.249)	1.094 (1.027, 1.165)	1.046 (0.987, 1.109)		1.082 (0.966, 1.212)
Gender							
Male	1.353 (1.158, 1.581)	1.292 (1.162, 1.437)	1.200 (1.110, 1.297)	1.138 (1.051, 1.231)	1.096 (1.019, 1.178)		1.120 (0.965, 1.298)
Female	1.444 (1.215, 1.716)	1.311 (1.162, 1.478)	1.131 (1.032, 1.240)	1.029 (0.938, 1.129)	0.975 (0.895, 1.063)		1.083 (0.922, 1.273)
Age							
＜18 years	1.329 (0.916, 1.929)	1.185 (0.915, 1.534)	1.044 (0.863, 1.262)	1.012 (0.835, 1.225)	1.034 (0.866, 1.235)		1.135 (0.808, 1.595)
18-64 years	1.358 (1.190, 1.549)	1.269 (1.158, 1.390)	1.142 (1.066, 1.223)	1.063 (0.992, 1.139)	1.017 (0.954, 1.085)		1.075 (0.950, 1.217)
≥65 years	1.484 (1.153, 1.909)	1.415 (1.191, 1.681)	1.290 (1.136, 1.465)	1.187 (1.044, 1.350)	1.109 (0.985, 1.248)		1.076 (0.844, 1.373)

Mechanism							
Road traffic injury	1.128 (0.763, 1.669)	1.162 (0.892, 1.514)	1.191 (0.988, 1.435)	1.180 (0.976, 1.428)	1.147 (0.963, 1.367)		1.244 (0.855, 1.811)
Falls	1.644 (1.387, 1.948)	1.483 (1.319, 1.667)	1.273 (1.167, 1.389)	1.156 (1.058, 1.263)	1.095 (1.009, 1.187)		1.142 (0.971, 1.342)
Mechanical injury	1.053 (0.921, 1.202)	1.039 (0.946, 1.142)	1.010 (0.940, 1.085)	0.980 (0.912, 1.053)	0.954 (0.892, 1.021)		0.985 (0.876, 1.107)
Other injury	1.935 (0.809, 4.626)	1.347 (0.744, 2.439)	0.831 (0.541, 1.275)	0.659 (0.428, 1.016)	0.626 (0.422, 0.928)		0.816 (0.354, 1.879)
Location							
Head and neck	1.209 (0.599, 2.440)	1.010 (0.610, 1.672)	0.808 (0.542, 1.204)	0.739 (0.496, 1.102)	0.736 (0.504, 1.074)		1.763 (0.853, 3.644)
Thorax	2.268 (1.398, 3.680)	1.981 (1.417, 2.770)	1.532 (1.187, 1.977)	1.228 (0.949, 1.588)	1.036 (0.818, 1.312)		0.945 (0.580, 1.539)
Abdomen	1.455 (0.898, 2.356)	1.397 (1.002, 1.950)	1.293 (1.008, 1.661)	1.206 (0.936, 1.553)	1.136 (0.900, 1.434)		1.094 (0.692, 1.729)
Upper extremity	1.130 (0.954, 1.338)	1.120 (0.996, 1.259)	1.095 (1.004, 1.194)	1.067 (0.978, 1.164)	1.040 (0.959, 1.127)		1.099 (0.942, 1.282)
Hip and thigh	1.420 (1.136, 1.775)	1.343 (1.149, 1.569)	1.232 (1.096, 1.386)	1.162 (1.033, 1.308)	1.120 (1.003, 1.250)		1.088 (0.881, 1.342)
Lower extremity	1.686 (1.355, 2.098)	1.486 (1.278, 1.727)	1.239 (1.108, 1.385)	1.114 (0.995, 1.247)	1.058 (0.953, 1.174)		1.111 (0.902, 1.369)

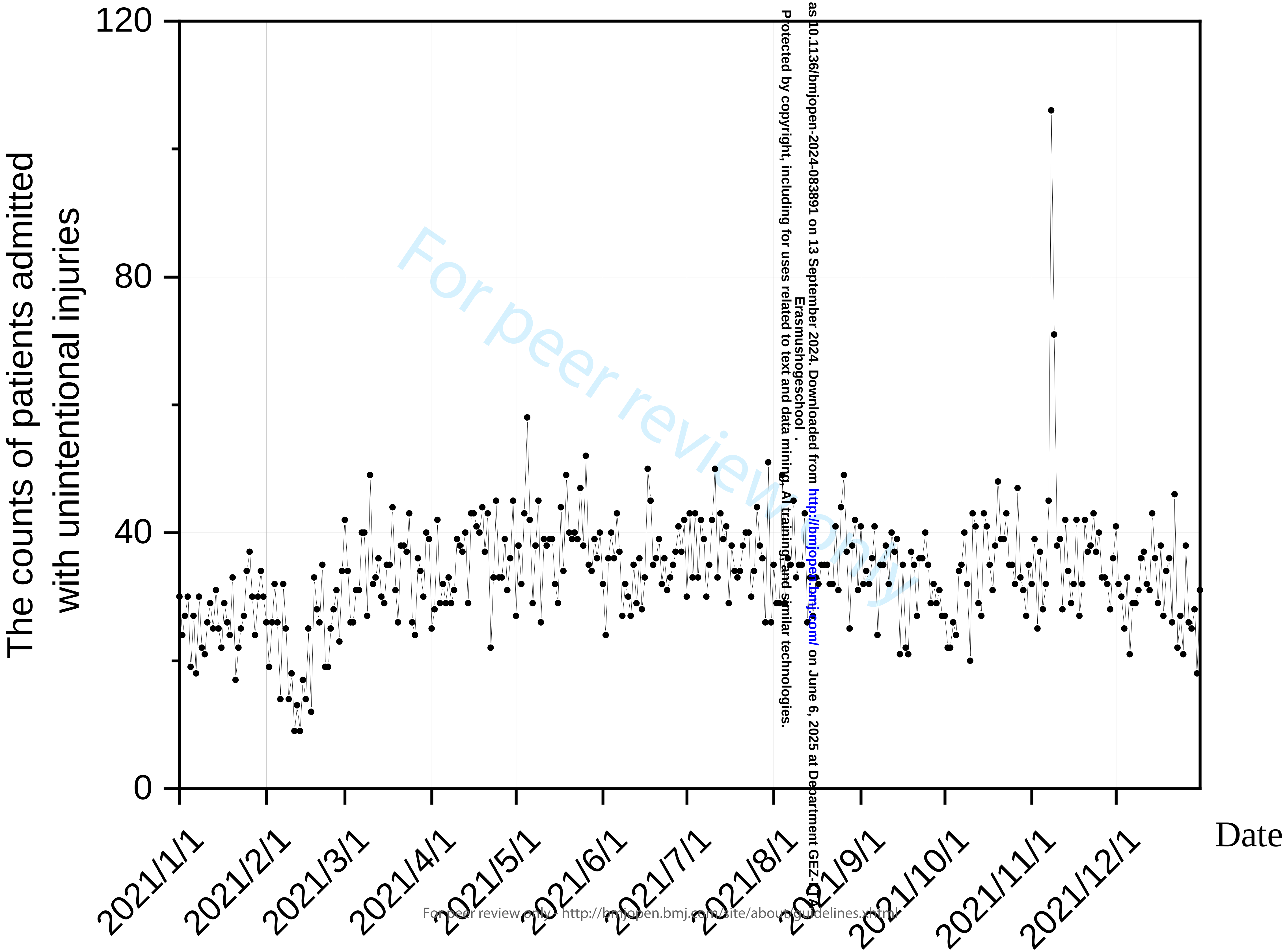
Multiple regions	1.053 (0.568, 1.950)	0.925 (0.601, 1.425)	0.811 (0.586, 1.122)	0.802 (0.577, 1.115)	0.852 (0.622, 1.166)		0.905 (0.516, 1.588)
Unspecified	2.653 (0.655, 10.757)	1.590 (0.629, 4.020)	0.830 (0.420, 1.639)	0.635 (0.310, 1.301)	0.631 (0.324, 1.229)		2.083 (0.497, 8.724)
Diagnosis							
Fracture	1.467 (1.287, 1.673)	1.357 (1.239, 1.486)	1.202 (1.123, 1.286)	1.108 (1.034, 1.187)	1.054 (0.989, 1.123)		1.066 (0.942, 1.208)
Non-fracture	1.085 (0.871, 1.351)	1.072 (0.920, 1.248)	1.047 (0.934, 1.174)	1.025 (0.913, 1.151)	1.007 (0.904, 1.121)		1.147 (0.944, 1.396)

Supplemental table 7 Cumulative associations between 25th temperature and unintentional injury over 0-28 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**		**…**	**28**
Total	1.210 (1.109, 1.320)	1.171 (1.104, 1.243)	1.110 (1.063, 1.160)	1.068 (1.022, 1.116)	1.039 (0.998, 1.082)		1.062 (0.977, 1.154)
Gender							
Male	1.206 (1.060, 1.373)	1.174 (1.076, 1.281)	1.125 (1.056, 1.197)	1.090 (1.022, 1.162)	1.066 (1.004, 1.131)		1.115 (0.984, 1.263)
Female	1.224 (1.090, 1.374)	1.170 (1.080, 1.267)	1.088 (1.026, 1.154)	1.034 (0.974, 1.098)	1.001 (0.948, 1.058)		1.041 (0.932, 1.163)
Age							
< 18 years	1.180 (0.909, 1.534)	1.102 (0.922, 1.318)	1.023 (0.899, 1.165)	1.007 (0.882, 1.148)	1.021 (0.904, 1.152)		1.111 (0.870, 1.420)
18-64 years	1.190 (1.086, 1.304)	1.152 (1.083, 1.227)	1.093 (1.044, 1.144)	1.051 (1.004, 1.101)	1.024 (0.981, 1.069)		1.056 (0.968, 1.153)
≥65 years	1.275 (1.030, 1.579)	1.243 (1.076, 1.436)	1.179 (1.063, 1.308)	1.121 (1.008, 1.246)	1.074 (0.974, 1.184)		1.054 (0.856, 1.298)
Mechanism							

Road traffic injury	1.103 (0.771, 1.578)	1.135 (0.892, 1.444)	1.159 (0.980, 1.371)	1.145 (0.964, 1.359)	1.109 (0.946, 1.301)		1.213 (0.859, 1.712)
Falls	1.347 (1.180, 1.538)	1.277 (1.167, 1.397)	1.176 (1.102, 1.255)	1.114 (1.042, 1.190)	1.077 (1.013, 1.145)		1.110 (0.977, 1.262)
Mechanical injury	1.014 (0.957, 1.074)	1.012 (0.972, 1.055)	1.005 (0.974, 1.036)	0.994 (0.963, 1.025)	0.983 (0.955, 1.011)		0.992 (0.942, 1.044)
Other injury	1.752 (0.791, 3.882)	1.211 (0.707, 2.074)	0.757 (0.518, 1.105)	0.621 (0.423, 0.911)	0.613 (0.430, 0.872)		0.785 (0.369, 1.669)
Location							
Head and neck	1.076 (0.743, 1.560)	1.009 (0.774, 1.315)	0.929 (0.756, 1.142)	0.895 (0.728, 1.099)	0.887 (0.732, 1.075)		1.300 (0.893, 1.893)
Thorax	1.643 (1.126, 2.397)	1.499 (1.160, 1.937)	1.278 (1.058, 1.543)	1.129 (0.931, 1.369)	1.035 (0.867, 1.235)		1.110 (0.757, 1.626)
Abdomen	1.255 (0.865, 1.820)	1.265 (0.983, 1.629)	1.253 (1.042, 1.507)	1.212 (1.004, 1.463)	1.159 (0.976, 1.377)		1.020 (0.720, 1.445)
Upper extremity	1.070 (0.954, 1.201)	1.071 (0.990, 1.158)	1.063 (1.004, 1.125)	1.047 (0.989, 1.110)	1.029 (0.976, 1.086)		1.060 (0.951, 1.181)
Hip and thigh	1.217 (1.046, 1.416)	1.183 (1.066, 1.312)	1.131 (1.048, 1.221)	1.097 (1.015, 1.185)	1.074 (1.000, 1.153)		1.082 (0.935, 1.251)
Lower extremity	1.374 (1.158, 1.630)	1.282 (1.142, 1.440)	1.160 (1.067, 1.262)	1.093 (1.003, 1.190)	1.060 (0.980, 1.146)		1.068 (0.907, 1.259)
Multiple regions	1.014 (0.775, 1.328)	0.961 (0.797, 1.159)	0.908 (0.789, 1.044)	0.900 (0.781, 1.038)	0.920 (0.804, 1.053)		0.957 (0.749, 1.223)

Unspecified	2.759 (0.709, 10.730)	1.617 (0.658, 3.973)	0.843 (0.440, 1.615)	0.668 (0.336, 1.326)	0.696 (0.366, 1.322)		1.983 (0.500, 7.856)
Diagnosis							
Fracture	1.251 (1.138, 1.375)	1.201 (1.126, 1.282)	1.127 (1.075, 1.181)	1.077 (1.027, 1.130)	1.046 (1.001, 1.093)		1.053 (0.961, 1.153)
Non-fracture	1.045 (0.901, 1.213)	1.044 (0.943, 1.155)	1.035 (0.961, 1.115)	1.021 (0.946, 1.101)	1.005 (0.937, 1.078)		1.095 (0.954, 1.257)



120
80
40
0
The counts of patients admited with unintentional injuries
2021/1/1
2021/2/1
2021/3/1
2021/4/1
2021/5/1
2021/6/1
2021/7/1
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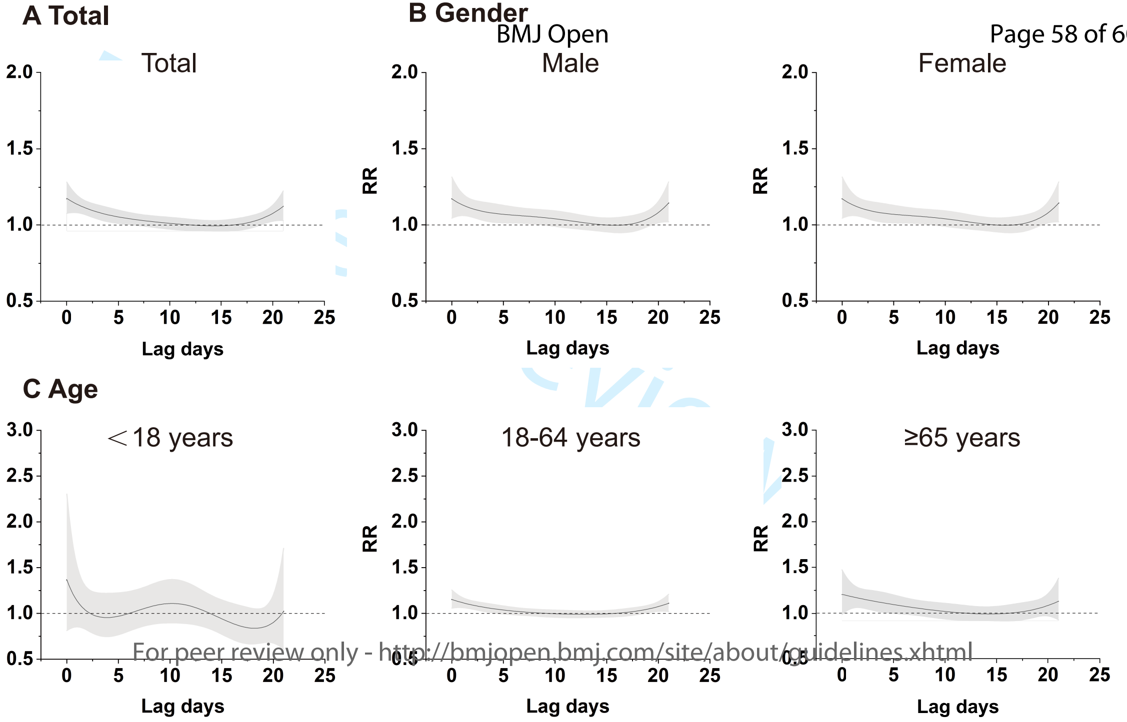
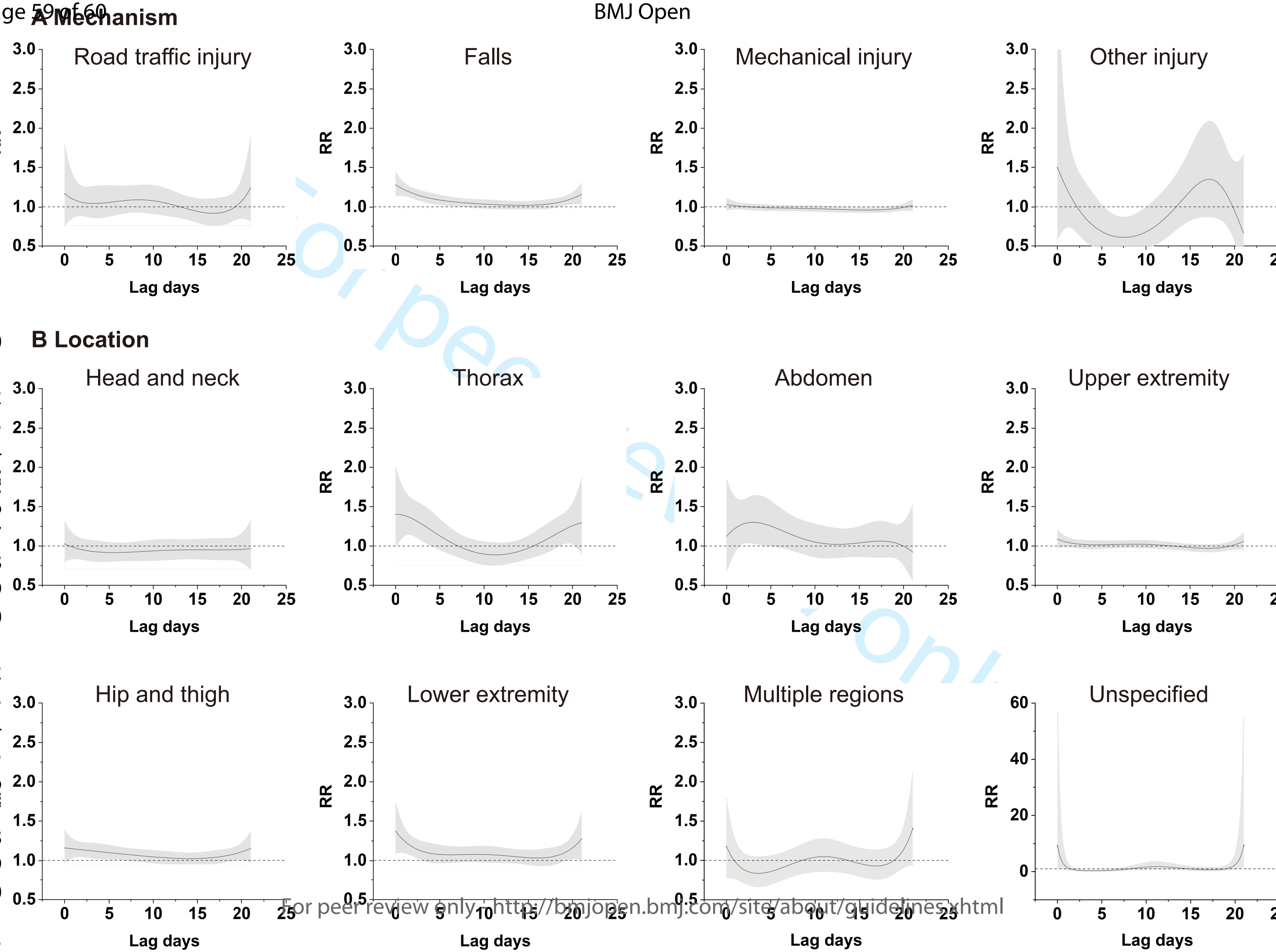
2021/12/1
Date


A Total
Total
B Gender
Male
Female
RR
2.0
1.5
1.0
0.5
0
5
10
15
20
25
Lag days
C Age
<18 years
18-64 years
≥65 years
3.0
2.5
2.0
1.5
1.0
0.5


A Mechanism
Road traffic injury
Falls
Mechanical injury
Other injury
B Location
Head and neck
Thorax
Abdomen
Upper extremity
Hip and thigh
Lower extremity
Multiple regions
Unspecified
RR
Lag days

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	√ P.1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	√ P.1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	√ P.3
Objectives	3	State specific objectives, including any prespecified hypotheses	√ P.4
Methods			
Study design	4	Present key elements of study design early in the paper	√ P.4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	√ P.4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	√ P.4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	√ P.5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	√ P.4-6
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	√ P.4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	√ P.6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	√ P.6-10
		(*b*) Describe any methods used to examine subgroups and interactions	√ P.8 and 10
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	√ P.10
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	√ P.10-11
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	√ P.11-12
		(b) Indicate number of participants with missing data for each variable of interest	√ P. 11-12
Outcome data	15*	Report numbers of outcome events or summary measures	√ P. 11-12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	√ P.12-15
		(*b*) Report category boundaries when continuous variables were categorized	√ P.12-15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	√ P.12-15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	√ P.12-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	√ P.16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	√ P.20-21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	√ P.16 - 19
Generalisability	21	Discuss the generalisability (external validity) of the study results	√ P.16 and 20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	√ P.23

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Association between ambient temperature and economic burden of unintentional injury in Tianjin: a case-crossover study

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Title page

Title: Association between ambient temperature and economic burden of unintentional injury in Tianjin: a case-crossover study

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Running title: Temperature and unintentional injury

Word Count: 4,847

Figure: 4

Table: 1

Association between ambient temperature and economic burden of unintentional injury in Tianjin: a case-crossover study

Abstract

Objective Unintentional injuries constitute a significant global public health issue with significant social and economic costs. Previous evidence suggests ambient temperatures are associated with unintentional injury occurrences. However, the impacts of ambient temperature on unintentional injury economic burden have received little research attention. The objective of the study was to examine the association between ambient temperature and economic burden of unintentional injury.

Design Time-stratified case-crossover study.

Setting This study was performed at Tianjin Hospital, the largest trauma center in Tianjin, by applying a hospital-based time-stratified case-crossover study.

Participants The 12 241 patients admitted with unintentional injuries and meteorological data were collected in Tianjin, China in 2021.

Primary and secondary outcome The association between ambient temperature and unintentional injury hospitalization was evaluated with a distributed lag nonlinear model, further temperature-attributable economic burden of unintentional injuries was quantified, and adjusted for demographic characteristics, injury mechanism, and injury location of injury.

Results The temperatures below 11.5 °C were significantly associated with the increased risk of unintentional injury hospitalization in Tianjin, in 2021. The effect was maximized on the current day. The relatively low temperature was responsible for 25.44% (95% CI: 13.74, 33.09) of unintentional injury patients, and was associated with the number of unintentional injury patients (3114, 95% CI: 1608, 4036). The relatively low temperature was associated with the excess economic burden for unintentional injury (197.52 million RMB, 95% CI: 102.00, 256.00; about 27.10 million dollars), accounting for 26.49% of the total economic burden. The cold temperatures generally had greater impacts on males (136.46 million RMB, 95% CI: 83.28, 172.42; about 18.67 million dollars) and the elderly (74.35 million RMB, 95%CI: 14.87, 102.14; about 10.24 million dollars).

Conclusion The temperature was associated with approximately 3000 unintentional injury patients and 200 million RMB (27 million dollars), accounting for 26% of the total economic burden in Tianjin, 2021.

Keywords Ambient temperature, Unintentional injury, Economic burden, Health effect

Strengths and limitations of this study

- A distributed lag nonlinear model was used to investigate the association between temperature and unintentional injury hospitalization.
- The economic burden of temperature-attributable due to unintentional injuries was quantified by calculating attribute numbers.
- The modification effects of different demographic and injury characteristics were explored using subgroup analysis.
- Being a single-city study limited the generalization of the findings.

INTRODUCTION

Unintentional injuries as a major public health issue increase disability and death, and also represent great economic costs. [1,2] As defined by the WHO, unintentional injuries occur in the absence of predetermined intent. It has been estimated that more than 5 million people die each year due to injuries, and nearly 80% of injury deaths are due to unintentional injuries. [3] Most unintentional injury cost estimates have been conducted in high-income countries. A study from the United States estimated unintentional injuries in the home to cost USD 217 billion annually. [4] Cost estimates for fall-related hospitalizations vary across regions of the world and within countries, [4] according to Sartini et al. in Italy ($7,945), [5] Roudsari et al. in the United States ($17,483), [6] and Stevens et al. in the United States ($7,355). [7]

It is widely recognized that increasing episodes of extreme weather are the phenomena associated with climate change and are currently accelerating. [8] Ambient temperature is of great interest as a major environmental health risk factor. [9,10] Previous studies determined the association between temperature and injuries associated with traffic accidents, [11] and the number of total injury admissions. [12] Liying Luo found that hot extremes were associated with increased unintentional injury mortality risk in China. [13] Hyewon Lee found that low temperature as well as high temperature significantly affected the risk of injury in Seoul, Korea.[2] There have been separate efforts to determine the association between ambient temperature and injury incidence. Nevertheless, the relationships between ambient temperature and the economic burden of unintentional injury have not been comprehensively investigated.

The current study used data of patients admitted with unintentional injury and meteorological data to evaluate the association between ambient temperature and unintentional injury hospitalization, applying a case-crossover design with a distributed lag nonlinear model (DLNM), and further quantify temperature-attributable economic burden of unintentional injuries. The findings will draw a comprehensive picture of the health impacts of temperature on unintentional injury hospitalization in Tianjin, China.

MATERIALS AND METHODS

Study area and data collection

Tianjin was a megacity located in northern China with a population of approximately 13.8 million inhabitants and covered 11946.88 km^2, which was administratively equivalent to a province (Figure S1). Tianjin (117.2 °E, 39.1 °N) experienced a warm temperate monsoon continental climate with four distinct seasons, including a hot and wet summer (due to monsoons), and a cold and relatively dry winter (due to vast Siberian anticyclones). [14] Given that Tianjin had a large population and a relatively wide range of ambient temperatures, it was an appropriate location for evaluating the association between ambient temperature and unintentional injury hospitalization with adequate statistical power.

This study was performed at Tianjin Hospital, the largest trauma center in Tianjin. It was a level 2 trauma center, and its emergency department (ED) provided 124,009 consultations per year. A retrospective study of all patients admitted with unintentional injuries (International Classification of Diseases, 10th Revision [ICD-10] codes: V00-X59) to Tianjin trauma center from ED was conducted based on the electronic medical record system from January 1 through

December 31, 2021. Information on patients included the date of onset, age, gender, injury mechanism, injury location, hospital length of stay and hospitalization cost. Furthermore, daily meteorological data for Tianjin in 2021 were obtained from the China Meteorological Data Sharing Service System (http://data.cma.cn/) issued by the National Meteorological Information Center of the China Meteorological Administration.

Outcome of interest

In the present study, the outcome of interest was the daily number of patients admitted with unintentional injuries. Data were collapsed by date to create time series of the daily number of patients admitted with unintentional injuries, and were stratified by gender, age, injury mechanism and injury location. Three age groups were considered (i.e., < 18 years, 18-64 years, and ≥ 65 years). The injury mechanism and injury location were coded using ICD-10. Unintentional injury was divided into road traffic injury (V00-V99), falls (W00-W19), mechanical injury from exposure to mechanical forces (W20-W64) and other injuries (W65-W99, X00-X59). Injury locations were divided into head and neck (S00-S19), thorax (S20-S29), abdomen (S30-39), upper extremity (S40-S69), hip and thigh (S70-79), lower extremity (S80-S99), multiple locations in the body (T00-T14) and unspecified (T08-T14, T20-T35, T66-T88, T90-98). The diagnosis was verified by the emergency department physician.

Exposure assessment

Daily meteorological data included daily mean temperature, max temperature, min temperature, barometric pressure, relative humidity, precipitation, average wind velocity, rain day and snow day at climate stations across Tianjin in 2021. We averaged the daily available weather conditions measurements of climate stations to represent the exposure in the target populations in Tianjin area. To control for the effect of potential confounding factors, the data for other meteorological variables were also obtained.

The holidays (except Saturday and Sunday), day of the week, calendar time and the number of confirmed cases of Coronavirus disease 2019 (COVID-19) as the epidemic indicator were considered as short-term covariates. Weekends were defined as Saturday and Sunday, and weekdays were from Monday to Friday. Holidays were defined as weekends and the Chinese statutory holidays (29 days per year), including New Year, Spring Festival, Qing Ming Festival, Labor Day, Dragon Boat Festival, Mid-Autumn Festival and Chinese National Day, and non-holidays as the other days.

Statistical analysis

Continuous variables were expressed as the mean ± standard deviation (SD) or the median [interquartile range]. Categorical variables were sorted by frequency (percentages). Spearman's correlation coefficients were used to summarize the similarities in daily meteorological variables. When the correlation coefficient between two variables was greater than 0.8, it indicated that there was a co-linear relationship between the two variables. There were high correlations among these three temperature measurements (Spearman r = 0.920 to 0.978). These temperature measurements were strongly correlated with barometric pressure (Spearman r =

0.796 to 0.850) (Table S1). Since mean temperature was a better predictor of population health than barometric pressure, maximum or minimum temperatures, we selected the daily mean temperature as the exposure indicator of ambient temperature. [15] Statistical analysis was performed using R software (version 4.2.1). All statistical tests were two-sided, and values of $P < 0.05$ were considered statistically significant.

Assessing the association between ambient temperature and unintentional injury admission

A time-stratified, case-crossover design was applied to investigate the association between ambient temperature and unintentional injury. This case-crossover design is useful for controlling for time-invariant characteristics and for slowly varying factors, as each patient serves as his/her own control. In the present study, each ED visit day of patients admitted with unintentional injuries was matched to all control days within a stratum, defined as a three-way interaction term (Year × Month × Day of the week). For instance, if a patient visited an ED with unintentional injuries on Thursday, July 1, 2021, all other Thursdays in July 2021 were selected as control days.

Daily mean temperature and the number of patients admitted with unintentional injuries were linked by date. A quasi-Poisson DLNM was employed to investigate their associations. DLNM is a modeling framework that simultaneously describes the nonlinear expose-response relationship and delay effect. DLNM usually quantified the lag effect and nonlinear effect of ambient temperature on injury risk. [2,13] Because the daily number of patients admitted with unintentional injuries typically followed an over-dispersed Poisson distribution, a model of quasi-Poisson was applied. In order to flexibly account for the potential lagged and nonlinear effect of mean temperature on the number of patients admitted with unintentional injuries, mean temperature was incorporated as a “cross-basis” function using DLNM. We empirically decided on a maximum lag of up to 21 days according to previous large studies. [16,17] A number of covariates were also incorporated as follows:

$$Log[E(Y_t)] = \alpha + cb(T_t) + \beta\, CW_t + \gamma\, DOW_t + s(DOY_t, 7/year) + \sum_{i=1}^{i} ns(W_{i,t}, df = 3)$$

Where t was the day of the observation; Y_t was the count of patients admitted with unintentional injuries on day t; α represents the intercept of the model; $cb\ (T_t)$ was a cross-basis of mean temperature; CW_t was a binary variable for holidays (1 if day t was classified as part of a holiday, 0 otherwise); DOW_t represented the day of the week which was modeled with six indicator variables through a dummy parameterization; β and γ were the vectors of regression coefficients; $s\ ()$ was a smooth function; DOY_t represented the day of the year specified through a natural cubic spline with 7 *df* per year to account for seasonality and long-term trends. $W_{(i,t)}$ meant covariates in meteorological variables without co-linear relationship on day t, including relative humidity, precipitation, average wind velocity, the number of COVID-19 confirmed cases, rain day and snow day, which was controlled by using natural cubic spline (*ns*) with 3 degrees of freedom (*df*) determined by the Akaike Information Criterion (quasi-likelihood for Akaike’s information criterion, Q-AIC).

The relative risks (RRs) of extreme temperature (e.g., 10th temperature percentile and 25th temperature percentile) were calculated compared with the referent temperature, i.e., the temperature with the minimum counts of patients admitted with unintentional injuries. The lag effect refers to the fact that changes in unintentional injury hospitalization are influenced not only by the current value of the ambient temperature, but also by its past values. Therefore, the lag structures in the effects of extreme temperature over lags of 0-21 days were also explored.[2,18,19] Subgroup analyses were conducted to assess whether the associations between temperature and unintentional injuries differed by demographic characteristics (age and gender), mechanism of injury and location of injury.

R packages of "dlnm" were used for the DLNM to explore the relationship between ambient temperature and unintentional injury hospitalization, and "spline" was used for the natural spline function to investigate the non-linear relationship between them.

Calculating economic burden of unintentional injuries due to ambient temperature

The attributable fraction (AF) and attribute numbers (AN), and their 95 % confidence intervals (CIs) were calculated using the following formulas:[20,21]

$$AF_t = 1 - \exp\left(-\sum_{l=l_0}^{L} \delta_{t-l}, l\right)$$

$$AN_t = n_t * AF_t$$

where AF_t referred to the attributable fraction of unintentional injury hospitalization due to ambient temperature on *t* day; we considered that the risk at day *t* was the cumulative effect of the previous period ($t\text{-}l_0$, ..., $t\text{-}L$) of exposure; L was the maximum lag time for the exposure factor; $\delta_{(t-l)}$ referred to the effect parameters of *Beta* at day *t-l*; AN_t referred to the count of patients admitted with unintentional injuries attributable to ambient temperature on *t* day; n_t

was the total number of patients with unintentional injuries in the population at day *t*.

The economic burden of the unintentional injury admissions associated with ambient temperature was further assessed by the Cost of Illness (COI) method. Economic burden was defined by the direct cost and indirect cost due to unintentional injury during hospital length of stay. [22] The direct cost relates to hospitalization costs, and indirect cost was estimated by lost productivity during hospital length of stay in this study. [23] Economic burden was shown as below: [24]

$$C_i = H_i * AN_i + (GDP' * T_i) * AN_i$$

Where C_i denoted the economic burden of subgroup *i*; H_i was the average hospital cost of subgroup *i*; AN_i referred to the count of patients admitted with unintentional injuries attributable to the ambient temperature of subgroup *i*; H_i referred to the hospitalization cost; $H_i *AN_i$ referred to the direct cost; *GDP'* referred to the daily GDP per capita per day; T_i was the average length of stay in hospital (days) of subgroup *i*; $(GDP' *T_i) *AN_i$ referred to the indirect cost. According to the *Tianjin Statistical Yearbook*, the GDP per capita per day was RMB 101614 in 2020. [25]

Sensitivity analysis

In addition, we conducted sensitivity analyses to confirm whether the main findings were robust to different model specifications by changing the lag period of 21 days for the lag-response association to 14 or 28 days. [2] In addition, we conducted a sensitivity analysis excluding snow from the DLNM.

Patient and public involvement

Patients and the public were not involved in the design or conduct of the study, formulation of research questions and outcome measures, or the recruitment process.

RESULTS

Descriptive analysis for meteorological variables and unintentional injury admission

Descriptive statistics for daily meteorological variables in Tianjin (2021) were summarized in Table S2. The median daily mean temperature was 14.2 °C, with temperatures ranging from -14.2 °C to 30.3 °C. The median daily maximum and minimum temperatures were 20.5 °C and 9.2 °C, respectively. There were 114 (31.2%) rainy days and 8 (2.2%) snowy days.

The epidemiology of patients admitted with unintentional injuries by gender, age, injury mechanism and injury location was summarized in Table S3. A total of 12 241 patients with unintentional injuries were admitted to Tianjin Hospital in ED in 2021. Among these, 7 360 (60.1%) were males, and 4 881 (39.9%) were females. For each age group (＜ 18, 18-64, and ≥ 65 years old), the numbers of patients with unintentional injuries by age were 1 118 (9.1%), 7 827 (63.9%) and 3 296 (26.9%), respectively. Injury mechanisms were road traffic injury (1 571, 12.8%), falls (7 521, 61.4%), mechanical injury (2 830, 23.1%), and others (319, 2.6%). The most common injury locations were upper extremity (4 375, 35.7%) lower extremity (3 373, 27.6%), and, hip and thigh (2 828, 23.1%). The leading diagnosis was fracture (9 969, 81.4%). The hospitalization costs were 60 907.12 RMB per capita for unintentional injury patients. Figure S2 showed daily counts of patients admitted with unintentional injuries during the study period.

Association between ambient temperature and unintentional injury admission on the current day

The impact of ambient temperature on the risk of hospital admission for unintentional injury was maximized on the current day (lag0). The relationship between ambient temperature and hospitalization for all unintentional injuries followed a L-shaped curve on the current day (Figure 1A). Increased risks were found during cold days, with higher risks during more cold extreme temperatures. Significant effects of cold were observed among all unintentional injury patients, with an estimated *RR* at the 25th percentile (5 °C) of 1.18 (95% CI: 1.08-1.28) and the 10th percentile (-1 °C) of 1.34 (95% CI: 1.18-1.52) (Figure S3A and Figure 3A). The risk of hospital admission for all unintentional injuries was statistically significant when the temperature was below 11.5 °C. The results from this sensitivity analysis excluding snow from the DLNM were consistent with the main analysis.

Results revealed that the risk was present for both males and females, with similar temperature-admission curves (Figure 1B). Females tend to be more sensitive to cold weather than males. The *RR* at the 25th percentile on the current day (lag0) was 1.17 (95% CI: 1.04-1.31) for males and 1.18 (95% CI: 1.06-1.31) for females (Figure S3B), and the RR at the 10th percentile was 1.31 (95% CI: 1.12-1.53) for males, compared with 1.38 (95% CI: 1.16-1.64) for females (Figure 3B).

For age groups, the highest risks were found among people aged ≥ 65 years old at 1.92 (95%

CI: 1.22-3.01), followed by people aged 18-64 years old at 1.869 (95% CI: 1.41-2.47) on the current day (lag0) at the lowest temperature (Figure 1C). RRs for the $<$ 18 years old group were not statistically significant. The *RR* at the 25th percentile on the current day (lag0) was 1.15 (95% CI: 1.06-1.26) for people aged 18-64 years old and 1.21 (95% CI: 0.99-1.47) for people aged ≥ 65 years old (Figure S3C). And the RR at the 10th percentile was 1.31 (95% CI: 1.15-1.50) for people aged 18-64 years old, compared with 1.37 (95% CI: 1.06-1.77) for people aged ≥ 65 years old (Figure 3C). The risk of hospital admission for unintentional injury for people aged ≥ 65 and 18-64 years old was statistically significant when the temperature was below 3.5 °C and 11 °C, respectively.

For injury mechanisms, only the risk of falls increased at relatively low temperatures (Figure 2A). RR at the 25th percentile (5 °C) was 1.28 (95% CI: 1.14-1.44) and the 10th percentile (-1 °C) was 1.55 (95% CI: 1.31-1.83). For injury locations, the risks of thorax, upper extremity, hip and thigh, and lower extremity injuries increased at relative low temperatures (Figure 2B). Significant effects of cold were observed in fracture patients, with an estimated RR at the 25th percentile (5 °C) of 1.23 (95% CI: 1.11-1.36) and in the 10th percentile (-1 °C) of 1.44 (95% CI: 1.25-1.66). When the temperature was below 12°C, the risk of fracture hospitalization was statistically significant.

Associations between ambient temperature and unintentional injury admission over lag days

Figure 3 depicted the associations between 10th temperature and unintentional injury over 0-

21 lag days. The effects of relative low temperatures on the risk of hospital admission for unintentional injury were presented to be acute (lasting for approximately 5 days), and maximized on the lag 0 day (Figure 3A). As the lag increased, the RR of unintentional injury moved close to 1. When stratified by gender and age, the results revealed significant risks lasting for less than 9 days in males, 3 days in females, 4 days in people aged 18-64 years old and 6 days in people aged ≥ 65 years old (Figure 3B and 3C). For injury mechanisms, significant risks lasted for 7 days for falls (Figure 4A). For injury locations, significant risks of thorax, upper extremity, hip and thigh, and lower extremity injury lasted for less than 4, 0, 7 and 3 days. The risk of fracture lasted for less than 6 days. Figure S3 and Figure S4 showed the overall cumulative 25th temperature-injury associations over 0-21 lag days. The sensitivity analysis was conducted by changing the lag period of 21 days for lag-response association to 14 or 28 days. It did not alter the main results (Table S4-S7).

Economic burden of unintentional injuries attributed to relative low temperature

Relatively low temperature was responsible for 25.44% (95% CI: 13.74, 33.09) of all unintentional injury patients during the study period, with higher AF for males (30.37%, 95%CI: 18.27, 37.77) than that for females (15.54%, 95%CI: -13.69, 29.41) (Table 1). For age groups, the highest AF was found among people aged ≥ 65 years old (31.26%, 95%CI: 6.78, 42.48), followed by people aged 18-64 years old (21.18%, 95%CI: 4.15, 30.87). For injury mechanisms, the highest AF was observed in falls (31.65%, 95%CI: 14.77, 40.62). For injury locations, the AF of the hip and thigh (39.92%, 95%CI: 19.79, 49.70) was higher than the others. The AF of the fracture was 27.61% (95%CI: 15.84, 35.63).

Short-term cold exposures were associated with the number of unintentional injury patients (3114, 95%CI: 1608, 4036) for several specific subgroups, accounting for 2235 (95%CI: 1364, 2824) for males, 1658 (95%CI: 443, 2445) for people aged 18-64 years old, 1030 (95%CI: 206, 1415) for people aged ≥ 65 years old, 2381 (95%CI: 1143, 3135) for falls, 1129 (95%CI: 527, 1411) for hip and thigh injuries, 2753 (95%CI: 1449, 3626) for fractures attributable to cold (Table 1).

Short-term cold exposures were responsible for 197.52 million RMB (95%CI: 102.00, 256.00; about 27.10 million dollars) of all unintentional injury patients during the study period, accounting for 26.50% total economic burden, and were associated with the excess economic burden of unintentional injury for several specific subgroups, accounting for 136.46 (95%CI: 83.28, 172.42; about 18.67 million dollars) million RMB for males, 104.62 (95%CI: 27.95, 154.27; about 14.34 million dollars) million RMB for people aged 18-64 years old, 74.35 (95%CI: 14.87, 102.14; about 10.24 million dollars) million RMB for people aged ≥ 65 years old, 155.00 (95%CI: 74.41, 204.09; about 21.37 million dollars) million RMB for the falls, 93.24 (95%CI: 43.52, 116.53; about 12.88 million dollars) million RMB for hip and thigh injury, 185.39 (95%CI: 97.58, 244.17; about 25.50 million dollars) million RMB for fracture attributable to cold (Table 1 and Table S7).

DISCUSSION

In the current study, 12 241 patients admitted with unintentional injuries were analyzed using a time-stratified case-crossover design with a DLNM. One interesting finding is that the risk of unintentional injury significantly increased at relatively low temperatures. Females were more vulnerable to cold weather than males, but the effect on males persisted longer. Relatively low temperatures were linked to an increased risk of unintentional injury in adults, more sensitive in the elderly. The mechanism-specific analyses showed that the risk of falls was significantly associated with relative low temperatures. The location-specific analyses showed that the risks of thorax, upper extremity, hip and thigh, and lower extremity injuries were significantly associated with relative low temperatures. The excess economic burden of unintentional injury associated with relative low temperatures was approximately 200 million RMB, and fracture accounted for 185 million RMB. The findings have provided a deeper insight into evidence that ambient temperature was associated with risks of unintentional injury admission. The findings have important implications for unintentional injury prevention and control in northern China.

Unintentional injuries increased at relative low temperatures

According to this research, unintentional injury risk was significantly associated with relative low temperatures, which was consistent with several studies. For example, a study conducted in Seoul, South Korea from 2008 to 2016 reported that patients with unintentional injuries who had visited emergency departments increased significantly at relative low temperatures. [2] Another study conducted between 2015 and 2016 in Shenzhen China found that high RR was for traffic accident injuries during cold exposure. However, other studies found that an increase in temperature was only associated with a relatively high risk of injury. [12] Therefore, the effect of relative low temperatures has been inconsistent and has not been observed as extensively. This discrepancy could be attributed to differences according to various geographical locations, temperature distribution, social factors and patients' characteristics. [2] For example, Tianjin has four distinct seasons with a freezing winter, and the minimum temperature during winter is below 0 ℃, which increases the risk of unintentional injury. Besides, the effect of high temperatures on unintentional injuries was not significant, likely owing to the small sample size.

Differences in relationship between unintentional injury risk and relative low temperatures in subgroups

The findings showed that cold temperatures generally had greater impacts on the elderly, which is in line with previous studies. [13,26,27,28] The reason for the results may be that the elderly are more susceptible to injury, associated with their osteoporosis due to calcium loss, and their gradually weakening ability of balance, [2,29,30] although older groups were positively associated factors of personal cold protection behaviors. [31] The study also observed that people aged 18-64 years old were also more likely to suffer from unintentional injury. In addition, the increased risk of hospital admission for unintentional injury for people aged ≥ 65 and 18-64 years old is statistically significant when the temperature is below 3.5 °C and 11 °C, respectively. Young and middle-aged people are more likely and more frequently exposed to outdoor working conditions around 10 °C in spring and autumn. [32,33] While older people are more likely to fall in winter when the temperature is below 0 °C. Therefore, in order to alleviate the injury burden of relatively low temperatures, policymakers need to account for the specific susceptible populations to unintentional injury when formulating targeted adaptation plans and priority protection.

As determined in this study, the increased risk of unintentional injury at relative low temperatures seems related to fall injuries. This finding supports evidence from previous observations. [34] Hassi et al. and Bell et al. both found an increase in slipping and falling injuries at low-temperature conditions. [35] Therefore, it is likely that the increase in injuries observed, which are associated with relative low temperatures, is caused by one's physical environment, such as snow or ice on the ground, freezing rain, and freezing temperatures, during winter. [36] The results from this sensitivity analysis were almost consistent with the main analysis. The reason could be that there were 8 (2.192%) snowy days in Tianjin (2021). As it is conceivable, considering the extremely small sample size, the study lacks statistical power and requires validation in larger sample.

Moreover, in the present study, the risk of fracture increased at relatively low temperatures. A study conducted in Tokyo, Japan over a 3-year period also found that fracture risk was the highest in the winter for some individuals. [37] José María Tenías found that the weather series showed a positive tendency, with a greater occurrence of fracture cases in the autumn and winter months. [38] Aviram M. Giladi, in their study of the population of the US, observed that the risk of distal radius fractures was higher in the winter months. [39] In particular, the risks of thorax, extremity, hip and thigh injury increase at relatively low temperatures in this study. Hip fractures among the elderly represent an important public health problem, [40] both because of their high incidence and the serious consequences that derive from them: increased mortality, morbidity, and high consumption of medical resources, especially considering the aging trend of the population in China.

As determined in the study, the effects of relative low temperatures on the risk of hospital admission for unintentional injury present lasted for approximately 5 days, and the risk decreased as the lag days decreased, which is consistent with other evidence that has consistently noted that the effects of relative low temperatures on the injury risk present are acute. [41] The lag days could be attributed to the following: (i) Patient factors (e.g., the time from onset to diagnosis); (ii) Meteorological factors (e.g., icy ground). These findings suggest that low-temperature warnings for trauma centers may need to last approximately 5 days to prepare for additional service demand pressures.

Economic burden of unintentional injuries increased at relative low temperatures

Previous studies have mainly focused on the economic burden of air pollution.[42] To the best of our knowledge, little is known about the economic burden of relative low temperatures on intentional injury. The findings highlight that, short-term cold exposures were associated with hospital admission (more than 3000 patients admitted with unintentional injuries) and economic burden (approximately 200 million RMB; 27 million dollars) for unintentional injury, especially susceptible groups in males, aged ≥ 18 years old, the falls, the hip and thigh injury and fractures. The economic impacts of cold weather on males tend to be greater than on females. The reason for the results is the influence of cold weather on males for a longer period than on females, because they are more likely and more frequently exposed to outdoor working conditions.[33] Though 83% of houses had central heating in winter in Tianjin, the majority of the population was potentially protected from the outdoor weather. Extremely cold days still posed some increased risks.[15] The following prevention measures may be necessary to decrease substantial economic burden: (i) Stratified analyses by gender and age identify vulnerable subgroups and provide warning signals. Public health agencies should consider using these warnings to trigger initiation of injury prevention strategies. (ii) Public health initiatives focused on injury prevention through fall prevention, bike helmets, sport impact policy changes, and other public safety measures. (iii) In addition to standard calendar-related factors (holidays, day of the week, calendar time), incorporating weather into resource planning models can improve the daily allocation of resources and staff of hospital. (iv) Personalized health education is critical for improving prevention practices among vulnerable groups and sensitive disease groups.[3]

Limitations

The major limitations of this study need to be acknowledged. First, temperature effects could be modified by many factors, and this is a single-city study for one year, which limits the generalizability of the findings to other regions and times. Second, temperature data from fixed sites were used rather than individual exposures. In contrast, data from fixed monitoring stations can only reflect meteorological conditions at a particular location and cannot accurately reflect the actual exposure of an individual. The temperature data from fixed sites may cause some inevitable measurement errors. Third, the effects of immediate cold waves and possible interventions by a cold warning system were not considered in this study. Fourth, some factors, such as injury severity, occupation status and public accident, etc., that might confound the associations between ambient temperature and unintentional injury were not controlled. Fifth, COVID-19 pandemic may have had some impact on the results in 2021. Finally, considering the loss of productivity after discharge and intangible costs, the costs of unintentional injury admission attributed to relative low temperatures were underestimated in this research.

CONCLUSIONS

This study assessed the association between ambient temperature and economic burden of unintentional injury, and identified characteristics of the population and diseases with high risks. Research results suggest that the risk of hospitalization for unintentional injury increased when it was below 11.5 °C in Tianjin, China. The temperature risk of unintentional injury was presented to be acute and the highest in the absence of the delay effect. Relative low temperature was responsible for approximately 3000 unintentional injury patients, and the economic burden attributable to cold exposures was up to approximately 200 million RMB (about 27 million dollars), approximately accounting for 26% of the total economic burden in Tianjin, 2021. People with male, aged above 18 years old, falls, hip and thigh injuries, and fractures were identified as particularly susceptible groups and sensitive diseases to relative low temperature. The findings may clarify the health impacts of temperature on unintentional injury economic burden. It is helpful for informing effective targeted public health interventions to prevent and control unintentional injury, and to increase resilience in response to climate change.

Declarations

Acknowledgments

Not applicable.

Author contributions

Yue Li: Conceptualization, Methodology, Writing-Original draft preparation. **Chao Yuan:** Resources, Data Curation, Writing-Original draft preparation. **Tao Liu:** Methodology, Software. **Zhao Yang:** Resources, Data Curation. **Fangguo Li:** Resources, Data Curation. **Ji Li:** Software, Validation. **Haojun Fan:** Funding acquisition, Supervision, Writing-Original draft preparation. **Chunxia Cao:** Funding acquisition, Writing- Reviewing and Editing. Haojun Fan and Chunxia Cao are the guarantors.

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Conflict of interest

None.

Ethical Aspects

The study protocol was approved by the ethics committee of Tianjin Hospital (2021-175). Data were analyzed at the aggregate level, as agreed by the Ethical Committee, and no participants were contacted.

Informed consent statement

Not applicable.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

Data may be obtained from a third party and are not publicly available.

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Figure Legends

Figure 1 Association between daily mean temperature and admission for unintentional injury according to age or gender on the current day

Dotted vertical lines represent the 10th temperature and 25th temperature.

Figure 2 Association between daily mean temperature and unintentional injury among subgroups according to injury mechanism and injury location on the current day

Dotted vertical lines represent the 10th temperature and 25th temperature.

Figure 3 Associations between 10th temperature and unintentional injury over 0-21 lag days according to age or gender

Figure 4 Associations between 10th temperature and unintentional injury over 0-21 lag days according to injury mechanism or injury location

Table Legends

Table 1 Attributable fractions (AF%), attribute numbers (AN) and hospitalization cost of unintentional injuries attributed to relative low temperature across lag0 21 day by age, gender, mechanism, location and diagnosis

TABLE 1 Attributable fractions (AF%), attribute numbers (AN) and economic burden of unintentional injuries attributed to relative low temperature across lag 21 day

	AF（%）	AN	Direct cost (million RMB)	Indirect cost (million RMB)	Economic burden (million RMB)
Total	25.44 (13.74, 33.09)	3114 (1608, 4036)	189.67 (97.94, 245.82)	7.856 (4.06, 10.18)	197.521 (102.00, 256.00)
Gender					
Male	30.37 (18.27, 37.77)	2235 (1364, 2824)	130.67 (79.75, 165.10)	5.79 (3.53, 7.31)	136.46 (83.28, 172.42)
Female	15.537 (-13.69, 29.41)	758 (-698, 1430)	48.96 (-45.08, 92.36)	1.84 (-1.69, 3.46)	50.80 (-46.78, 95.83)
Age					
＜18 years	30.49 (-23.66, 45.62)	341 (-308, 501)	12.91 (-11.67, 18.97)	0.71 (-0.64, 1.04)	13.62 (-12.31, 20.02)
18-64 years	21.18 (4.15, 30.87)	1658 (443, 2445)	100.36 (26.82, 148.00)	4.26 (1.14, 6.28)	104.62 (27.95, 154.27)
≥65 years	31.26 (6.78, 42.48)	1030 (206, 1415)	71.71 (14.34, 98.51)	2.64 (0.53, 3.63)	74.35 (14.87, 102.14)
Mechanism					
Road traffic injury	31.38 (-2.02, 43.82)	493 (-62, 668)	42.11 (-5.30, 57.06)	1.77 (-0.22, 2.39)	43.87 (-5.52, 59.45)
Falls	31.65 (14.77, 40.62)	2381 (1143, 3135)	149.62 (71.82, 197.00)	5.38 (2.58, 7.09)	155.00 (74.41, 204.09)
Mechanical injury	-43.07 (-181.52, -1.55)	-1219 (-5001, -22)	-53.73 (-220.43, -0.97)	-3.22 (-13.20, -0.06)	-56.95 (-233.63, -1.03)
Other injury	-71.63 (-3430.24, 37.31)	-228 (-13123, 116)	-9.98 (-574.65, 5.08)	-0.56 (-31.95, 0.28)	-10.54 (-606.60, 5.36)
Location					
Head and neck	-571.08 (-287618.52, 35.60)	-697 (-270310, 39)	-50.80 (-19701.35, 2.84)	-3.31 (-1282.77, 0.19)	-54.11 (-20983.12, 3.03)
Thorax	28.57 (-73.59, 49.00)	171 (-459, 293)	8.49 (-22.79, 14.55)	0.45 (-1.22, 0.78)	8.94 (-24.01, 15.33)
Abdomen	1.364 (-138.84, 38.07)	8 (-959, 209)	0.72 (-85.72, 18.68)	0.03 (-3.48, 0.76)	0.74 (-89.19, 19.44)
Upper extremity	11.47 (-20.91, 26.24)	502 (-910, 1140)	22.55 (-40.87, 51.20)	1.14 (-2.06, 2.58)	23.68 (-42.93, 53.78)

Hip and thigh	39.92 (19.79, 49.70)	1129 (527, 1411)	90.16 (42.08, 112.68)	3.08 (1.44, 3.85)	93.24 (43.52, 116.53)
Lower extremity	23.52 (-6.45, 38.72)	793 (-191, 1290)	48.75 (-11.74, 79.30)	1.82 (-0.44, 2.97)	50.57 (-12.18, 82.26)
Multiple regions	-189.12 (-9038.17, 38.70)	-333 (-18675, 68)	-29.70 (-1665.67, 6.07)	-1.45 (-81.21, 0.30)	-31.15 (-1746.88, 6.36)
Unspecified	-1049.44 (-11132.00, 23.57)	-2330 (-3081363, 50)	-133.95 (-177141.30, 2.87)	-6.32 (-8358.09, 0.14)	-140.27 (-185499.39, 3.01)
Diagnosis					
Fracture	27.61 (15.84, 35.63)	2753 (1449, 3626)	178.52 (93.96, 235.13)	6.87 (3.62, 9.05)	185.39 (97.58, 244.17)
Non-fracture	-10.75 (-111.71, 21.51)	-1072 (-9798, 2146)	-46.78 (-427.57, 93.65)	-2.84 (-25.92, 5.68)	-49.62 (-453.48, 99.32)

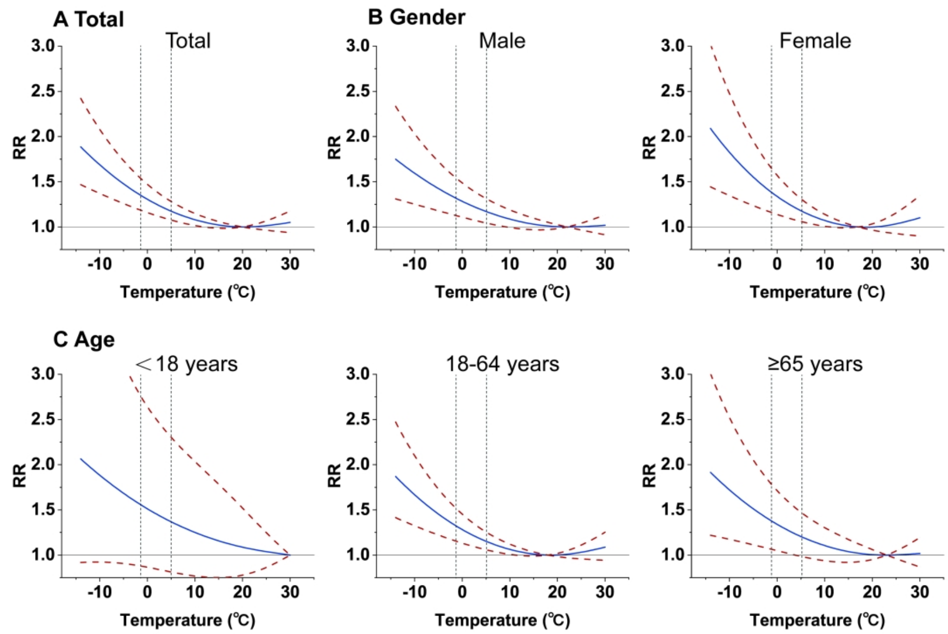

Figure 1 Association between daily mean temperature and admission for unintentional injury according to age or gender on the current day
Dotted vertical lines represent the 10th temperature and 25th temperature.

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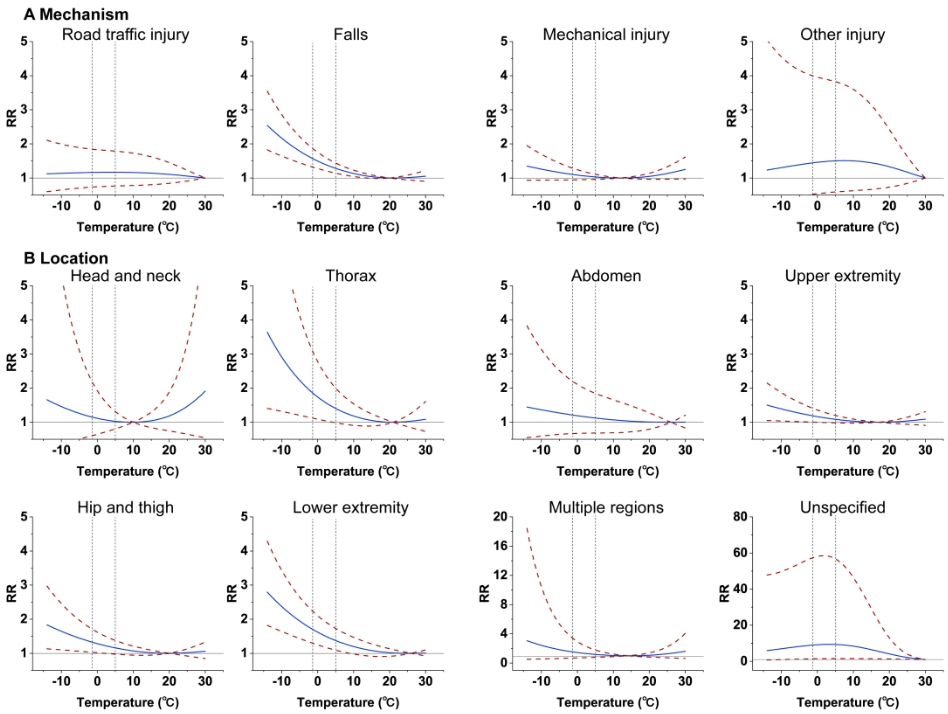

Figure 2 Association between daily mean temperature and unintentional injury among subgroups according to injury mechanism and injury location on the current day
Dotted vertical lines represent the 10th temperature and 25th temperature.

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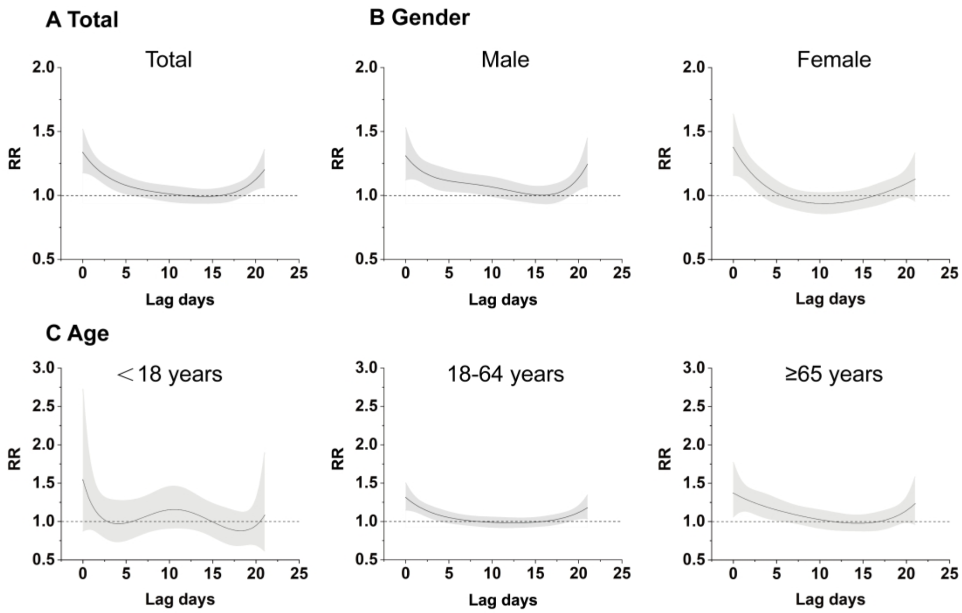

Figure 3 Associations between 10th temperature and unintentional injury over 0-21 lag days according to age or gender

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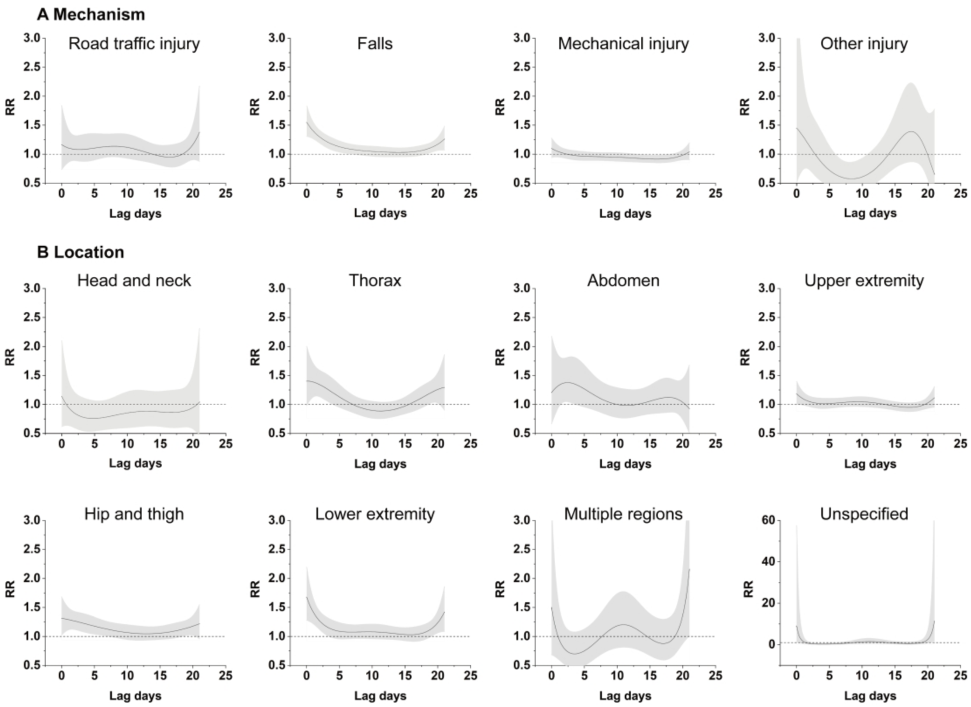

Figure 4 Associations between 10th temperature and unintentional injury over 0-21 lag days according to injury mechanism or injury location

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Supplemental Figure Legends

Supplemental figure 1 The location of Tianjin

Supplemental figure 2 Time series of daily counts of patients admitted with unintentional injuries

Supplemental figure 3 Cumulative associations between 25th temperature and unintentional injury over 0-21 lag days according to age or gender

Supplemental figure 4 Cumulative associations between 25th temperature and unintentional injury over 0-21 lag days according to injury mechanism or injury location

Supplemental Table Legends

Supplemental table 1 Correlations between the meteorological variables

Supplemental table 2 Descriptive statistics for daily meteorological variables

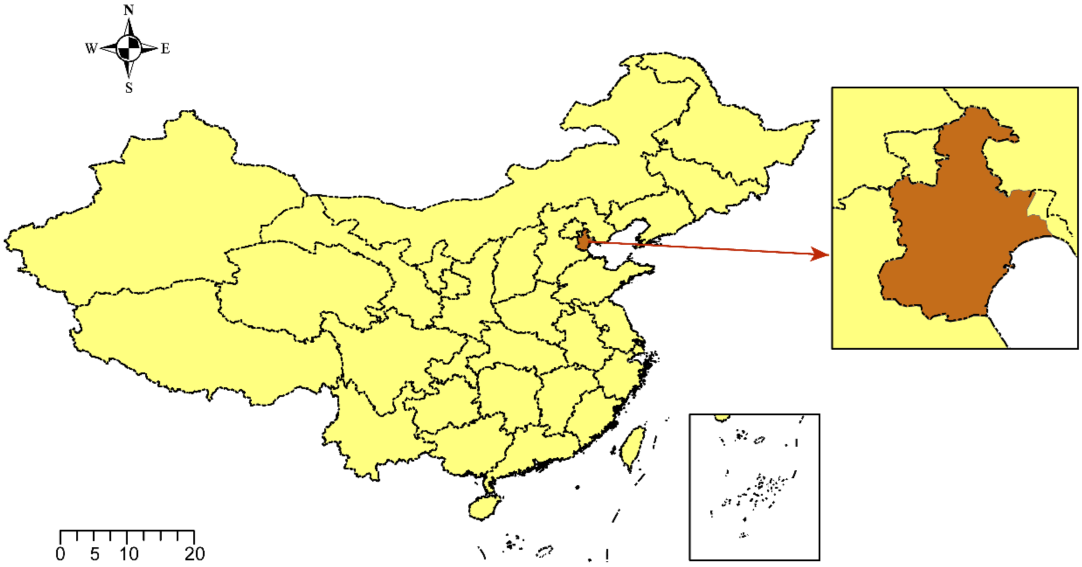
Supplemental table 3 Epidemiology of patients admitted with unintentional injuries

Supplemental table 4 Cumulative associations between 10th temperature and unintentional injury over 0-14 lag days

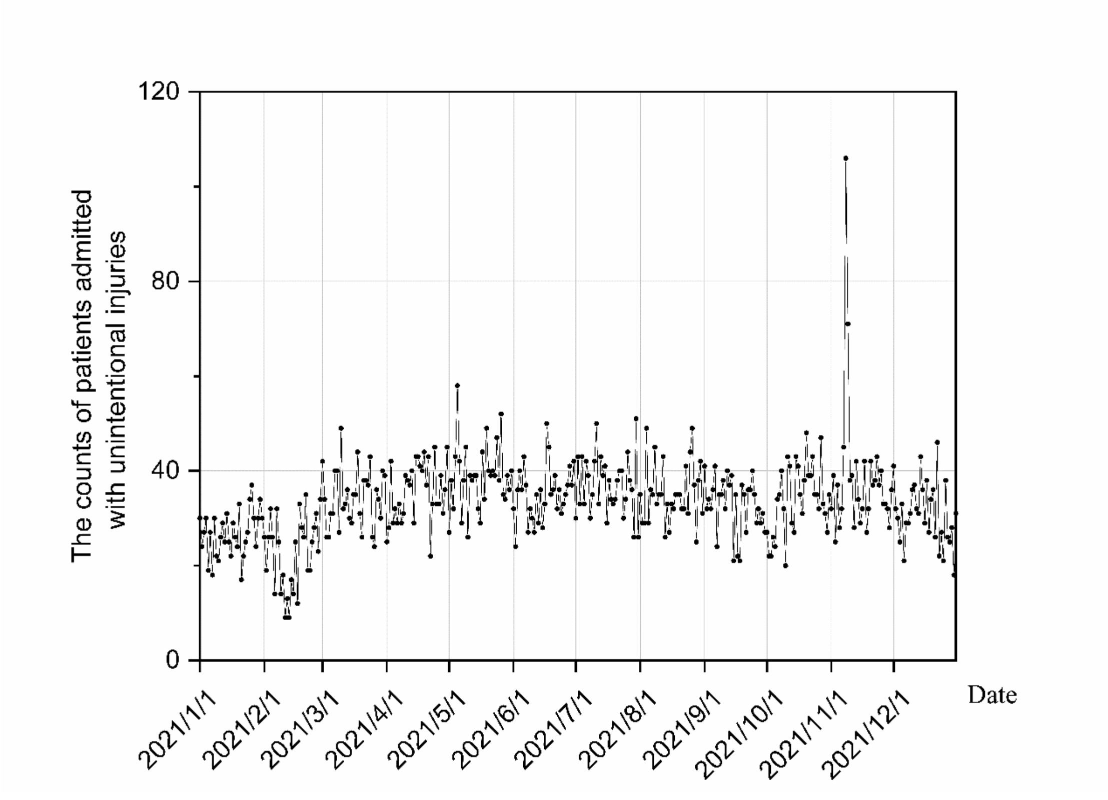
Supplemental table 5 Cumulative associations between 25th temperature and unintentional injury over 0-14 lag days

Supplemental table 6 Cumulative associations between 10th temperature and unintentional injury over 0-28 lag days

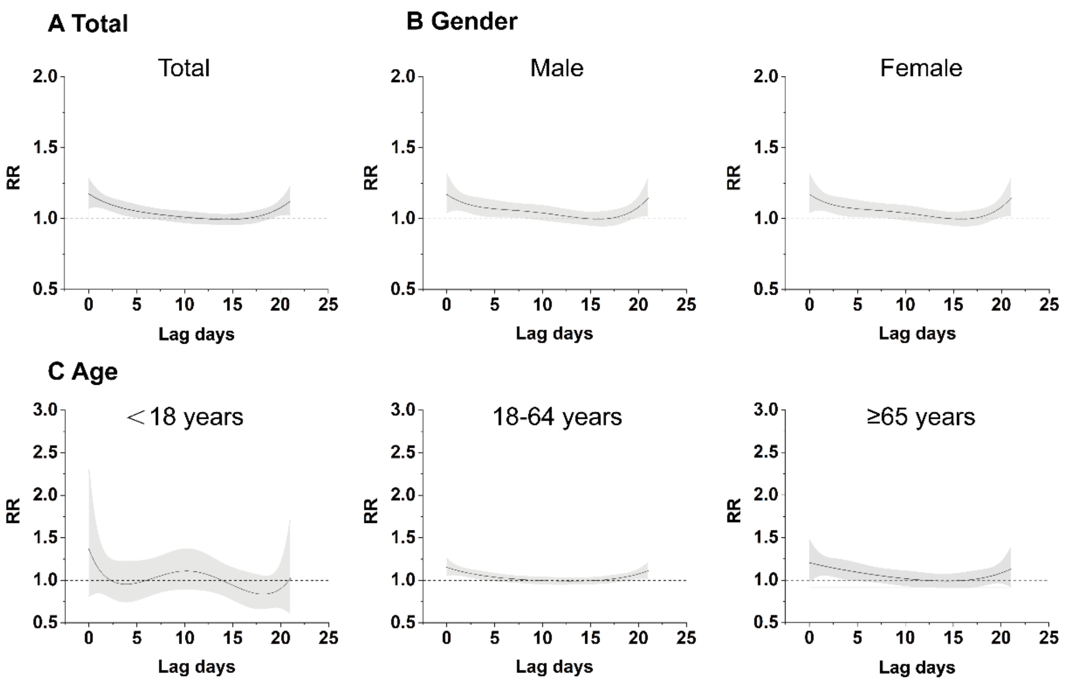
Supplemental table 7 Cumulative associations between 25th temperature and unintentional injury over 0-28 lag days



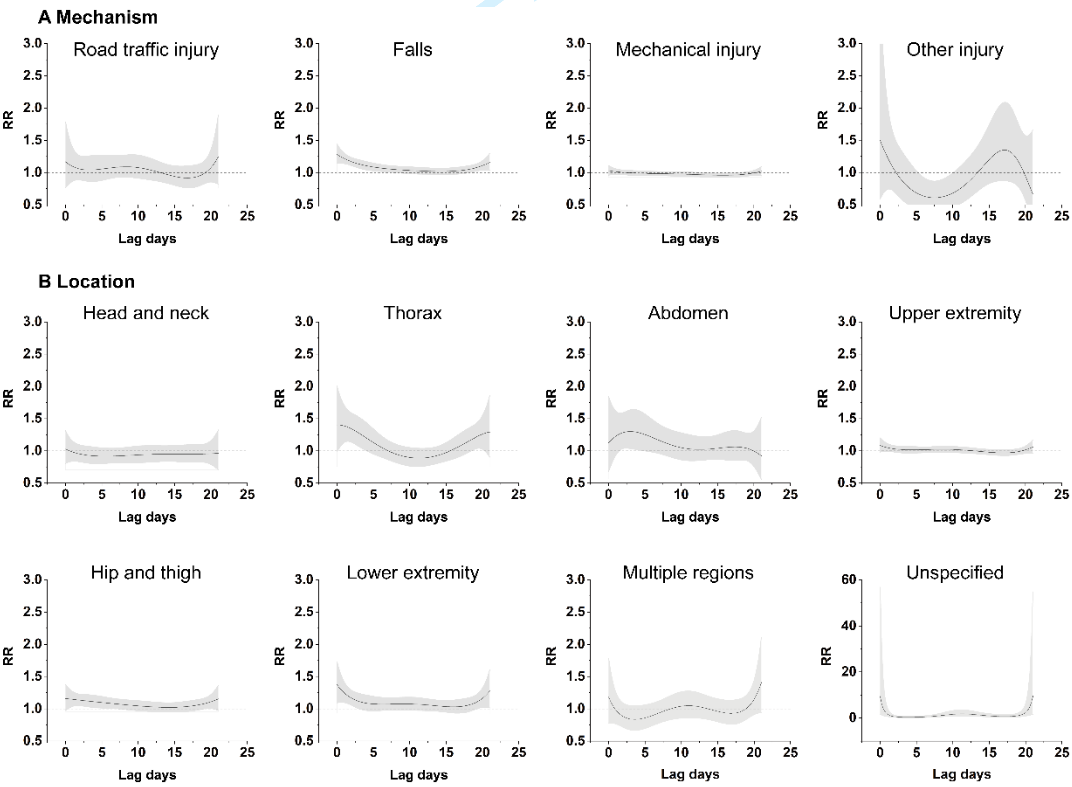
Supplemental figure 1 The location of Tianjin



Supplemental figure 2 Time series of daily counts of patients admitted with unintentional injuries



Supplemental figure 3 Cumulative associations between 25th temperature and unintentional injury over 0-21 lag days according to age or gender



Supplemental figure 4 Cumulative associations between 25th temperature and unintentional injury over 0-21 lag days according to injury mechanism or injury location

Supplemental table 1 **Correlations between the meteorological variables**

Weather variables	Barometric pressure	Mean temperature	Max temperature	Min temperature	Relative humidity	Precipitation	Average wind velocity
Barometric pressure	1.00	-	-	-	-	-	-
Mean temperature	**-0.87****	1.00	-	-	-	-	-
Max temperature	**-0.85****	**0.98****	1.00	-	-	-	-
Min temperature	-0.80**	**0.97****	**0.92****	1.00	-	-	-
Relative humidity	-0.25**	0.37**	0.29**	0.48**	1.00	-	-
Precipitation	-0.25**	0.29**	0.21**	0.38**	0.46**	1.00	-
Average wind velocity	-0.14**	0.07	0.05	0.08	-0.37**	0.02	1.00

**: *P*≤0.01; Bold font: The Spearman correlation coefficients were greater than 0.8.

Supplemental table 2 Descriptive statistics for daily meteorological variables

Meteorological variables	***Min***	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	***Max***
Mean temperature (°C)	-14.2	-1.1	4.9	14.2	23.6	27.0	30.3
Max temperature (°C)	-7.9	4.6	11.0	20.5	28.6	31.6	36.9
Min temperature (°C)	-19.9	-5.8	-0.5	9.2	19.1	22.8	26.5
Barometric pressure (hPa)	994.4	1002.9	1007.6	1016.4	1024.3	1028.7	1044.5
Relative humidity (%)	18.3	30.2	45.4	65.0	75.8	85.2	98.8
Precipitation (mm)	0.0	0.0	0.0	0.0	0.0	3.5	136.6
Average wind velocity (m/s)	0.7	1.4	1.8	2.4	3.1	4.1	8.0

Supplemental table 3 Epidemiology of patients admitted with unintentional injuries

Variable	n (%)
Total	12 241 (100%)
Gender	
Male	7 360 (60.13%)
Female	4 881 (39.9%)
Age	
< 18 years	1 118 (9.1%)
18-64 years	7 827 (63.9%)
≥ 65 years	3 296 (26.9%)
Mechanism	
Road traffic injury	1 571 (12.8%)
Falls	7 521 (61.4%)
Mechanical injury	2 830 (23.1%)
Other injury	319 (2.6%)
Location	
Head and neck	122 (1.0%)
Thorax	597 (4.9%)
Abdomen	548 (4.5%)
Upper extremity	4 375 (35.7%)
Hip and thigh	2 828 (23.1%)
Lower extremity	3 373 (27.6%)

Multiple regions in the body	176 (1.4%)
Unspecified	222 (1.8%)
Diagnosis	
Fracture	9 969 (81.4%)
Non-fracture	2 272 (18.6%)

Supplemental table 4 Cumulative associations between 10th temperature and unintentional injury over 0-14 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**	**7**	**…**	**14**
Total	1.30 (1.12, 1.50)	1.23 (1.14, 1.33)	1.13 (1.04, 1.22)	1.07 (1.00, 1.17)	1.06 (0.97, 1.12)		0.91 (0.78, 1.06)
Gender							
Male	1.27 (1.07, 1.50)	1.21 (1.11, 1.32)	1.13 (1.04, 1.24)	1.10 (1.02, 1.19)	1.09 (1.01, 1.19)		0.89 (0.75, 1.06)
Female	1.34 (1.09, 1.65)	1.25 (1.12, 1.40)	1.11 (1.00, 1.24)	1.02 (0.93, 1.12)	0.97 (0.88, 1.07)		0.93 (0.75, 1.15)
Age							
< 18 years	1.64 (0.86, 3.14)	1.16 (0.84, 1.60)	0.97 (0.70, 1.36)	1.06 (0.81, 1.39)	1.12 (0.84, 1.48)		1.92 (1.00, 3.68)
18-64 years	1.24 (1.069, 1.448)	1.21 (1.120, 1.31)	1.11 (1.03, 1.20)	1.03 (0.96, 1.10)	1.00 (0.93, 1.08)		0.84 (0.72, 0.97)
≥65 years	1.380 (1.038, 1.835)	1.27 (1.10, 1.47)	1.19 (1.03, 1.38)	1.16 (1.02, 1.31)	1.12 (0.98, 1.28)		0.96 (0.72, 1.28)
Mechanism							

Road traffic injury	1.38 (1.04, 1.84)	1.27 (1.10, 1.47)	1.19 (1.03, 1.38)	1.16 (1.02, 1.31)	1.12 (0.98, 1.28)		0.96 (0.72, 1.28)
Falls	1.58 (1.28, 1.95)	1.35 (1.22, 1.51)	1.17 (1.05, 1.31)	1.13 (1.03, 1.24)	1.12 (1.02, 1.24)		0.93 (0.75, 1.15)
Mechanical injury	1.08 (0.90, 1.30)	1.04 (0.95, 1.15)	1.00 (0.90, 1.10)	0.97 (0.90, 1.08)	0.97 (0.88, 1.06)		0.94 (0.79, 1.13)
Other injury	1.09 (0.34, 3.54)	1.43 (0.81, 2.51)	1.12 (0.63, 2.00)	0.64 (0.40, 1.03)	0.47 (0.28, 0.78)		0.85 (0.26, 2.71)
Location							
Head and neck	1.48 (0.73, 3.02)	0.93 (0.62, 1.37)	0.73 (0.49, 1.08)	0.84 (0.59, 1.19)	0.94 (0.62, 1.41)		1.17 (0.46, 2.93)
Thorax	2.05 (1.20, 3.51)	1.72 (1.29, 2.29)	1.51 (1.14, 2.01)	1.40 (1.09, 1.80)	1.15 (0.88, 1.52)		1.19 (0.69, 2.03)
Abdomen	1.00 (0.98, 1.02)	0.99 (0.98, 1.00)	0.99 (0.98, 1.01)	1.00 (0.99, 1.01)	1.01 (1.00, 1.02)		1.01 (0.99, 1.03)
Upper extremity	1.16 (0.95, 1.40)	1.09 (0.98, 1.20)	1.02 (0.92, 1.12)	1.01 (0.93, 1.10)	1.05 (0.95, 1.15)		0.86 (0.70, 1.04)
Hip and thigh	1.40 (1.01, 1.94)	1.19 (1.01, 1.41)	1.13 (0.95, 1.34)	1.20 (1.04, 1.38)	1.20 (1.04, 1.40)		1.09 (0.78, 1.52)
Lower extremity	1.58 (1.21, 2.07)	1.37 (1.20, 1.58)	1.14 (1.00, 1.32)	1.06 (0.94, 1.19)	1.04 (0.92, 1.18)		0.98 (0.75, 1.29)
Multiple regions	1.45 (0.66, 3.17)	1.03 (0.68, 1.56)	0.76 (0.51, 1.15)	0.79 (0.55, 1.13)	0.94 (0.65, 1.38)		0.88 (0.40, 1.94)

Unspecified	1.92 (0.27, 13.76)	1.57 (0.62, 4.00)	0.57 (0.23, 1.42)	0.27 (0.12, 0.61)	0.33 (0.14, 0.78)		0.34 (0.05, 2.40)
Diagnosis							
Fracture	1.45 (1.23, 1.71)	1.28 (1.17, 1.39)	1.12 (1.03, 1.22)	1.09 (1.01, 1.17)	1.08 (1.00, 1.16)		0.96 (0.81, 1.13)
Non-fracture	1.14 (0.84, 1.55)	0.98 (0.83, 1.16)	0.92 (0.79, 1.08)	0.99 (0.86, 1.14)	1.04 (0.89, 1.20)		1.34 (1.00, 1.79)

Supplemental table 5 Cumulative associations between 25th temperature and unintentional injury over 0-14 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**		**…**	**14**
Total	1.15 (1.04, 1.27)	1.12 (1.07, 1.18)	1.08 (1.02, 1.14)	1.05 (1.01, 1.10)	1.03 (0.99, 1.08)		0.95 (0.85, 1.05)
Gender							
Male	1.14 (1.01, 1.28)	1.12 (1.05, 1.18)	1.08 (1.02, 1.15)	1.06 (1.01, 1.11)	1.06 (1.00, 1.11)		0.93 (0.82, 1.04)
Female	1.16 (1.02, 1.32)	1.13 (1.05, 1.21)	1.07 (1.00, 1.15)	1.03 (0.97, 1.09)	0.99 (0.93, 1.06)		0.98 (0.85, 1.12)
Age							
＜18 years	1.44 (0.80, 2.61)	1.10 (0.82, 1.47)	0.97 (0.72, 1.31)	1.06 (0.84, 1.35)	1.11 (0.86, 1.42)		1.79 (1.00, 3.20)
18-64 years	1.11 (1.01, 1.22)	1.11 (1.06, 1.16)	1.07 (1.02, 1.12)	1.02 (0.98, 1.07)	1.01 (0.96, 1.05)		0.90 (0.82, 0.99)
≥65 years	1.21 (0.97, 1.50)	1.16 (1.04, 1.28)	1.11 (1.00, 1.24)	1.09 (1.00, 1.20)	1.07 (0.97, 1.18)		0.97 (0.78, 1.20)
Mechanism							

Road traffic injury	1.21 (0.97, 1.50)	1.16 (1.04, 1.28)	1.11 (1.00, 1.24)	1.09 (1.00, 1.20)	1.07 (0.97, 1.18)		0.97 (0.77, 1.20)
Falls	1.31 (1.12, 1.53)	1.19 (1.10, 1.28)	1.10 (1.02, 1.20)	1.10 (1.03, 1.17)	1.10 (1.02, 1.17)		0.97 (0.830, 1.14)
Mechanical injury	1.02 (0.93, 1.12)	1.01 (0.97, 1.07)	1.00 (0.96, 1.05)	0.99 (0.95, 1.03)	0.98 (0.94, 1.03)		0.96 (0.88, 1.06)
Other injury	1.43 (0.48, 4.27)	1.31 (0.78, 2.20)	0.91 (0.54, 1.53)	0.64 (0.42, 0.980)	0.56 (0.36, 0.88)		1.06 (0.37, 3.02)
Location							
Head and neck	1.14 (0.86, 1.51)	0.97 (0.83, 1.14)	0.91 (0.77, 1.06)	0.96 (0.83, 1.10)	0.98 (0.84, 1.16)		1.07 (0.74, 1.54)
Thorax	1.43 (1.02, 2.01)	1.34 (1.12, 1.59)	1.27 (1.06, 1.51)	1.20 (1.03, 1.40)	1.06 (0.90, 1.25)		1.19 (0.84, 1.69)
Abdomen	1.01 (0.80, 1.28)	0.91 (0.81, 1.03)	0.93 (0.83, 1.05)	1.04 (0.94, 1.16)	1.10 (0.97, 1.23)		1.09 (0.87, 1.36)
Upper extremity	1.07 (0.95, 1.20)	1.05 (0.99, 1.11)	1.02 (0.96, 1.08)	1.01 (0.96, 1.06)	1.03 (0.97, 1.08)		0.91 (0.81, 1.03)
Hip and thigh	1.23 (0.94, 1.60)	1.08 (0.95, 1.22)	1.05 (0.92, 1.20)	1.13 (1.01, 1.26)	1.15 (1.02, 1.29)		1.13 (0.87, 1.48)
Lower extremity	1.30 (1.07, 1.59)	1.21 (1.10, 1.34)	1.09 (0.99, 1.21)	1.04 (0.96, 1.13)	1.04 (0.95, 1.13)		0.95 (0.78, 1.16)
Multiple regions	1.11 (0.78, 1.56)	1.01 (0.85, 1.21)	0.91 (0.76, 1.09)	0.90 (0.77, 1.05)	0.95 (0.80, 1.12)		0.91 (0.64, 1.29)

Unspecified	2.30 (0.34, 15.74)	1.58 (0.63, 3.94)	0.55 (0.23, 1.33)	0.30 (0.14, 0.65)	0.40 (0.18, 0.89)		0.54 (0.06, 3.38)
Diagnosis							
Fracture	1.23 (1.10, 1.37)	1.15 (1.08, 1.21)	1.08 (1.02, 1.14)	1.06 (1.01, 1.11)	1.05 (1.00, 1.11)		0.98 (0.87, 1.10)
Non-fracture	1.20 (0.79, 1.83)	0.97 (0.77, 1.22)	0.89 (0.72, 1.11)	0.98 (0.81, 1.19)	1.06 (0.86, 1.29)		1.50 (1.01, 2.24)

Supplemental table 6 Cumulative associations between 10th temperature and unintentional injury over 0-28 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**	**7**	**…**	**28**
Total	1.39 (1.23, 1.56)	1.30 (1.20, 1.41)	1.17 (1.10, 1.25)	1.09 (1.03, 1.17)	1.05 (0.99, 1.11)		1.08 (0.97, 1.21)
Gender							
Male	1.35 (1.16, 1.58)	1.29 (1.16, 1.44)	1.20 (1.11, 1.30)	1.14 (1.05, 1.23)	1.10 (1.02, 1.180)		1.12 (0.97, 1.30)
Female	1.44 (1.22, 1.72)	1.31 (1.16, 1.48)	1.13 (1.03, 1.24)	1.03 (0.94, 1.13)	0.98 (0.90, 1.06)		1.08 (0.92, 1.27)
Age							
< 18 years	1.33 (0.92, 1.93)	1.19 (0.92, 1.53)	1.04 (0.86, 1.26)	1.01 (0.84, 1.23)	1.03 (0.87, 1.24)		1.14 (0.81, 1.60)
18-64 years	1.36 (1.19, 1.55)	1.27 (1.16, 1.39)	1.14 (1.07, 1.22)	1.06 (0.99, 1.14)	1.02 (0.95, 1.09)		1.08 (0.95, 1.22)
≥65 years	1.48 (1.15, 1.91)	1.42 (1.19, 1.68)	1.29 (1.14, 1.47)	1.19 (1.04, 1.35)	1.12 (0.99, 1.25)		1.08 (0.84, 1.37)

Mechanism							
Road traffic injury	1.13 (0.76, 1.67)	1.16 (0.89, 1.51)	1.19 (0.99, 1.44)	1.18 (0.98, 1.43)	1.15 (0.96, 1.37)		1.24 (0.86, 1.81)
Falls	1.64 (1.39, 1.95)	1.48 (1.32, 1.67)	1.27 (1.17, 1.39)	1.16 (1.06, 1.26)	1.10 (1.01, 1.19)		1.14 (0.97, 1.34)
Mechanical injury	1.05 (0.92, 1.20)	1.04 (0.95, 1.14)	1.01 (0.94, 1.09)	0.98 (0.91, 1.05)	0.95 (0.89, 1.02)		0.99 (0.88, 1.11)
Other injury	1.94 (0.81, 4.63)	1.35 (0.74, 2.44)	0.83 (0.54, 1.28)	0.66 (0.43, 1.02)	0.63 (0.4, 0.93)		0.82 (0.35, 1.88)
Location							
Head and neck	1.21 (0.60, 2.44)	1.01 (0.61, 1.67)	0.81 (0.54, 1.20)	0.740 (0.50, 1.10)	0.74 (0.50, 1.07)		1.76 (0.85, 3.64)
Thorax	2.27 (1.40, 3.68)	1.98 (1.42, 2.77)	1.53 (1.19, 1.98)	1.23 (0.95, 1.59)	1.04 (0.82, 1.31)		0.95 (0.58, 1.54)
Abdomen	1.46 (0.90, 2.36)	1.40 (1.00, 1.95)	1.29 (1.01, 1.66)	1.21 (0.94, 1.55)	1.14 (0.90, 1.43)		1.09 (0.69, 1.73)
Upper extremity	1.13 (0.95, 1.34)	1.12 (1.10, 1.26)	1.10 (1.00, 1.19)	1.07 (0.98, 1.16)	1.04 (0.96, 1.13)		1.10 (0.942, 1.282)
Hip and thigh	1.42 (1.14, 1.78)	1.34 (1.15, 1.57)	1.23 (1.10, 1.39)	1.16 (1.03, 1.31)	1.12 (1.00, 1.25)		1.09 (0.88, 1.34)
Lower extremity	1.69 (1.36, 2.10)	1.49 (1.28, 1.73)	1.24 (1.11, 1.39)	1.11 (1.10, 1.25)	1.06 (0.95, 1.17)		1.11 (0.90, 1.37)

Multiple regions	1.05 (0.57, 1.95)	0.93 (0.60, 1.43)	0.81 (0.59, 1.12)	0.80 (0.58, 1.12)	0.85 (0.62, 1.17)		0.91 (0.52, 1.59)
Unspecified	2.65 (0.66, 10.76)	1.59 (0.63, 4.02)	0.83 (0.42, 1.64)	0.64 (0.31, 1.30)	0.63 (0.32, 1.23)		2.08 (0.50, 8.72)
Diagnosis							
Fracture	1.47 (1.29, 1.67)	1.36 (1.24, 1.49)	1.20 (1.12, 1.29)	1.11 (1.03, 1.19)	1.05 (0.99, 1.12)		1.07 (0.94, 1.21)
Non-fracture	1.09 (0.87, 1.35)	1.07 (0.92, 1.25)	1.05 (0.93, 1.17)	1.03 (0.91, 1.15)	1.00 (0.90, 1.12)		1.15 (0.94, 1.40)

Supplemental table 7 Cumulative associations between 25th temperature and unintentional injury over 0-28 lag days

Subgroups	**Lag**						
	0	**1**	**3**	**5**	7	**…**	**28**
Total	1.21 (1.11, 1.32)	1.17 (1.10, 1.24)	1.11 (1.06, 1.16)	1.07 (1.02, 1.12)	1.04 (1.10, 1.08)		1.06 (0.98, 1.15)
Gender							
Male	1.21 (1.06, 1.37)	1.17 (1.08, 1.28)	1.13 (1.06, 1.20)	1.09 (1.02, 1.16)	1.07 (1.00, 1.13)		1.12 (0.98, 1.26)
Female	1.22 (1.09, 1.37)	1.17 (1.08, 1.27)	1.09 (1.03, 1.15)	1.03 (0.97, 1.10)	1.00 (0.95, 1.06)		1.04 (0.93, 1.16)
Age							
< 18 years	1.18 (0.91, 1.53)	1.10 (0.92, 1.32)	1.02 (0.90, 1.17)	1.01 (0.88, 1.15)	1.02 (0.90, 1.15)		1.11 (0.87, 1.42)
18-64 years	1.19 (1.09, 1.30)	1.15 (1.08, 1.23)	1.09 (1.04, 1.14)	1.05 (1.00, 1.10)	1.02 (0.98, 1.07)		1.06 (0.97, 1.15)
≥65 years	1.28 (1.03, 1.58)	1.24 (1.08, 1.44)	1.18 (1.06, 1.31)	1.12 (1.01, 1.25)	1.07 (0.97, 1.18)		1.05 (0.86, 1.30)
Mechanism							

Road traffic injury	1.10 (0.77, 1.58)	1.14 (0.89, 1.44)	1.16 (0.98, 1.37)	1.15 (0.96, 1.36)	1.11 (0.95, 1.30)		1.21 (0.86, 1.71)
Falls	1.35 (1.18, 1.54)	1.28 (1.17, 1.40)	1.18 (1.10, 1.26)	1.11 (1.04, 1.19)	1.08 (1.01, 1.15)		1.11 (0.98, 1.26)
Mechanical injury	1.01 (0.96, 1.07)	1.01 (0.97, 1.06)	1.01 (0.97, 1.04)	0.99 (0.96, 1.03)	0.98 (0.96, 1.01)		0.99 (0.94, 1.04)
Other injury	1.75 (0.79, 3.88)	1.21 (0.71, 2.07)	0.76 (0.52, 1.11)	0.62 (0.42, 0.91)	0.61 (0.43, 0.87)		0.79 (0.37, 1.67)
Location							
Head and neck	1.08 (0.74, 1.56)	1.01 (0.77, 1.32)	0.93 (0.76, 1.14)	0.90 (0.73, 1.10)	0.89 (0.73, 1.08)		1.30 (0.89, 1.89)
Thorax	1.64 (1.13, 2.40)	1.50 (1.16, 1.94)	1.28 (1.06, 1.54)	1.13 (0.93, 1.37)	1.04 (0.87, 1.24)		1.11 (0.76, 1.63)
Abdomen	1.26 (0.87, 1.82)	1.27 (0.98, 1.63)	1.25 (1.04, 1.51)	1.21 (1.00, 1.46)	1.16 (0.98, 1.38)		1.02 (0.72, 1.45)
Upper extremity	1.07 (0.95, 1.20)	1.07 (0.99, 1.16)	1.06 (1.00, 1.13)	1.05 (0.99, 1.11)	1.03 (0.98, 1.09)		1.06 (0.95, 1.18)
Hip and thigh	1.22 (1.05, 1.42)	1.18 (1.07, 1.31)	1.13 (1.05, 1.22)	1.10 (1.02, 1.19)	1.07 (1.00, 1.15)		1.08 (0.94, 1.25)
Lower extremity	1.37 (1.16, 1.63)	1.28 (1.14, 1.44)	1.16 (1.07, 1.26)	1.09 (1.00, 1.19)	1.06 (0.98, 1.15)		1.07 (0.91, 1.26)
Multiple regions	1.01 (0.78, 1.33)	0.96 (0.80, 1.16)	0.908 (0.789, 1.044)	0.900 (0.781, 1.038)	0.920 (0.804, 1.053)		0.957 (0.749, 1.223)

Unspecified	2.76 (0.71, 10.73)	1.62 (0.66, 3.97)	0.84 (0.44, 1.62)	0.67 (0.34, 1.33)	0.70 (0.37, 1.32)		1.98 (0.50, 7.86)
Diagnosis							
Fracture	1.25 (1.14, 1.38)	1.20 (1.13, 1.28)	1.13 (1.08, 1.18)	1.08 (1.03, 1.13)	1.05 (1.00, 1.09)		1.05 (0.96, 1.15)
Non-fracture	1.05 (0.90, 1.21)	1.04 (0.94, 1.16)	1.04 (0.96, 1.12)	1.02 (0.95, 1.10)	1.01 (0.94, 1.08)		1.10 (0.95, 1.26)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	√ P.1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	√ P.1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	√ P.3
Objectives	3	State specific objectives, including any prespecified hypotheses	√ P.3-4
Methods			
Study design	4	Present key elements of study design early in the paper	√ P.4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	√ P.4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	√ P.4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	√ P.5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	√ P.5-6
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	√ P.4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	√ P.5-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	√ P.6-10
		(*b*) Describe any methods used to examine subgroups and interactions	√ P.9
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	√ P.10
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	√ P.11-12
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	√ P.11-12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	√ P. 11-12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	√ P.12-15
		(*b*) Report category boundaries when continuous variables were categorized	√ P.12-15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	√ P.12-15
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	√ P.12-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	√ P.16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	√ P.21
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	√ P.16 - 20
Generalisability	21	Discuss the generalisability (external validity) of the study results	√ P.16 and 20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	√ P.23

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.