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# Temperature-related emergency injury visits in Hanoi, Vietnam

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## ABSTRACT

**Background** The short-term association between increasing temperatures and injury has been described in high-income countries, but less is known for low-income and middle-income countries, including Vietnam.

**Methods** We used emergency injury visits (EIV) data for 2017–2019 from 733 hospitals and clinics in Hanoi, Vietnam to examine the effects of daily temperature on EIV. Time-series analysis with quasi-Poisson models was used to estimate a linear relative risk increase (RRI) for overall populations and ones stratified by age and sex. Exposure–response curves estimated non-linear associations as an RR between daily temperature and injury. Models were adjusted for the day of week, holidays, daily relative humidity, daily particulate matter, and long-term and seasonal trends.

**Results and conclusions** A total of 39 313 EIV were recorded averaging 36 injuries daily. Injuries more likely occurred in males and those aged 15–44, and aged 44–60. For linear effects, a 5°C increase in same day mean temperature was associated with an overall increased EIV (RRI 4.8; 95% CI 2.3 to 7.3) with males (RRI 5.9; 95% CI 3.0 to 8.9) experiencing a greater effect than females (RRI 3.0; 95% CI –0.5 to 6.5). Non-linear effects showed an increase in EIV at higher temperatures compared with the threshold temperature of 15°C, with the greatest effect at 33°C (RR 1.3; 95% CI 1.2 to 1.6). Further research to investigate temperature–injury among different populations and by the cause of injury is warranted.

## INTRODUCTION

Injury is a leading factor in the global burden of morbidity and mortality and has significant economic consequences. Injuries take the lives of 4.4 million people worldwide each year, accounting for nearly 8% of all deaths.<sup>1</sup> The economic burden of injury is substantial and can impact national economies due to loss of life, medical care expenditures and decreased worker productivity. In the USA, the Centers for Disease Control and Prevention reported that the economic cost of injury was US\$4.2 trillion, including US\$327 billion in medical care, US\$69 billion in work loss and US\$3.8 trillion in statistical life and quality of life losses in 2019.<sup>2</sup> In Thai Binh, Vietnam, a study estimated that the mean total costs of injury by 12-month postdischarge were nearly 1.2 times higher than the annual average income.<sup>3</sup>

The existing literature has supported an association of increasing injuries during elevated temperatures in high-income countries, but few studies have

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Exposure to high temperature is associated with adverse health effects, including injuries. The relationship between temperature and injuries has psychological underpinnings and has been assessed in epidemiological studies from high-income countries. Less is known the temperature and injury relationship in low-income and middle-income countries, which have unique populations that are often most vulnerable to extreme weather events.

## WHAT THIS STUDY ADDS

⇒ Increasing temperature is associated with emergency injury visits in Hanoi, Vietnam.  
⇒ Temperature-related injuries were more likely occur in males and people aged 15–44, and aged 45–60 years (a working age group).

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Further research to investigate temperature–injury associations among different populations and by cause of injury is warranted.  
⇒ Policy-makers and public health researchers need to develop guidelines for heat-related emergency injury visits for different age groups and incorporate risk of emergency injury visits into heat adaptation plans.  
⇒ Healthcare facilities should communicate with medical staff and plan for increased emergency injury visits on extreme heat days.

been conducted in low-income and middle-income countries (LMICs).<sup>4,5</sup> Males and younger workers are identified as higher risk for temperature-related injury,<sup>6,7</sup> while older adults have a higher risk of fall-related injury during winter.<sup>5,8</sup> A study in Seoul, South Korea, indicated that unintentional injury increased at both high and low temperature extremes, but intentional injury increased only at high temperatures.<sup>5</sup> Hot days were also associated with all-cause injury-related, vehicle crash-related, accidental fall-related and heat-related hospital visits in New Hampshire, USA.<sup>4</sup> A review of injuries in high-income countries estimated that the risk of injury increased 0.4%–5.3% with each 1°C increase in temperature.<sup>9</sup> A single-city study reported that high temperatures increased the risk of fall-related injury at lag 0, and the effects of ambient temperature varied in age and gender.<sup>8</sup>

Vietnam, an LMIC, has suffered from a heavy toll of the burden of injury. The aged-standardised



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incidence rate of all injuries increased by 14.6% (11.5%–18.2%) between 2007 and 2017.<sup>10</sup> Moreover, the average total medical care costs paid out-of-pocket for hospitalisation due to injury was US\$270, which is higher than the 1-month average wage for Vietnamese people (US\$180).<sup>11</sup> The costs were higher for more severe injuries and complex surgeries.<sup>12</sup> Moreover, Hanoi is undergoing rapid change in population density,<sup>13</sup> which may increase the risk of temperature change on human health. In this study, we present an analysis of the association between daily ambient temperature and emergency visits due to injury in Hanoi, Vietnam, from 2017 to 2019.

## METHODS

We conducted a 3-year retrospective time-series analysis to explore the short-term effects of acute temperature on emergency visits due to injury within the 30 districts of Hanoi, Vietnam.

### Emergency injury visits

The study outcome was the daily count of emergency injury visits (EIV). EIV data were derived from a dataset of all hospitalisations in Hanoi from January, 2017 to December, 2019 provided by Hanoi Social Security (HSS), Hanoi's governmental insurance organisation. The dataset included information from 733 hospitals and clinics, located in Hanoi, with all 27 national hospitals, 110 provincial and district hospitals, and 596 public and private clinics. The HSS captures all healthcare encounters in these covered sites and the summary information required for appropriate payment of medical costs is systematically recorded. This includes primary diagnoses and an indication if it is an emergency encounter. Diagnoses and collected information was verified by HSS before paying for patient emergency visits. Data were acquired through a request form to HSS to extract only necessary information to create a limited deidentified dataset without information such as patient identifiers or medical costs. Patients with missing data were removed from our dataset. Permission for data use was acquired from HSS and approval by the University of Minnesota Institutional review board.

All records designated as a first-time emergency visit (ie, not a follow-up visit) were included for review. The data included the date of admission and discharge, age, gender, primary diagnosis and residence status. These administrative data were limited by one diagnostic code per visit; thus, injury was designated by either an external cause or an injury diagnosis. For this analysis, we included all diagnoses indicating an unintentional injury, which were classified by the 10th revision of International Classification of Diseases. External causes of injury (S00–T32), accidents (V01–X59) and other injury-related factors (T66–T78, Y20–Y34 and Y90–Y98) were selected (online supplemental table S1). Visits from patients living outside Hanoi were excluded based on their residence status.

### Atmospheric conditions

Atmospheric data included daily mean and maximum temperatures (°C), daily relative humidity (RH) (%) and daily fine particulate matter (PM<sub>2.5</sub>) (μg/m<sup>3</sup>). Atmospheric data were obtained from The Hanoi Environment and Natural Resource Department and Vietnam Environment Administration, which manages 12 monitors measuring 24-hour weather data in Hanoi. Estimates of daily environmental measures based on the average of hourly data were calculated from the 24-hour data of each monitor after removal of illogical measurements, for example,

humidity over 100%. This approach has been applied on previous research.<sup>14–16</sup>

### Data analysis

Time-series analysis with quasi-Poisson models were fitted to estimate the short-term effects of temperature on EIV on both linear and non-linear scales. The quasi-Poisson is a variant of the Poisson model that allows for potential scaled overdispersion in the data that can result from days with zero EIVs.<sup>17</sup> We also examined delayed effects (lagged effects) of temperature on emergency visits based on potential evidence from previous studies that found relationships between exposures and outcomes for up to 5 days.<sup>5 18</sup> The 0 day of lag represents the first day of temperature exposure on the day of an EIV. Lags of 1, 2, 3, 4 and 5 days represent the emergency visit on those days after an exposure event has taken place. It is possible that patients may delay seeking medical care after an injury has occurred, necessitating the need to assess a lagged response.

For both linear and non-linear effect models, we adjusted for time (defined by the count of days from 1 January 2017 to 31 December 2019), the day of week, holiday, daily RH and daily PM<sub>2.5</sub> as potential confounding factors. Smooth function of time (natural cubic splines) with 7 df per year was used to adjust for long-term and seasonal trends. Previous studies showed that 7 df provide adequate control for seasonality and another confounding by trends in time.<sup>19 20</sup> The day of week was used to control for variable baseline emergency visits by day. We controlled for daily mean PM<sub>2.5</sub> and daily mean RH using natural cubic splines with 3 df on the same day. Holiday was a binary indicator classified as holiday or non-holiday. Holidays included all Vietnamese public holidays, including New Year's Eve, Lunar New Year's Event, Labour Day, Independence Day and the preceding Friday or following Monday if a holiday falls on a Saturday or Sunday (<https://www.officeholidays.com/countries/vietnam/2020>).

The linear effects were reported as percentage increase in the relative risk increase (RRI) of EIVs occurring for each 5°C increase in daily mean temperature and the RRI of injury for each quintile of daily mean temperature. The RRI was calculated as the (relative risk–1)×100 and was used to make relative risks of small magnitude more easily interpretable. We examined the sensitivity of our findings with respect to df in the smooth functions of time (5 and 9 df); df in the smooth functions of daily RH and daily PM<sub>2.5</sub> (4 and 5 df); and using daily maximum or daily minimum temperature instead of daily mean temperature.

To examine non-linear effects, distributed lag non-linear models (DLNMs) were fitted with quasi-Poisson regressions. The relative risk was interpreted as the effect of the exposure vs a reference and reported as both distributed lag effects and individual lag days.<sup>21</sup> All covariates were similar to linear models, day of week, holiday, time, RH and PM<sub>2.5</sub>. DLNMs use a cross-basis function to describe two-dimensional temperature–injury associations along the dimensions of temperature and lag.<sup>22</sup> We choose 5 df for daily temperature and 4 df for lag. In this study, the centring value was 15°C which equals the second percentile of daily temperature to demonstrate the change in risk from a low-temperature exposure point. We fitted separate models to evaluate variation in estimated risks across total visits, different age groups and gender using single-day temperature lag models from 0 to 5 days. For sensitivity analysis, we examined 5 and 9 df, 4 and 6 df, and 2 and 4 df for time, daily temperature and lag, respectively. All models were performed using the R Statistical software, V.4.2.0 (<https://www.r-project.org/>)

**Table 1** Descriptive statistics for daily emergency visits and daily atmospheric conditions in Hanoi, Vietnam

	Total injuries (%)	Mean daily injuries±SD	Range of injuries
Daily injury visits			
Total	39 313 (100)	35.9±16.7	4; 92
Daily injury visits by gender			
Male	23 855 (60.8)	21.9±10.1	1; 56
Female	15 458 (39.2)	14.1±7.6	0; 45
Daily injury visits by age groups			
<15	13 154 (33.2)	12.0±6.1	1; 34
15–44	13 023 (33.2)	11.9±5.9	0; 35
45–60	6859 (16.5)	6.2±3.8	0; 21
≥60	6277 (17.1)	5.8±4.2	0; 24
Daily atmospheric conditions			
	Total data days (%)	Mean daily conditions±SD	Range of conditions
Temperature (°C)	1093* (99.8)	26.5±5.5	10.6; 38.5
RH (%)	1093* (99.8)	64.5±13.5	35.7; 88.1
PM <sub>2.5</sub> (µg/m <sup>3</sup> )	1093* (99.8)	38.6±18.5	5.3; 140.5

\*Number of days having atmospheric data.

PM<sub>2.5</sub>, particulate matter; RH, relative humidity.

### Patient and public involvement

No patients with identifiable information were involved in this records-based study.

### RESULTS

There were 39 313 emergency visits due to injury across all districts of Hanoi over the study period with an average of 36 injuries per day (table 1). The percentage of visits for males (60.8%) was higher than for females (39.2%) though the population of Hanoi is evenly distributed by gender. Those under the age of 15 or over 45 were modestly over-represented in injury occurrence when compared with the population of Hanoi. The trend of daily emergency visits increased from 2017 to 2019 (online supplemental figures S1 and S2). The daily mean temperature was 26.5°C and ranged from 10.6°C to 38.5°C (table 1). We observed high proportion of available data for atmospheric conditions with 99.8%.

From the linear effects models, a 5°C increase in same day mean temperature was associated with a 4.7% (95% CI 2.3% to 7.2%) increase in the occurrence of EIV (table 2). If average temperatures were 5°C higher, this would equate to an additional 621 (95% CI 304 to 947) annual injury-related emergency visits. The RRI differed by sex, with males experiencing a greater effect than females; RRI 5.9% (95% CI 3.0% to 8.9%) and RRI 3.0% (95% CI -0.5% to 6.5%), respectively. The temperature-injury association differed by age groups with the lowest association in people aged 60 and older (RRI 1.3%, 95%CI -3.2% to 6.2%) but was similar in the other age groups. When stratified by age and gender there was considerable heterogeneity of the effect estimates by gender for ages 45 and older, with a null or negative effect for females. The highest effect is among males aged 45–59 (RRI 10.7, 95% CI 3.7 to 18.3) and the lowest effect is among females aged 60 and older (RRI -1.4, 95% CI -7.6 to 5.3).

The evaluation of injury visits by quintile of temperature supported a general trend of increased number of EIV with increasing temperature. We observed for both gender and age groups that people exposed to temperatures in quintiles 2–5 had

**Table 2** The estimated relative risk increase (RRI) of emergency injury visits for each 5°C increase in daily mean temperature by total visits and stratified by age and gender (lag 0)

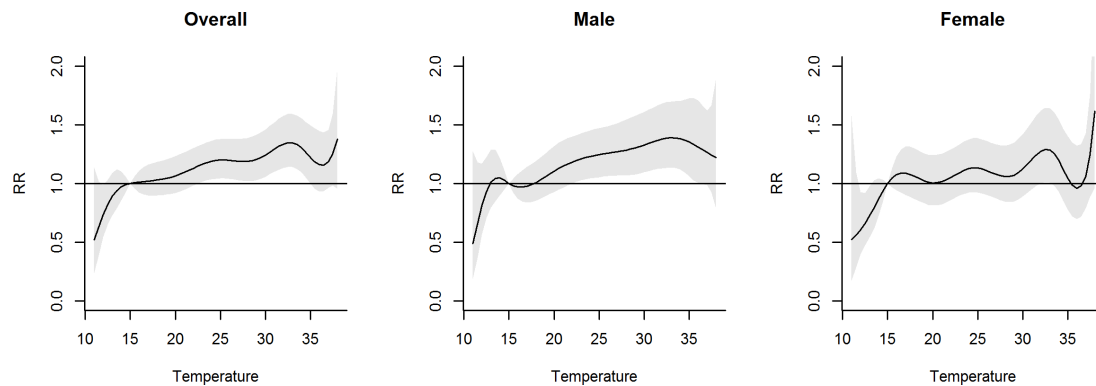
	RRI	95% CI
Total injury	4.7	2.3 to 7.2
Stratified by gender		
Male	5.9	3.0 to 8.9
Female	3.0	-0.5 to 6.5
Stratified by age (years)		
<15	5.0	1.2 to 9.0
15–44	5.6	1.8 to 9.6
59	5.8	0.5 to 11.3
60	1.3	-3.2 to 6.2
Stratified by age and gender		
<15 years		
Male	4.3	2.1 to 10.6
Female	6.8	0.3 to 13.9
15–44 years		
Male	5.9	1.1 to 10.1
Female	5.2	-0.6 to 11.4
59 years		
Male	10.7	3.7 to 18.3
Female	-0.8	-8.1 to 7.2
60 years		
Male	4.9	-2.5 to 12.8
Female	-1.4	-7.6 to 5.3
Adjusted by day of week, holiday, time, RH and PM <sub>2.5</sub>		

elevated EIV compared with those in Q1 (<21.30°C) (online supplemental table S2). The RRIs within gender are similar to the RRIs shown in table 2 with temperature associated injury for males greater than females. A positive association was generally observed across age groups, but the estimates in people over 60 years were statistically imprecise.

In the non-linear effects model, we observed an increase in EIV at higher temperatures compared with the threshold exposure of 15°C (figure 1). The temperature-injury curves differed between males and females and echoed the results from the linear and categorical models. For males, the curve increases to 33°C, at which point the association decreases in an inverted U-shape response. For females, however, the curve fluctuated and then reached the highest at the highest temperature, however the estimates in these upper temperature ranges were less precise with a high degree of uncertainty in the exposure-response curves.

When stratified by age category and gender, the non-linear effects models reinforce the variability in temperature associated injury. The associations are most apparent among people aged 15–44 but were null to inversely associated among people aged 60 and older. The temperature-injury curve shows an increase in EIV above 15°C among females aged 15–44, however, males aged 15–44 showed no increase below 25°C (figure 2). Other models indicated that males had a more EIV than females when exposed to increased temperature.

We examined the potential lagged associations between temperature and injury visits stratified by gender and age, in both linear and non-linear effects (online supplemental table S3, figures S3 and S4). In linear effect estimates, total visits showed similar results at lag 0–4 with decreasing association at lag 5. Males and people aged 60 and older showed the highest effect at lag 0, while females and people aged under 15 showed the



**Figure 1** Plot of non-linear exposure–response association curves between daily mean temperature and emergency injury visits for all, males and females. Shaded areas denote 95% CIs. Adjusted by day of week, holiday, RH, PM2.5 and time. Referencing temperature is at 15°C. PM2.5, particulate matter; RH, relative humidity; RR, relative risk.

highest effect by lag 3. All age groups presented the lowest estimated association at lag 5. Overall, we observed some evidence of delayed effects between temperature and emergency visits due to injury with differing associations by gender and age groups.

To assess the sensitivity of our models, we fitted models with varying df for time and using alternate exposures of minimum and maximum temperature (online supplemental tables S4–S6). Overall, these changes did not result in substantive variation in the estimates or the interpretation of the models (online supplemental figures S5–S7). In non-linear models, the variation was most apparent in age-stratified models with adjusted df for time. For males and females, we observed attenuated exposure–response curves, but the trends remained increasing.

## DISCUSSIONS

We observed a short-term positive association between daily temperature and the number of emergency visits due to injury in Hanoi, Vietnam. If average daily temperatures increased by 3 df, this would be associated with an estimated 372 additional EIV, while a 5 df average increase would result in an additional 621 EIV. The effect differed by gender and age with males and people under age 60 most likely to be represented in the number of EIV as the temperature increases. Moreover, the non-linear analysis indicated the association may vary over the range of temperature for the population combined and within subgroups, which may indicate potentially different mechanisms of effect. The relationship between temperature and injury has not been previously studied in Vietnam, despite being a nation with both a large population that work outdoors and being geographically at risk from increasing temperatures due to climate change.

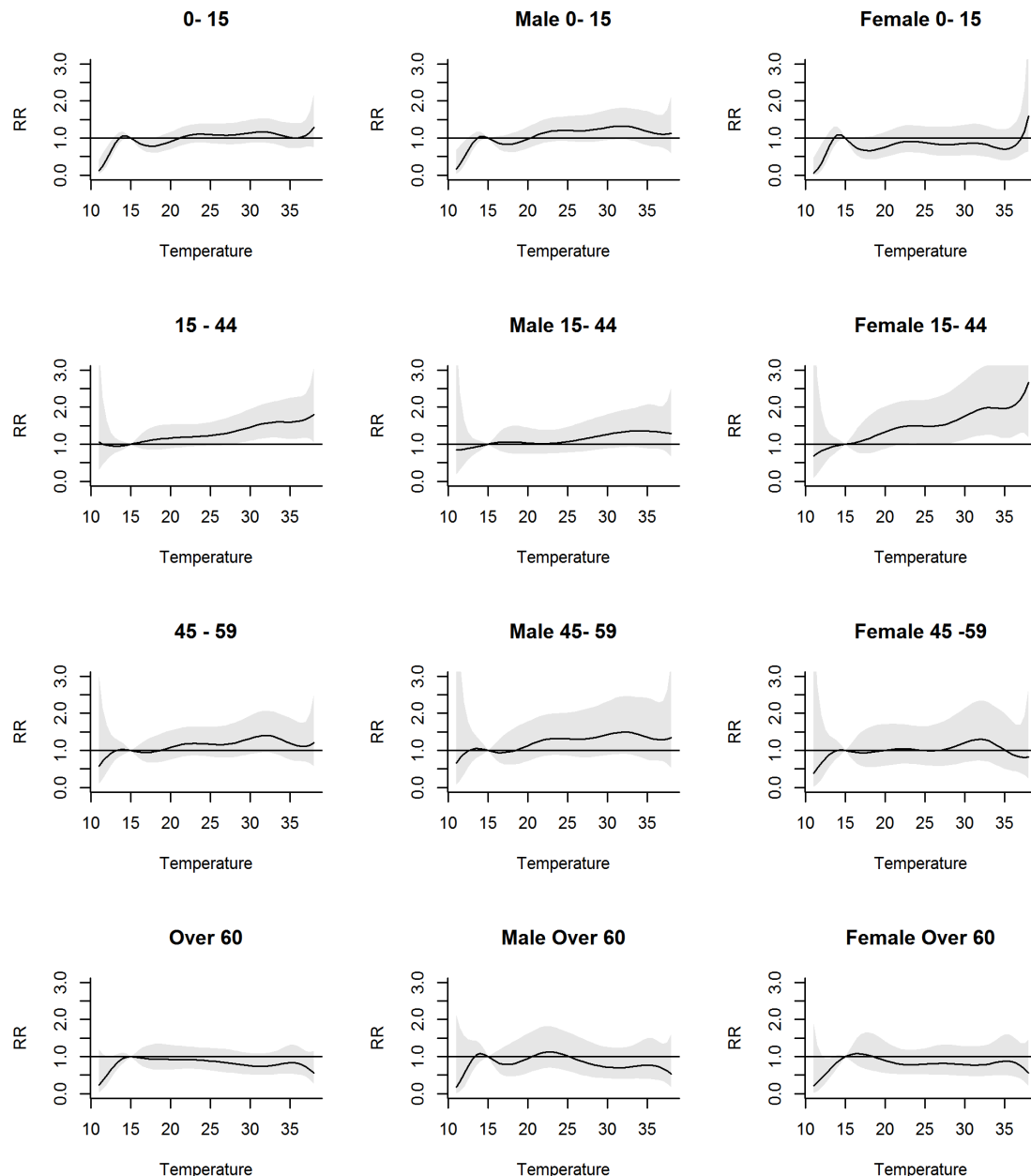
There are some potential pathways to explain temperature–injury associations. The WHO points out that exposure to high temperature may increase risk of injuries, such as drowning, work-related injuries, traffic injuries and aggressive behaviours, some of which result in injuries.<sup>23</sup> As temperature rises, people are naturally attracted by bodies of water to cool off, called aquatic exposure, thereby increasing a risk of drowning, slips or falls.<sup>24 25</sup> Additionally, exposure to high temperature decreases human capability of performing physical and intellectual tasks, such as driving and job performances,<sup>26 27</sup> which cause traffic crashes and work-related injuries particularly for people with outdoor occupations. Finally, the temperature-aggression theory postulates that warm weather may invoke a physiological response that leads to aggressive behaviours, criminal activity and subsequent human harm. In conclusion, evidence suggests the presence of a positive relationship between temperature and

risk of injuries, although this has been sparsely studied in the epidemiological literature in low-income and middle-income nation settings.

Our findings indicated that young people experienced a higher risk of injury than people 60 and older when exposed to increased temperature across three temperature measurement models, however, low temperatures did not increase injury. In contrast, other studies found a positive association between injury related to low temperature among the elderly.<sup>5 8</sup> These differences may be attributed to differences in climate conditions. In east Asian studies, Hanoi winters are not as cold as South Korea and China with an absence of snow and freezing temperatures, which reduces cold weather slips and falls injury risk for the elderly. Furthermore, occupational studies found that young workers (aged under 25) and middle-aged groups had higher risks of injury-related temperature than other age groups.<sup>6 7 28</sup> Younger workers may be more likely to work in more hazardous jobs and possibly pay less attention to occupational safety and health measures,<sup>29</sup> which may result in an overall increased risk of injury during extreme temperature events.

The effect of increased temperature was greater for males than females in our Hanoi population. This aligns with previous research on work-related injury that reported males having higher risk of temperature-related injury than females.<sup>7 28–30</sup> Similarly, population-based research has observed males having a higher temperature associated injury than females.<sup>9 31–33</sup> The reason for these differences is not fully understood, but plausible behavioural pathways include males being more likely to engage in outdoor work or recreational activities than females during warmer conditions.<sup>34</sup>

We found some evidence for delayed effects between temperature and injury across all genders and ages, except for the elderly. The greatest effects were observed 0–3 days after exposure and differed by age and gender groups; however, these differences were not large, and the interpretation may not be clear. Furthermore, it is unknown if a lagged effect is due to the timing of the temperature exposure or from patients not presenting to hospitals for one or more days after the injury. A qualitative study in Vietnam indicated that patients may delay going to a hospital for injury treatment due to sociocultural and financial concerns.<sup>35</sup> Patients may additionally seek traditional healers (traditional medicine) for treatment instead of going to modern medicine emergency departments.<sup>35</sup> Patients may also fear sharing a room with others and waiting a long time for treatment due to overcrowding in Hanoi hospitals, especially in public hospitals.<sup>35 36</sup> Additionally, patients delayed going to hospitals because average



**Figure 2** Exposure–response curves between daily mean temperature and emergency injury visits by age and age groups stratified by gender. Shaded areas denote 95% CIs. Adjusted by day of week, holiday, RH, PM and time. Reference temperature is 15°C. PM2.5, particulate matter; RH, relative humidity; RR, relative risk.

total medical care costs paid out-of-pocket are higher than monthly average salary in Vietnam.<sup>3 12</sup> Understanding these factors is important for future research on injuries presenting to hospitals in southeast Asian nations, as the timing of health risks and hospital burden may differ from other parts of the world.

The findings of this study must be interpreted with respect to the following limitations. We were not able to investigate the causes of injury based on the available information. Our data had only one diagnosis code, thus the external cause of injury was not available for nearly 96% of the data. Additional information on the nature of injury, such as occupational injuries, was not available so distinguishing work-related and nonwork-related injuries was not possible. Certain occupations are at higher risk of temperature-related injury than others, for example, outdoor workers<sup>37</sup> who are regularly exposed to higher-than-recommended temperatures,<sup>38 39</sup> but the extent to which this

populations risk has changed over time is not known. This is also single-city study in a major urban area and the findings may not necessarily be generalisable to other cities in Vietnam or elsewhere. Misclassification of the daily temperature may additionally occur due to missing data from weather monitors in parts of Hanoi. However, Hanoi is a relatively small area, thus the average temperature across monitors is a reasonable estimate of day-to-day changes and population-level exposures. Finally, we lacked data on other atmospheric conditions, such as rainfall, wind speed and sunshine duration, which may influence these results. Unfortunately, these atmospheric conditions were not available in Hanoi to adjust for this study.

This study examined the effects of temperature on emergency visits due to injury in Hanoi, Vietnam, where prior work on this topic is limited. Our findings support the hypothesis that increasing temperature is associated with emergency visits due

to injury and that this effect may vary by the age and gender of the population at risk. Understanding these associations may provide evidence to develop adaptation strategies for injury prevention and control. Further research is warranted to investigate temperature–injury associations for specific causes of injury and populations at risk.

**Correction notice** This article has been corrected since it was first published online. The corresponding author's email address has been updated.

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**Patient consent for publication** Not applicable.

**Ethics approval** The study was approved by the University of Minnesota Institutional review board as not human research.

**Provenance and peer review** Not commissioned; externally peer reviewed.

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