## Letter to the Editor

# Diurnal Temperature Range and Daily Emergency Room Admissions among the Elderly in Beijing, China*

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In recent years, more attentions have been paid to the association between climate change and human health. Increasing and more variable global surface temperature is one of the key climatic change factors which have been consistently reported about the effect on human health. So far, more researches have revealed that temperature lead not only to direct deaths and illnesses but also to aggravation of cardiovascular and respiratory diseases[1-3]. Typically, the relationship between temperature and mortality or morbidity is V-, U-, or J- shaped, with optimum temperature corresponding to the lowest point in the temperature mortality curve[3-4].

Although the independent impacts of temperature on human health have been widely explored, less evidence is available to illustrate the acute effects of diurnal temperature range (DTR) on emergency room (ER) admissions of elderly people. DTR, defined as the difference between maximal and minimal temperature within 1 day, was considered as an important index of climate change and variability due to providing more information than the mean temperature alone[5]. Recently, limited researches have been showed the associations between DTR and mortality and morbidity in Shanghai[6], Hong Kong[7], and Korea[8]. However, this association has never been reported in Beijing, the capital and largest metropolitan city of China. It remains a need for validating the findings in cities , where characteristics of levels of economic development, outdoor air pollution, socio-demographic status of local residents, weather patterns and latitudes may be different[9]. Additionally, with a rapidly ageing population, the elderly people, who were usually susceptible to heat- or cold- related health risks[10], should be the high-risk group to give more attention.

The aim of this paper is to confirm the short-term effect of DTR on ER admissions of elderly people in Beijing, China during 2009 to 2011. Analysis was conducted for overall and stratified groups by age and gender to examine the DTR effects on cardiopulmonary ER admissions of elderly people using time-series analyses. Better understanding the adverse effect of DTR on morbidity among elderly will provide relevant information for developing public health plans and risk assessments in the ambient environment.

***Data Collection*** Data on daily ER admissions were collected between Jan 1, 2009 and Dec 31, 2011 from three largest comprehensive hospitals in Haidian district of Beijing. The cases of people aged 65 years or older were extracted and coded according to the International Classification of Disease, tenth revision (ICD-10) for diseases of the cardiovascular (ICD10: I00-I99), respiratory (ICD10: J00-J99). Meteorological data on daily minimum, maximum and mean temperature and relative humidity were obtained from the Beijing Meteorological Bureau. Daily air pollution data was obtained from the web sites of the Beijing Public Net for Environmental Protection[11].

***Data Analysis*** As the number of daily hospital admission data belongs to a kind of small probability event and has a Poisson distribution, Poisson generalized additive model (GAM) approach was used to analyze the ER admissions, DTR and covariate data. Non parametric smoothing terms were fitted for long-term trends and seasonal patterns, as well as the daily mean temperature and relative humidity (by means of the regression spline function), with the dummy variables for days of the week (DOW) and holiday, and a linear term for air pollutant concentrations ($PM_{10}$, $NO_2$, and $SO_2$). A season variable, defined as cold (November to April) and warm (May to October), was also added to the model to adjust for possible seasonal effects. Then we introduced the DTR to analyze their effects on daily ER admissions. We also considered the lag effects of weather conditions and pollutant concentrations when constructed the model. Residuals of the basic models were used to check whether there were discernable patterns and autocorrelation by means of residual plots and PACF plots.

*doi: 10.3967/bes2013.010*

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The estimated effects were expressed as the increased percentage and their 95% confidence interval (95% CI) of the daily ER admissions of the elderly with a 1 °C increase in DTR. All analyses were running in R 2.14.0 statistical software by using mgcv package.

From 2009 to 2011 (1098 days), a total of 114 870 elder ER admissions (59 389 or 51.70% male; 55 481 or 48.30% female) were recorded. For different age groups, the accounts of 65-74, 75+ were 54 670 and 60 200 for 47.59% and 52.41% of total number of ER admissions respectively. On average, there were approximately 105 cases per day in our study population, including 20 cases from cardiovascular and 15 cases from respiratory. During the study period, the minimal, mean and maximal DTR were 1.10, 9.85, and 21.90 °C. The average temperature and relative humidity were 13.15 °C and 50.38%. The average concentrations of $PM_{10}$, $SO_2$, and $NO_2$ were 110.16 μg/m$^3$, 28.07 μg/m$^3$, and 51.88 μg/m$^3$ respectively.

Table 1 shows the estimates for the percent increase in the number of ER admissions associated with a 1 °C increase of DTR in different lag structures after adjustment for time trends and other confounders. In single-day lag structures, the effect estimates varied for total and respiratory ER admissions. The significant associations were found for total ER admissions with DTR at lag 3 and lag 4 days. Respiratory admissions were associated with DTR at lag 0, lag 3, and lag 4 days. However, no significant association between cardiovascular admissions and DTR was found in single-day lag structures. The multi-day metrics of DTR exposure showed a larger effect on ER admissions than single-day exposures. Generally, for total and respiratory ER admissions, the effects of DTR increased from lag 01 day and were greatest at lag 06 day. For cardiovascular ER admissions, the effect of DTR reached a maximum on lag 02 day.

Figure 1 graphically shows the exposure-response relationships between DTR and ER admissions at the largest lagged-day in the time-series analysis. There were similar positive linear relationships between DTR and total, cardiovascular and respiratory ER admissions, which indicated the relative risk of ER admissions increased as DTR increased in Beijing during the study period.

Table 2 shows the magnitude of the effects of DTR varied with gender and age. The significant associations were found between DTR and ER admissions by gender with the exception of cardiovascular ER admissions among male. In two different age groups, the significant effects of DTR on ER admissions clearly increased with age. The effect estimates of DTR among those aged ≥75 were higher than among the 65-74 age groups for total, cardiovascular and respiratory ER admissions.

**Table 1.** Percent Change (mean and 95% CI ) of ER Admissions Associated with a 1 °C Variation in DTR in Beijing during 2009-2011*

| Lag Structures | Total | Cardiovascular | Respiratory |
|---|---|---|---|
| Single-day Lag | | | |
| 0 | 0.11 (-0.10-0.33) | 0.42 (-0.06-0.90) | 0.56 (0.00-1.13) |
| 1 | 0.09 (-0.11-0.30) | 0.42 (-0.04-0.88) | 0.38 (-0.16-0.92) |
| 2 | 0.12 (-0.06-0.31) | 0.24 (-0.18-0.66) | 0.35 (-0.14-0.85) |
| 3 | 0.26 (0.09-0.44) | 0.10 (-0.30-0.51) | 0.58 (0.10-1.07) |
| 4 | 0.32 (0.15-0.50) | 0.06 (-0.34-0.46) | 0.49 (0.01-0.97) |
| 5 | 0.15 (-0.03-0.32) | -0.26 (-0.66-0.14) | 0.33 (-0.15-0.80) |
| 6 | 0.10 (-0.08-0.27) | -0.34 (-0.74-0.05) | 0.18 (-0.29-0.66) |
| Multi-day Lag | | | |
| 01 | 0.19 (-0.10-0.47) | 0.73 (0.11-1.36) | 0.84 (0.10-1.59) |
| 02 | 0.28 (-0.04-0.60) | 0.85 (0.15-1.55) | 1.06 (0.22-1.91) |
| 03 | 0.47 (0.14-0.81) | 0.82 (0.07-1.57) | 1.43 (0.53-2.35) |
| 04 | 0.68 (0.32-1.03) | 0.77 (-0.01-1.56) | 1.68 (0.72-2.65) |
| 05 | 0.73 (0.36-1.10) | 0.50 (-0.32-1.33) | 1.83 (0.81-2.87) |
| 06 | 0.75 (0.36-1.15) | 0.23 (-0.62-1.09) | 1.89 (0.81-2.98) |

***Note.*** *Models were controlled for time trend, DOW, holiday, season, mean temperature, humidity, and air pollutants ($PM_{10}$, $NO_2$, and $SO_2$).

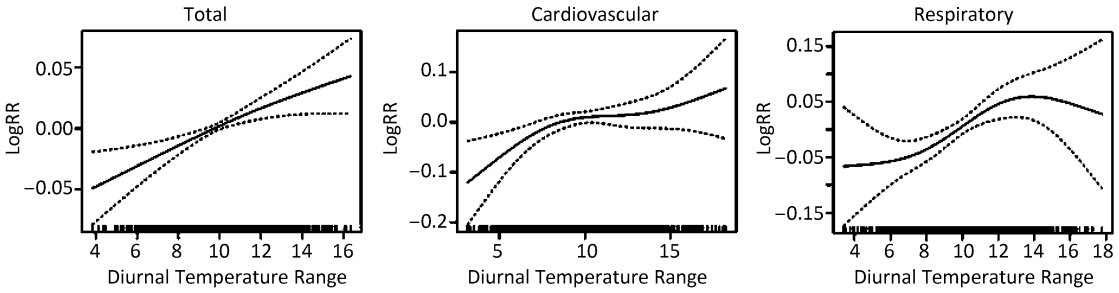


**Figure 1**. Smoothing plots of DTR against ER admissions risk of total, cardiovascular and respiratory. X-axis is the DTR (°C). The solid lines indicate the estimated mean percentage of change in daily ER admission, and the dotted lines represent twice the standard error. Multi-day lag 06 (L06) DTR was used for total and respiratory ER admissions and multi-day lag (L02) DTR was used for cardiovascular ER admissions. Models were controlled for time trend, DOW, holiday, season, average temperature, humidity, and air pollutant concentrations.

**Table 2.** Percent Change (mean and 95% CI ) of ER Admissions Associated with a 1 °C Variation in DTR by Gender and Age Group in Beijing during 2009-2011*

| Groups | Total | | Cardiovascular | | Respiratory | |
|---|---|---|---|---|---|---|
| | *n*[a] | %change (95% CI) | *n*[a] | %change (95% CI) | *n*[a] | %change (95% CI) |
| Gender | | | | | | |
| Male | 54.24 | 0.83 (0.29-1.38) | 9.92 | 0.39 (-0.60-1.38) | 8.43 | 1.63 (0.24-3.04) |
| Female | 50.67 | 0.60 (0.05-1.15) | 9.94 | 1.20 (0.23-2.18) | 6.46 | 1.56 (0.00-3.15) |
| Age (years) | | | | | | |
| 65-74 | 49.93 | 0.66 (0.10-1.22) | 8.82 | -0.13 (-1.16-0.91) | 6.55 | 1.74 (0.10-3.40) |
| ≥75 | 54.98 | 0.77 (0.24-1.31) | 11.04 | 1.63 (0.70-2.56) | 8.34 | 1.85 (0.46-3.25) |

***Note.*** *Multi-day lag 06 (L06) DTR was used for total and respiratory ER admissions; multi-day lag 02 (L02) DTR was used for cardiovascular ER admissions. All models were controlled for time trend, DOW, holiday, season, mean temperature, humidity and air pollutants ($PM_{10}$, $NO_2$, and $SO_2$). [a] Number of daily ER admission.

In present study, we found the significant association between the ER admissions of elderly people and DTR after adjustment for temperature and other covariates in Beijing, which provides the additional evidence that DTR is an independent risk factor for ER admissions among elderly person.

When the data were stratified by cause of ER admission, the significant associations were showed for both cardiovascular and respiratory ER admissions. The subgroup analyses for gender and age indicated that elderly woman and those aged 75 and over were more vulnerable to DTR for total, cardiovascular and respiratory ER admissions. According to those of previous studies, a linear DTR-mortality relationship has been showed in Shanghai and Korean cities. In Shanghai, Kan[6] found that DTR was related to daily mortality, and the percentage change of cardiovascular and respiratory mortality were increased by 1.86% and 1.29%, respectively. In six Korean cities, Lim[12] found that the effects of DTR was associated with mortality and the effect estimates varied form 0.1% to 0.8%. The risk of hospital admissions of cardiovascular and respiratory diseases attributable to DTR increased when DTR was increased in Korea[8]. Females and those 75 years and older were found to be associated more strongly with DTR than with the corresponding categories[8,12]. The present study showed a greater effect of DTR among elderly, which was consistent with these reported studies.

The physiological mechanism for the effect of temperature fluctuation on human health remains unclear, although there are possible explanations for its effects. Greater DTR may cause cardiovascular related diseases by increasing oxygen uptake, heart rate, and cardiac workload[13-14]. Graudenz's finding showed that sudden temperature changes may led to the pathophysiological responses of the respiratory epithelium at a tissue level, such as bronchospasms and inflammatory changes[15]. These results may apply to the finding in this study to explain some of the mechanisms associated with the effect of DTR on ER admissions. Elderly people have a lower ability to regulate body temperature and

elevated sweating threshold, compared with younger people[16], a large change in temperature within one day may cause a sudden change on the heart and circulation of elderly people, especially for those patients with cardiorespiratory diseases, which all may react on increasing the risk of cardiopulmonary diseases or may led to fatal consequences. Currently, the usefulness of global-average diurnal temperature range (DTR) was considered as an important index of climate change and variability. Early warning systems for impending large temperature changes may reduce the impact of DTR on people's health[7].

Our study has several limitations. Firstly, we just use the monitoring results of weather conditions from one station as surrogates of personal exposure level to diurnal temperature range. The use of ambient rather than personal exposure measures is expected to result in exposure misclassification. However, the difference between these proxy values and the true exposures are an inherent and unavoidable type of measurement error. Secondly, the data of ER admissions which we collected was limited in three hospitals, a selection basis may exist in our study. Finally, temperature variation may occur both indoors and outdoors, the effect of air conditioning or heating on the association between DTR and morbidity need to be investigated further.

In summary, we observed significant associations between exposure to diurnal temperature range (DTR) and increased ER admissions of elderly people in Beijing. The people aged 75 years and older was associated more strongly with DTR than the 65-74 age groups. Our finding provides additional evidence for the association between the ER admissions among elderly people and DTR. Some prevention programs that targeted the elderly and other high risk subgroups for impending large temperature changes may reduce the impact of DTR on people's health.

## ACKNOWLEDGEMENTS

We thank the National Scientific Data Sharing Platform for Population and Health for collecting data.

*The study was supported by the Gong-Yi Program of China Meteorological Administration (GYHY201106034) and the National Science & Technology Infrastructure Foundation of China (2005DKA32403) and the National Key Project of the Scientific and Technical Supporting Programs (2012BAJ18B08).

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Received: September 30, 2012;
Accepted: December 26, 2012

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