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Diurnal temperature range and mortality in Urmia, the Northwest of Iran

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ABSTRACT

Diurnal Temperature Range (DTR) is a meteorological index which represents temperature variation within a day. This study assesses the impact of high and low values of DTR on mortality. Distributed Lag Non-linear Models combined with a quasi-Poisson regression model was used to assess the impact of DTR on cause, age and gender specific mortality, controlled for potential confounders such as long-term trend of daily mortality, day of week effect, holidays, mean temperature, humidity, wind speed and air pollutants. As the effect of DTR may vary between the hot season (from May to October) and cold season (from November to April of the next year), we conducted analyses separately for these two seasons. In high DTR values (all percentiles), the Cumulative Relative Risk (CRR) of Non-Accidental Death, Respiratory Death and Cardiovascular Death increased in the full year and hot season, and especially in lag $(0-6)$ of the hot season. In the cold season and high DTR values (all percentiles), the CRR of Non-Accidental Death and Cardiovascular Death decreased, but the CRR of Respiratory Death increased. Although there was no clear significant effect in low DTR values. High values of DTR increase the risk of mortality, especially in the heat season, in Urmia, Iran.

1. Introduction

Climate change is perhaps the greatest threat to human health in the 21st century (Costello et al., 2009). These changes have been associated with an increasing trend in mean temperature, and temperature variation in the past 50 years (WHO, 2008). The impact of temperature changes on human health is an important public health problem (Curriero et al., 2002). Recent studies have shown a relation between different temperature indicators such as mean, minimum and maximum temperature, mean, minimum and maximum apparent temperature, Heat Stress Index, humidex and DTR and human health (Guo et al., 2011a; Lin et al., 2009; Rocklöv and Forsberg, 2010). Some documents indicate a rise in deaths from accidents and injuries (trauma) in the warm seasons (Ranandeh Kalankesh et al., 2015). In most urban areas of the world since the increase in the minimum night temperature is happening faster than the increase in the maximum day temperature; DTR is decreasing (Ha et al., 2011). For example, there was a 1.7 °C decrease in DTR in Guangzhou, China during 1960–2005 and the overall mean DTRdecrease was 0.07 °C per decade in 1950–2004 (Li and Chen, 2009; Vose et al., 2005). Despite the decreasing trend of DTR, the importance of the relation between this indicator and health is growing, because health of a huge population in the world is subject to the DTR index (Lim et al., 2013, 2012, Xu et al., 2013a, 2013b). Changes of the DTR value may have adverse effects on the human cardiovascular, nervous and immunological systems (Liang et al., 2008). A recent studied showed that early childhood pneumonia was associated with prenatal exposure to the diurnal temperature variations during pregnancy (Zeng et al., 2017). High levels of DTR may lead to high blood pressure, increased heart rate and the oxygen consumption (Liang et al., 2008; Lim et al., 2013).

DTR is a weather indicator associated with climate change and urbanization (Luo et al., 2013), and it is the difference between the minimum and maximum temperature over a day. In fact, this index shows temperature changes or stability within a day (Makowski et al., 2008). Therefore, in order to study the impact of climate change on human health, DTR may be a more efficient indicator (Luo et al., 2013). Studies have shown that temperature changes can have effects on human health and most of them have addressed the relation between

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the change in day to day mean, minimum and maximum temperature and its effects on health; but there are less studies on the impact of temperature changes during each day on human health (Cao et al., 2009).

So far, a few studies, mainly in South-East Asia, have been conducted to study the impact of DTR on mortality and most of them have investigated the association between high levels of DTR and mortality (Liang et al., 2009; Lim et al., 2012; Song et al., 2008). As far as we know,no investigation has been conducted in Iran in this regard. In this research paper, we study the effect of high and low levels of DTR on mortality,adjusted for factors such as season, age and gender

2. Material and methods

2.1. Study site

Urmia city is located in the northwest of Iran. In the 2017 census, its population was more than 750,000 people("Available at: https://www.amar.org.ir," 2017). Urmia is situated at an altitude of 1330 m above sea level, and is georeferenced as 37°32′59.3″N and 45°4′43.06″E ("Urmia Latitude and Longitude–Distancesto.com https://www.distancesto.com/coordinates/ir/urmia-latitude-longitude/history/11888.htm," n.d.).

2.2. Data

The research proposal of this project was approvedby the Ethics Committee of Kerman University of medical Sciences (EthicCode No; IR.KMU.REC.1395.246). Then, the number of deaths were inquired from the Urmia city death registration. Death information was obtained based on the International Classification of Death (ICD-10) codes from 2005 to 2010 for 6 years; in age and gender subgroups. The Urmia city death registration is located at the Health Department of Urmia University of Medical Sciences. Then the death due to external factors such as death due to accidents (codes codes S and after) were excluded and only the deaths codes A00-R99 were included in the study (Luo et al., 2013; Yang et al., 2013). The death data analysed in this study were divided into three general categories:

A-Non-Accidental Death (A00-R99)

B- Respiratory Death (J00-J99)

C- Cardiovascular Death (I00-I99)

Meteorological data about minimum daily temperature, maximum daily temperature, average temperature, average wind speed and average relative humidity over 6 years was obtained from the Urmia Meteorological Organization, West Azerbaijan Province.

The mean daily concentration of air pollutants including PM_{10}, SO_2, NO_2 for the period under study were inquired from the Environmental Protection Office of the West Azarbayejan Province which includes the city of Urmia. The city of Urmia has 4 air pollution monitoring stations, but only two were active. When both stations were active the average pollutant concentration of the stations was used. The missing data about air pollutants did not exceed 10% in any of the pollutants. In order to estimate the missing data the corresponding data of the previous or next years was averaged. Fortunately, there were no missing information in the meteorological or mortality data.

2.3. DTR index

In order to calculate the DTR index, the difference between the maximum and minimum daily temperatures over a day was calculated. Then the 1, 2.5, 5, 10, 50, 90, 95, 97.5 and 99 percentiles of the DTR index were calculated. In order to calculate the effect of the DTR index on mortality, mortality risk at low levels (10th percentile or less) and high levels of DTR (90th percentile and more) were calculated relative to the mortality risk at the 50th percentile of the DTR index (Luo et al., 2013). In order to evaluate the impact of demographic variables, DTR index and mortality relations were calculated in the age groups of below 65, 65–74 and over 75. In order to assess the seasonal effects on the relation between the DTR index and mortality, the whole year was divided into two warm (from June until November) and cold (from December until May) periods (Luo et al., 2013)and the relation between DTR index and mortality in both cold and warm periods was analyzed separately.

3. Theory/calculations

Counts of daily mortality data typically follow a Poisson distribution. Therefore, in this study, Distributed Lag Non-linear Models (DLNM) combined with quasi-Poisson regression models was used to assess the impact of DTRon cause, age and sex specific mortality. In this study, a "natural cubic spline–natural cubic spline" DLNM was adopted to model both the non-linear DTR effect and the lagged effect. Spline knots were set at equally spaced values on the log scale of lags. A maximum lag of 27 days was used to completely capture the overall DTR effect (Luo et al., 2013). In this study potential confounders were controlled for. These confounders were long-term trend of daily mortality, day of week, holidays, temperature, humidity, wind speed and air pollutants. The long term and seasonal trend of daily mortality was controlled for similar to other studies by using a natural cubic spline of time which had 7 degrees of freedom (df) per year (Zhou et al., 2014). Previous studies found that mean temperature and relativehumidity both significantly affect mortality (Zanobetti and Schwartz, 2008). We also conducted sensitivity analyses by changing lag structures for mean temperature and relative humidity back to the previous 2 weeks. Eventually we selected lag structures up to 7 days (lag 7) to control for temperature and relative humidity. Wind speed, PM_{10}, SO_2 and NO_2 on the current day were controlled for using 3 df natural cubic splines (Gasparrini et al., 2010; Guo et al., 2011b; Luo et al., 2013; Muggeo and Hajat, 2009). We also controlled for the day of the week and holidays as categorical variables. As the effect of DTR may vary between the hot season (from May to October) and cold season (from November to April), we conducted analyses separately for these two seasons (Luo et al., 2013).

We evaluated the model fit using Q-AIC.All statistical tests were two-sided, and values of $p < 0.05$ were considered statistically significant. We used R software (version 3.4.0) to fit all models, and the 'dlnm' package(version2.3.2) to create the DLNM (Gasparrini, 2017).

4. Results

4.1. descriptive results

During the 6-years under study 12,756 cases of Non-Accidental Death (A00-R99)(Linares et al., 2015)were recorded in the death registration system of Urmia out of which 1444 cases were caused by respiratory disease and 4880 cases were due to cardiovascular diseases. Respectively 33, 50% and 17% of deaths were related to the age groups of below 65, 65–74 and over 75 years. The mean (standard deviation, SD) and median of DTR index changes were 13(± 4)°C and 14 °C.The mean (SD) and median of temperature were 9(± 11)°C and 12 °C.The mean (SD) 24-h concentration of atmospheric pollutants, NO_2, SO_2 and PM_{10} were respectively 83(± 90)μg/m3, 106(± 89)μg/m3, and 88(± 57)μg/m3. The mean relative humidity was 58(± 16) % and the mean wind speed was 2(± 0.01) m/s.

4.2. Annual analysis

The three-dimensional Fig. 1 shows the relation between the changes in DTR index vs. mortality. As Fig. 1(a) shows NAD risk increases at higher DTR values in the initial lags; and in low levels of DTR in the final lags.

Fig. 1(b) is about respiratory mortality shows, at higher DTR values,