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Physiological Equivalent Temperature Index and mortality in Tabriz (The northwest of Iran)

Rahim Sharafkhani[a], Narges Khanjani[b,c,*], Bahram Bakhtiari[d], Yunes Jahani[e], Jafar Sadegh Tabrizi[f]

[a] Neurology Research Center, Kerman University of Medical Sciences, Kerman, Iran
[b] Environmental Health Engineering Research Center, Kerman University of Medical Sciences, Kerman, Iran
[c] Monash Centre for Occupational & Environmental Health, School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia
[d] Water Engineering Department, College of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran
[e] Department of Biostatistics and Epidemiology, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran
[f] Tabriz Health Services Management Research Center, Faculty of Management and Medical Informatics, Tabriz University of Medical Sciences, Tabriz, Iran

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ABSTRACT

There are few epidemiological studies about climate change and the effect of temperature variation on health using human thermal indices such as the Physiological Equivalent Temperature (PET) Index in Iran. This study was conducted in Tabriz, the northwest of Iran and Distributed Lag Non-linear Models (DLNM) combined with quasi-Poisson regression models were used to assess the impacts of PET on mortality by using the DLNM Package in R Software. The effect of air pollutants, time trend, day of the week and holidays were controlled as confounders. There was a significant relation between high (30 °C, 27 °C) and low (−0.8 °C, −9.2 °C and −14.2 °C) PET and total (non-accidental) mortality; and a significant increase in respiratory and cardiovascular deaths in high PET values. Heat stress increased Cumulative Relative Risk (CRR) for total (non-accidental), respiratory and cardiovascular mortality significantly ($CRR_{\text{Non Accidental Death, PET}=30\ °C,\ \text{lag}\ 0–30}$ = 1.67, 95%CI: 1.31–2.13; $CRR_{\text{Respiratory Death, PET}=30\ °C,\ \text{lag}\ 0–13}$ = 1.88, 95%CI: 1.30–2.72; $CRR_{\text{Cardiovascular Death, PET}=30\ °C,\ \text{lag0-30}}$ = 1.67 95%CI: 1.16–2.40). Heat stress increases the risk of total (non-accidental), respiratory mortality, but cold stress decreases the risk of total (non-accidental) mortality in Tabriz which is one of the cold cities of Iran.

1. Introduction

Over the past few decades, there has been growing concerns and scientific debates about the negative effects of extreme temperature events on human health around the world (Parry et al., 2007; Solomon, 2007). Weather changes are a risk factor for health and many studies have been conducted to show the relation between environmental variables (especially air temperature) and mortality (Nastos and Matzarakis, 2012). Heat stress is associated with heart rate changes (Ghotbi Ravandi et al., 2016), and exposure to temperature outside of the thermal comfort zone can increase the risk of death and hospital admissions (Xu et al., 2013).

Thermal indices are used to examine and understand the effects of temperature stress on human health (Ndetto and Matzarakis, 2015). If a reasonable balance is created between the heat generated by the body and the heat lost, then the human is in a thermal comfort condition (Brager et al., 2004; Roshan et al., 2016b). In this case, there is no burden on the body's thermal adjustment system. By increasing thermal stress (cold or heat), the cardiovascular system's activity increases to regulate body heat. After several days of thermal stress, "thermal adaptation" occurs, which makes it easier to deal with temperature stress. Exposure to extreme temperature stress increases the risk of physiological disorders, and physiologic disorders lead to health threats and even death in people with cardiorespiratory problems, children, and the elderly (Laschewski and Jendritzky, 2002). Ambient air temperature and the apparent temperature are the most common direct indicators of thermal stress (Xu et al., 2013). The increasing need for validated methods to estimate open air thermal comfort zones for meteorological services, urban planning, tourism and health; has led to the development of thermal indicators (Jendritzky et al., 2012; Roshan et al., 2016a). Bragger et al. (2004) emphasizes that people's thermal comfort conditions are not solely determined by simple atmospheric and meteorological variables; but other parameters such as air humidity, wind speed, average radiant temperature, and physiological factors such as type of physical activity and clothing affect it as well.

The Physiological Equivalent Temperature is part of the Munich

* Correspondence to: Department of Epidemiology and Biostatistics, School of Public Health, Kerman University of Medical Sciences, Kerman 76169-13555, Iran.
E-mail address: n_khanjani@kmu.ac.ir (N. Khanjani).

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Energy-Balance Model for Individuals (MEMI) outputs. Although the Physiological Equivalent Temperature Index is one of the most comprehensive indicators for assessing meteorological conditions such as thermo-physiological stress (Esmaili et al., 2011), the use of the PET index in assessing the effect of thermal change or stress on mortality has been rare (Lin et al., 2012). Considering the lack of epidemiological studies in Iran that have addressed the effect of thermal changes on human health by human thermal indices such as PET, this study aimed to investigate the impact of PET index changes on mortality in Tabriz (northwestern Iran).

2. Materials and methods

2.1. Study site

Tabriz is the fifth largest city and one of the historical capitals of Iran and the capital of the East Azerbaijan Province (http://www.i-dem.ir/Pages/Eng/AboutTabriz.aspx, n.d.). In the 2017 census, its population was more than 1,600,000 people (https://www.amar.org.ir, 2017). Tabriz is situated at an altitude of 1361 m above sea level, and is georeferenced as 38°5′N and 46°16'E (http://www.tabriz.climatemps.com/map.php, n.d.).

2.2. Data

Tabriz's death records were inquired from the death registration system of the Health Deputy at Tabriz University of Medical Sciences according to the International Classification of Death. ICD10 codes from 2010 to 2015 for a period of 6 years, were classified into age and gender subgroups. Mortality due to external factors such as accidents, suicide and murder (codes S and thereafter) were excluded and only death records from A00 to R99 were included in this study (Linares et al., 2015). Death cases were divided into three general categories as follows:

A. Non-Accidental Deaths (NAD)(A00-R99)
B. Respiratory Deaths(RD)(J00-J99)
C. Cardiovascular Deaths(CVD)(I00-I99)

Meteorological data on daily ambient air temperature, wind speed, relative humidity and cloudiness was obtained from the Meteorological Organization of the Province. Cloudiness was reported for 8 times a day at 0, 3, 6, 9, 12, 15, 18 and 21 h.

Data about the concentration of air pollutants was acquired from the Environmental Protection Agency of the Province. Tabriz had 7 weather stations some of which were inactive at some point of time. The average of the recorded data of all active stations per day (24-h average of pollutants) were used in this study. The percent of missing data in NO_2, SO_2 and PM_{10} were 23%, 12% and 4%, respectively. The EM (Expectation-Maximization) method, which is a statistical method for missing imputation (Lin, 2010), was used to estimate missing data by SPSS software (version 22).The meteorological and mortality data was complete and did not have any missing.

2.3. PET index

PET index was presented in 1999 as a global benchmark for thermal stress assessment (Höppe, 1999). It could be deemed as the room temperature where the human body experiences a degree of thermal stress equal to the one experienced outdoors (Roshan et al., 2016b). In this study, the Rayman software was used to calculate the PET index values (Matzarakis et al., 2010, 2007).

The required variables to calculate the PET index include: A) geographical variables such as altitude and latitude of the area under study, B) meteorological variables such as dry air temperature (°C), relative humidity (%), wind speed(m/s)and cloudiness(octas); and C) individual variables such as height, weight, age, gender, clothing and physical activity (W/m^2).

Table 1
Physiologically Equivalent Temperature (PET) for different grades of thermal sensation and physiological stress on human beings (during standard conditions).

PET (°C) in Iran[a]	Thermal sensation	Physiological stress level
< −10.7	Very cold	Extreme cold stress
−10.7 to −0.7	Cold	Strong cold stress
−0.7–8.8	Cool	Moderate cold stress
8.8–17.7	Slightly cool	Slight cold stress
17.8–27	Comfortable	No thermal stress
27–35.1	Slightly warm	Slight heat stress
35.1–43	Warm	Moderate heat stress
43–50.8	Hot	Strong heat stress
> 50.8	Very hot	Extreme heat stress

[a] Farajzadeh H. Evaluation and analysis of Climatic comfort conditions for tourism in Iran using bioclimatic Indices. Dissertation, Kharazmi University. 2017.

The individual variables are the same as the physiological parameters that are included in the model. Given that the physiological characteristics vary in different people, standard parameters as follows were used in the model. Male gender, height = 175 cm, weight = 75 kg, age = 35 years, clothing = 0.9 (Clo), and level of physical activity = 80 W/m^2 (Roshan et al., 2016b).

Rayman software calculated 8 values per day for the PET index and then the eight values were averaged. After calculating the mean daily PET index, the PET classification in Table 1, presented for Iran's climatic conditions by Farajzadeh (2017), was used. In this table, the thermal comfort zone is set between 17.8 and 27 °C, which means in this zone no thermal stress is imposed on humans.

2.4. Statistics

Distributed Lag Non-linear Models (DLNM) combined with quasi-Poisson regression models were used to assess the impact of the PET index on mortality. The long term and seasonal trend of daily mortality was adjusted by using a natural cubic spline of time with 7 degrees of freedom (df) per year.

PM_{10}, SO_2, $NO_2$and were controlled by using the stratified distributed lag model with 7 day lags (0−7) and 3 df. We created different breaks in the data, and eventually based on the Quasi Akaike Information Criteria (QAIC) we made 3 strata (lag 0–2, lag3-5 and lag 5–7) in our data, to use in constrained DLNM. Air pollutants are potential confounders in the association between environmental stressors and mortality (Buadong et al., 2009). We also controlled for the day of the week and holidays as categorical variables. The DLNM is developed based on a 'cross-basis' function, which allows simultaneous estimation of the non-linear effects across lags. It shows the relationship between PET and mortality at each mean daily value of PET and its lags. DLNM also calculates the cumulative effect of lagged variables (Gasparrini

Table 2
Descriptive statistics for Physiological Equivalent Temperature (PET), Non Accidental Death (NAD), Respiratory Death (RD), Cardiovascular Death (CVD), air pollutants and age groups.

Variable	Mean (SD)	Median	N
$PET_{(°C)}$	9(11.8)	8.9	2191
$PM_{10(\mu g/m3)}$	77(38)	71.7	2191
$SO_{2(\mu g/m3)}$	66(46)	60.5	2191
$NO_{2(\mu g/m3)}$	47(33)	43.5	2191
NAD	18.8(5)	19	41,293
RD	1.9(1.5)	2	4269
CVD	8.6(3.5)	8	18,886
Age < 65	5.3(2.6)	5	11,616
Age 65–74	3.6(1.9)	3	8033
Age > =75	9.8(3.6)	9	21,623