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ANALYZING THE INFLUENCE OF AIR TEMPERATURE ON THE CARDIOVASCULAR, RESPIRATORY AND STROKE MORTALITY IN TEHRAN

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ABSTRACT
The quantification of the relationship between daily mortality and air temperature, as a fundamental policy is essential to enhance the accuracy of the warning system of decrease and increase of temperature. The objective of this study was to investigate the relationship between temperature and death rate in Tehran during the period (2002-2005) by combining statistical and geographic information system methods. The Results of this study indicate that there is a strong and meaningful correlation between air temperature and death rate especially between monthly averages ones. The highest rate of mortality has occurred in the cold months of the year (December, January and February). and as the temperature decrease, the death rate increase. The increase in death rate caused by cardiovascular, respiratory and stroke diseases in the cold months of the year, bears proof to this matter. Among 22 zones of Tehran, zones 9, 6 and 12 have got the highest number of death occurrence. The correlation between daily death rate and daily temperature averages was V-shaped. Results of this study confirm some previous findings such as those in Moscow, United States, Hong Kong, Madrid, Athens and Shanghai. Temperature minimum mortality for Tehran was calculated as 28.5°C. The obtained results also indicate that the higher was the temperature difference from the Temperature minimum mortality, the more the death rate increased. Finally, the optimum policies for the mitigation of mortality in Tehran are presented.

Keywords: Death rate, Disease, Temperature minimum mortality, Climate, Geographic Information System, Tehran

INTRODUCTION
The relationship between climate and human health has been examined by researchers from various disciplines (Mather 1974; Oliver, 1981). There are growing interests in the investigation of seasonal variations of mortality and weather-mortality relationship by the medical and climatology disciplines. Different studies have shown that mortality is generally higher in winter (Tromp, 1963; Bako *et al.* 1988; Douglas *et al*. 1991; Lerchl, 1998; McKee *et al*., 1998). Kalkstein and Davis (1989) found that warm, humid and calm weather conditions were related to elevated summer mortality whereas cloudy, damp and snowy conditions were associated with the highest mortality rate in winter. Shumway *et al*. (1988) showed that temperature, but not relative humidity, contributed significantly to mortality. Alberdi *et al.* (1998) discovered a J-shaped relationship between temperature, relative humidity and mortality in Madrid, and mortality was found to be negatively associated with high humidity in summer. The influence of weather on human mortality was studied in Hong Kong by Yan (2000). He found a significant relationship between weather conditions and some diseases types. El-Zein *et al.* (2004) analyzed time series of mortality and air temperature in Great Beirut and suggested

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that heat-related mortality at moderately high temperatures could be a significant public health issue in countries with warm climates. Wu and Li (2007) studied association between esophageal cancer and drought in China by using Geographic Information System. Their study showed that drought plays a key role in the occurrence and development of esophageal cancer mortality in China. Also, Kan *et al.* (2007) have studied diurnal temperature range and daily mortality in Shanghai. Their results showed strong association between diurnal temperature and daily mortality. Kassomenos *et al*. (2007) studied association between daily mortality and air mass types in Athens using generalized additive models and extending Poisson regression and found effects on mortality, independent of temperature, are observed mainly for lag 0 during the cold period, but persist longer during the warm period.

The impact of stressful weather on mortality has been well studied and the number of deaths from circulatory and respiratory causes has been found to be strongly associated with weather conditions. The so-called V-shaped (Martens, 1998) and J-shaped (Mc Michaels *et al*., 1996) curves refer to a pattern in which daily mortality decreases, as mean temperature increases from its winter lows, to reach a mortality minimum. Mortality then rises, sometimes quite abruptly, beyond a certain threshold of mean summer temperatures. The temperature minimum mortality (TMM), could be as low as 16 °C in the Netherlands (Kunst *et al.,* 1993) and as high as 27.2 °C in Miami (Curriero *et al.,* 2002) and 29 °C for cerebral infarction mortality in Taiwan (Wen-Harn *et al.,* 1995).

The literature on the association between mortality and temperature in Iran, and more generally, in the Middle-east and North Africa is limited. Douglas *et al.* (1991), analyzing monthly death counts in Kuwait, concluded that socio-economic progress had reduced the seasonality of infant and total mortality. No analysis of the relationship between temperature and total daily mortality in semi-arid cities of the eastern coast of the Mediterranean appears to have been carried out. Only five countries in this region, with no more than 16% of the total population, supplied any mortality data to the World Health Organization between 1985 and 1990 (United States Bureau of the Census, 1999).

The main objective of this study was the analysis of daily death counts for the city of Tehran, which aimed to identify any significant association with temperature. In addition, the constructed regression models were used to evaluate the likely impact of monthly and annual temperature on cardiovascular, respiratory, stroke disease and total mortality and analyzing the geographic distribution of mortality in 22 zones of Tehran.

MATERIALS AND METHODS

Study area

The city of Tehran, the capital city of Iran, is located in Tehran province. The city having more than 7 million people is the most populated city in the country. The city is surrounded by Alborz Mountains in the northeast. Fig. 1 shows the location of study area. and also the 22 administrative zones of the city and 5 weather stations.

Data used

Weather variables including mean, maximum and minimum temperature were obtained from Iranian meteorological Organization for 5 weather stations located on Tehran city for the period of 2002-2005.

Also daily mortality data from 2002 to 2005 were obtained from the Behesht Zahra organization. The obtained data were classified based on region, types of diseases, gender and age but no data was available assigned to zone 21. Also population data for zone 21 of Tehran was provided from centre of geographic information systems of Tehran Municipality.

Method

In order to determinate the seasonal mortality, prior to analysis, the diseases that had strong correlation with temperature including cardiovascular, respiratory and stroke diseases never selected based on previous studies (Yan, 2000; Kan *et al.,* 2007). To eliminate the effect of population growth, total mortality data was divided by their corresponding annual mid year population. Daily mortality rate (per 100,000) was classified for age specific group among 22 zones of Tehran, shown in Table 1.

In order to examine the existence of mortality seasonality, the months of the year were divided into two groups (dummy variable) including winter months which cover October, November, December, January, February, March, and summer months which cover April, May, June, July, August and September. Then ANOVA was utilized to test for differences in seasonal mortality. for determination of temperature-mortality relationship, the mean daily and monthly temperature was calculated for 5 considered weather stations.

To determine the temperature in which the minimum mortality occurs, daily temperature and mortality has been used. There was a slight relationship between daily temperature and mortality so that mean monthly temperature has been used.

The data of climatology and mortality were arranged as time series together. Regression analysis was used to ascertain that how great is the effect of temperature on mortality, by highest coefficient determination (r^2) for specific mortality and others. The relationship between the temperature and death rate was investigated and analyzed by the utilization of statistical methods. For showing geographic distribution of data and information, GIS software (ArcGIS) was used.

RESULTS

Description of mortality in Tehran city

There was a total number of 166069 deaths in the study area and these rates were attributed to cardiovascular and respiratory systems failure, stroke and some other diseases such as neoplasm and digestive disease which in this research have not been discussed.

The causes of death by cardiovascular, respiratory systems failure and stroke comprised 38.5, 4.5 and 4.9 percent, respectively (Fig. 2). The geographic distributions of total mortality and mortality in age over 65 in Tehran zones per 100.000 people are shown in Fig. 3 and 4., in which the central zones have high rates of both mortality and over 65 mortality.

Classified data of mortality into 5 age groups (Table 1) indicates that the highest mortality was relevant to the age over 65 and the lowest mortality was for the age, range of 17-24. It shows that maximum mortality both for high age groups and low age groups is located in 6, 9 and 12 zones, but for high age groups it is more obvious than low age groups. In other zones, the maximum of mortality for age specific groups did not occur in high age groups because people who live in these regions are younger.

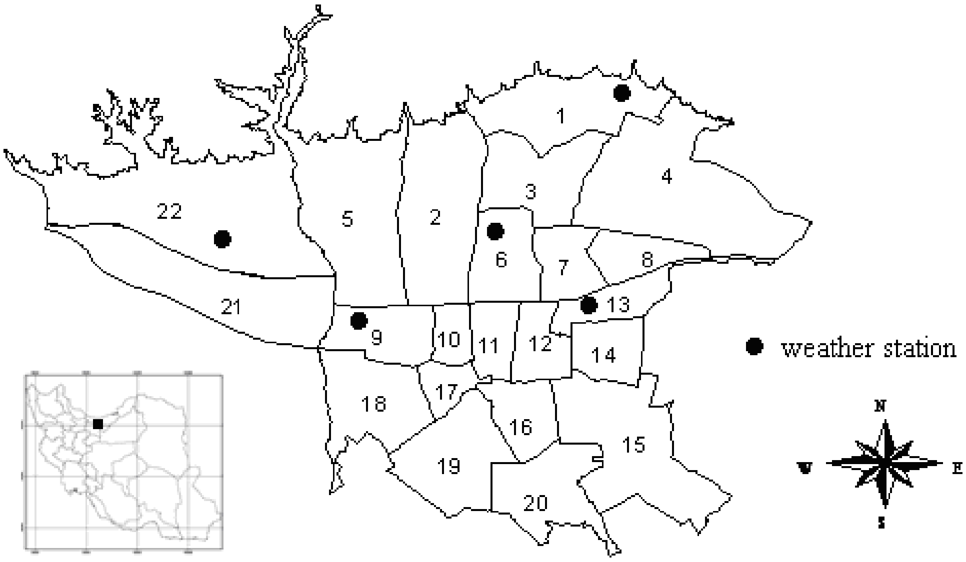

Fig. 1: The map of 22 administrative zones and 5 weather stations in Tehran

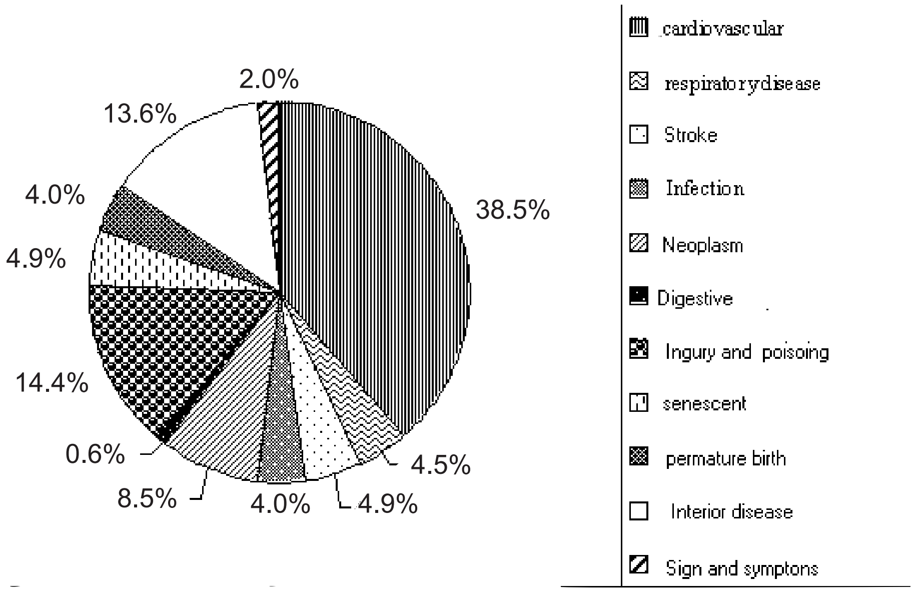

Fig. 2: Actual numbers of total diseases in Tehran 2002-2005

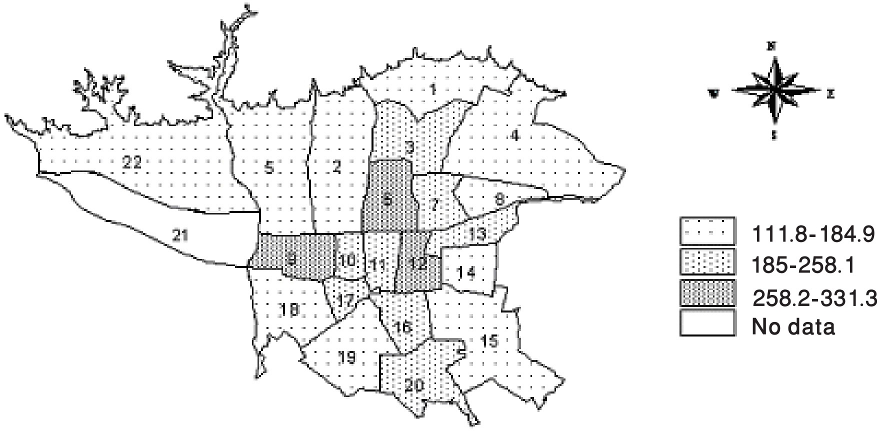

Fig. 3: Geographic distribution of the total mortality in Tehran per 100,000 (2002-2005)

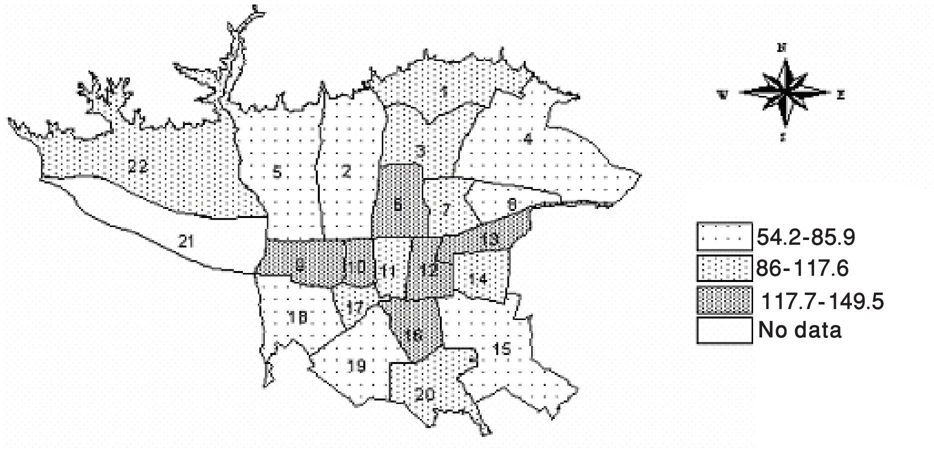

Fig. 4: Geographic distribution of the over 65 mortality in Tehran per 100,000 (2002-2005)

Mortality seasonality
The study of mortality in different months (Fig. 5 (A)) indicated that the mean of daily total mortality during cold months including December, January and February was significantly higher than that in warm months, including May to October.

Table1: Daily mortality rate (per 100,000) for age specific group among 22 zones of Tehran (2002-2005)

Zones	Specific daily mortality by cardiovascular, respiratory diseases and stroke					Daily mortality by other diseases					Total
	Age 0-16	Age 17-24	Age 25-44	Age 45-64	Age ≥65	Age 0-16	Age 17-24	Age 25-44	Age 45-64	Age ≥65	
1	4.08	0.7	3.2	15.9	59.7	30.1	4.6	9.9	14.8	39.1	182.4
2	2.9	0.3	2.55	15.4	52.3	18.8	3.5	8.1	12.8	30.3	147.6
3	6.2	0.5	3.5	16.2	63.2	37.8	4.0	10.9	13.9	42.5	199
4	2.0	0.5	2.8	13.3	36.4	12.9	4.2	8.2	10.0	20.9	111.8
5	2	0.6	2.7	14	39	11.8	3.7	8.8	10.9	22.6	116.4
6	8.2	0.6	4.6	22.4	91.8	64.4	4.6	14.2	19.2	53.2	283.6
7	4.5	0.6	4.5	18.4	66.9	27.6	4.4	12.3	14.1	38.0	191.6
8	2.7	0.2	3.8	15.64	50.1	17.2	3.8	10.7	11.1	28.3	144
9	6.1	1.5	8.5	29.9	94.2	43.4	9.9	23.2	22.6	55.3	295.1
10	3.8	0.7	5.4	24.3	80	25.3	5.5	15.5	15.7	39.7	216.4
11	4	0.6	4.6	18.4	61.1	36.4	4.5	13.5	13.9	34.1	191.6
12	10.4	0.9	13.1	32.1	78.5	75.9	8.4	42.1	27.1	42.3	331.3
13	5.1	0.8	5.2	22.6	77	30.3	5	15.1	15.7	43	220.3
14	2.9	0.8	4.4	18.6	57.6	16.7	4.7	11.3	13.3	32.9	163.7
15	3	0.8	4.8	15	42.7	15.1	5.7	13	10.3	24.1	137
16	4.1	0.7	6.3	22.5	78.7	26.3	6.8	17.3	16.3	39	218.5
17	4.2	0.4	5.8	20	59.2	26.1	5.3	17	15.4	34.8	188.6
18	3.5	0.6	3.8	14.1	34.1	23.8	5	10.7	10.9	20	127.1
19	4.2	0.7	4.2	17.3	41.9	29.9	5.8	14.2	13	26.1	157.7
20	5.1	1	7.3	26.4	75.1	31.9	9.7	22.6	18.5	38.7	236.7
21	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
22	6.8	0.5	3.5	12.2	23.4	66.5	5.6	13.1	11.2	14.4	157.8

There was a significant correlation with r = -0.87 between monthly temperature and mean number of daily mortality. The more monthly temperature decreased, the more mean number of monthly mortality increase. For the specific deaths from selected causes (cardiovascular, stroke and respiratory) the temporal distribution of daily mortality in different months are shown in Fig.5 (B) and (C).

Correlation coefficient between the mean mortality with cardiovascular, stroke and respiratory calculated as -0.93, -0.89 and -0.86, respectively showed a significant relation between selected diseases mean temperature. The rate of mortality caused by cardiovascular was higher and more sensitive than those made by stroke and respiratory. Maximum mortality caused by cardiovascular, respiratory and stroke was occurred in cold months (December, January and February) and minimum mortality caused by them was occurred in warm months (July, August and September).

The Results of the regression analysis using dummy variables (Table 2) revealed a positive relationship between mortality and the winter months, so higher deaths occurred in winter. Statistically significant reliable winter peaks in gender specific and total deaths from all causes, cardiovascular, stroke and respiratory diseases, were noted.

Table 2 (p value in total death) shows that there was no difference between selected diseases and other diseases in winter. There was a difference between male and female for stroke disease but there wasn not any difference between them for cardiovascular and respiratory diseases in winter. The results from ANOVA (Table 3) exhibited significant differences of mortality among seasons, and this further confirmed the existence of a reliable winter peak for all causes and selected disease mortality. The contributing temperature variable affecting female mortality from all causes was similar with those of male mortality, but for stroke was slightly different. Female mortality caused by stroke was higher than that of male.

The winter and summer mortality rates for the age specific deaths, presented in Table 4, further revealed the minimal seasonal mortality differences among the younger age groups. Maximum mortality was occurred in two oldest groups (45-64 and ≥ 65) and minimum mortality was related to two groups (17-24 and 25-44). The evaluation of temperature impact on mortality for various age groups revealed that maximum mortality for cardiovascular, respiratory and stroke diseases in total age groups, was occurred in winter, but for total and other diseases it was somehow different. For all causes of mortality, maximum mortality for age groups (0-16 and 17-24) occurred in summer, but for age group of over 24 it was in winter.

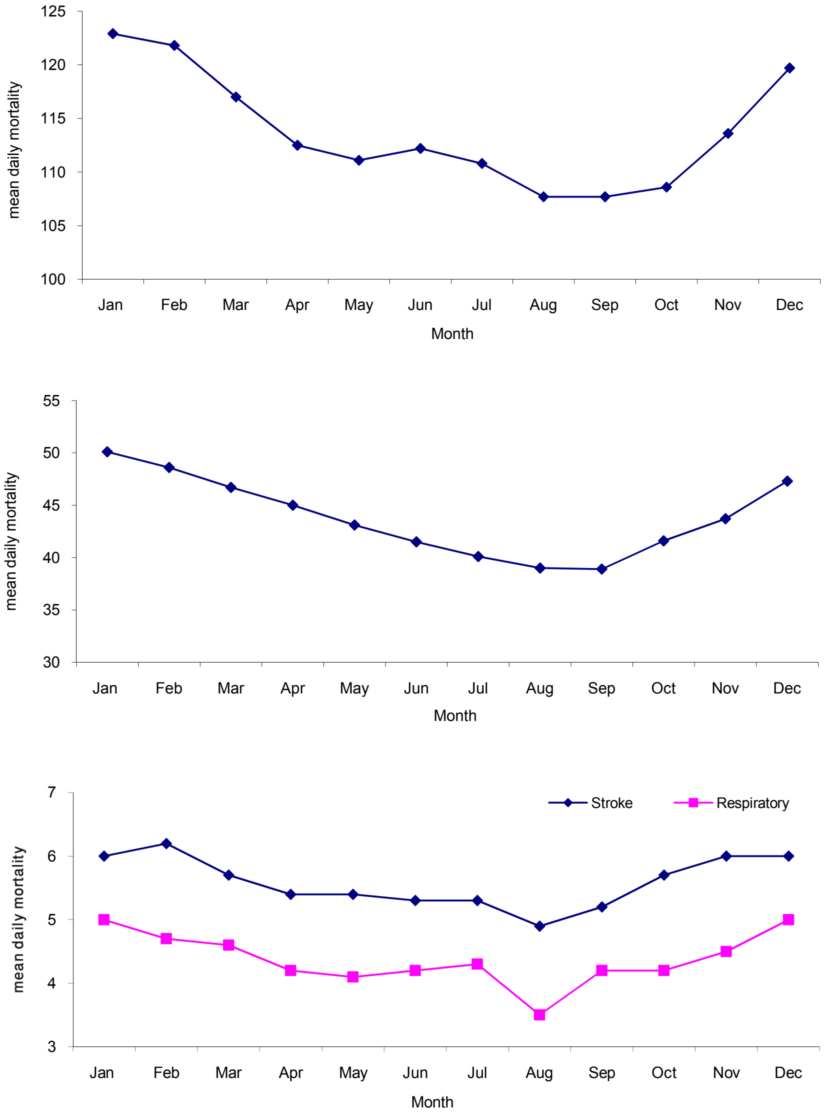

Fig. 5: Daily total mortality (A), cardiovascular (B), stroke and respiratory diseases (C) in different months of year (2002-2005)

Table 2: Models for mortality seasonality (winter peak)

	Total death		Male		Female		Age≥ 65	
	Regression coefficient	p	Regression coefficient	p	Regression coefficient	p	Regression coefficient	p
Cardiovascular	0.53	p<0.001	0.96	P<0.001	1.05	p<0.001	0.87	P<0.001
Respiratory	0.10	p<0.001	0.15	P<0.001	0.24	p<0.001	0.18	P<0.001
Stroke	0.03	p<0.001	0.04	0.10	0.08	p<0.001	0.05	P<0.001
Other diseases	0.33	p<0.001	0.52	P<0.001	0.77	p<0.001	0.52	P<0.001

Table 3: Results of ANOVA for mortality seasonality

	Total death		Male		Female		Age≥ 65	
	F ratio	p	F ratio	p	F ratio	p	F ratio	p
Cardiovascular	36.4	p<0.001	46.37	p<0.001	20.78	p<0.001	26.6	p<0.001
Respiratory	16.5	p<0.001	11.63	p<0.001	21.41	p<0.001	19.28	p<0.001
Stroke	4.52	p<0.001	2.88	0.10	6.75	p<0.001	4.82	p<0.001
Other diseases	25.43	p<0.001	18.17	p<0.001	31.32	p<0.001	16.62	p<0.001

Table 4: Mean daily mortality rates (per 100,000) for age specific groups

Factors	All causes		Cardiovascular		Respiratory		Stock		Other causes	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Age 0-16	47.8	49.1	4.6	4.5	1.8	1.5	0	0	41.2	43
Age 17-24	8.9	9.8	.8	0.7	0.2	0.2	0.3	0	7.8	8.8
Age 25-44	29.1	28.8	5.4	5.0	1.9	1.4	0.3	0.3	21.4	22
Age 45-64	53.5	50	25.8	23.1	3.0	2.3	2.3	2.1	22.2	22.4
Age ≥65	149.1	135.7	77.2	68.9	6.9	6.1	11.9	10.6	53.1	50

Temperature-mortality relationship

The relationship between daily mortality and mean temperature was found to follow the so-called V-shape (Fig. 6). TMM, for the total population and for those who were more than 65 years old, was revealed from the plots by generating Lowess-smoothed curves and graphically locating the minimum, to the nearest 0.25°C. Six different smoothing bandwidths were tried, equidistantly from 0.2 to 1, all yielding the same value of TMM. The graphic determination of TMM yielded value of 28.5 °C. An identical TMM value for the age ⩾ 65 was obtained (the graph was not shown here).

The results of the regression analysis are shown in Table 5. There was a significant relationship between temperature and mortality. Minimum and maximum temperature had the most significant impact on deaths from the selected causes. For mortality from all causes, a significant negative relationship between minimum temperature and mortality were observed.

Table 6 shows overall statistics of daily mortality and temperature parameter. The higher mortality was occurred in 2003 in which temperature value was equal to 18 °C and daily mortality rate was 119.8. But in other years, the daily mortality rate was less than 2003 because the temperature was higher. The more annual temperature decreased, the more mortality rate increased.

Table 5. Regression analysis of temperature and total and specific mortality

	Total mortality			Cardiovascular			Respiratory			Stroke		
	R	CR	p	R	CR	p	R	CR	p	R	CR	p
Mean temperature	0.76	-0.48	p<0.001	0.86	-0.36	p<0.001	0.75	-0.03	P<0.001	0.79	-0.03	P<0.001
Minimum temperature	0.77	-0.51	p<0.001	0.88	-0.39	p<0.001	0.74	-0.04	P<0.001	0.79	-0.04	P<0.001
Maximum temperature	0.77	-0.46	p<0.001	0.88	-0.34	p<0.001	0.75	-0.03	P<0.001	0.79	-0.03	P<0.001

R: R-square
CR: coefficient regression
P: p value

Table 6. Overall mortality and temperature statistic (SD: standard deviation)

Factors	All years		2002		2003		2004		2005	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Total daily mortality	113.8	(5.9)	108.1	(5)	119.8	(6.9)	112.9	(6.5)	114.4	(5.4)
Age over 65 total daily mortality	55	(3.9)	51.6	(3.5)	57.4	(5.6)	54.9	(3.1)	56.2	(3.4)
Mean daily temperature in °C	18.4	(9.7)	18.8	(9.9)	18	(9.8)	18.5	(9.3)	18.6	(9.9)
Minimum daily temperature in °C	13.6	(8.6)	14	(8.9)	13	(8.6)	13.7	(8.3)	14	(8.7)
Maximum daily temperature in °C	23.3	(10,3)	23.5	(10,6)	23	(10,5)	23.5	(9,8)	23.5	(10.6)

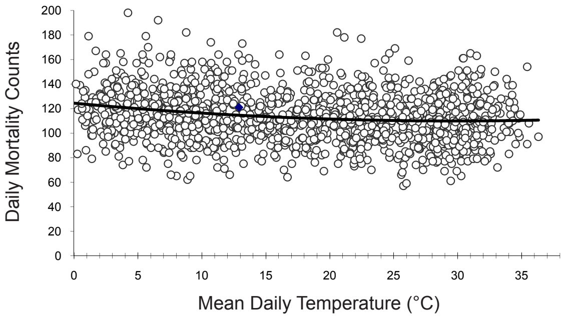

Fig. 6: Scatter diagram of total mortality with temperature for total population (lowest smoother, bandwidths 0.6).

DISCUSSION

The maximum total mortality was occurred in 6, 9 and 12 zones and for the age ⩾ 65 the maximum mortality was occurred in the above-mentioned and their neighboring regions. Tehran is characterized as a major socio-economic city whose inhabitants are dramatically different in terms of standard of living with other cites in Iran, but the different regions of Tehran are not homogeneous in their access to facilities, socio-economic state, and education and environment characters.

The unhygienic micro-environments, poor educated people, crowded and busy environment, etc in the 6, 9 and 12 regions and neighboring zones have been recognized as risk factors which increase vulnerability to heat and cold. Additionally, in these zones people are older than the others that can be considered as a strong reason.

A number of authors have pointed out that population in cold regions are vulnerable to heat, while those living in warm climates are more sensitive to cold weather (Applegate *et al.*, 1981; Semenza *et al.*, 1995; Curriero *et al.*, 2002). Long-term physiological adaptation is often presented as an explanation. However, this conclusion is based on studies conducted in the relatively prosperous countries of Europe and North America, with temperate to cold climates. Results of this study confirm some previous findings: for example in Moscow similar to Tehran, there is a winter excess of deaths but this is much smaller than many western countries rate (Mc kee *et al.*, 1998). 11 cities of eastern United States demonstrated an association between temperature and mortality across a range of less extreme temperatures (Curriero *et al.*, 2002).

In Hong Kong, a winter peak in sex specific and total deaths from all causes, circulatory and respiratory diseases were ascertained (Yan *et al.*, 2000); also in Madrid, mortality proved to be inversely related to cold temperature (4 to 11-day lag) and directly to warm temperature (1-day lag) (Alberdi *et al.*, 1998); in Athens, mortality was observed mainly for lag 0 during the cold period, but persisted longer during the warm period (Kassomenous *et al.*, 2007); in Shanghhai, the effects of diurnal temperature range on total non-accidental and cardiovascular mortality were significant on both cold (below 23°C) and warm (at least 23°C) days, although respiratory mortality was only significantly associated with diurnal temperature on cold days.

Above-mentioned researches show a good relationship between weather conditions and mortality which could be established in different regions of the world to predict future occurrences.

The relationship between total daily mortality and mean daily temperature for Tehran follows the V-shaped curve observed in many other cities around the world. The value of TMM for Tehran calculated 28.5°C. The more different the temperature is from the TMM, the more the death rate is increased. The confusing effect of influenza, on the other hand, may yield steeper below TMM slopes but will have no effect on the above TMM deaths. Another factor contributing to the steep above TMM slope may be socio-economic conditions and another environment factors. The highest number of mortality was occurred in the cold months of the year (December, January –February). It is so that as the temperature decreases, the death rate increases. The contributing temperature variable affecting female mortality from stroke is different from those of male mortality. It is found that exposure to the cold whether increases blood pressure, blood viscosity and heart rate (Kunst *et al.*, 1993) and may rash circulatory diseases.

The increase in death rate caused by cardiovascular, respiratory disease and stroke in the cold months of the year brings evidence to this matter. The strong weather-mortality associations in age group over-65 and very weak relationships for the three youngest age groups (ranging from 0 to 44 years-old) are important indications. They are consistent with previous research findings that the elderly are more susceptible to weather stress. This apparent weather-mortality relationship is due to the failure of homeostatic defense mechanism with advancing age that facilitates the onset of hyperthermia or hypothermia, which in turn would trigger circulatory and other diseases (Douglas *et al.*, 1991).

Further research in these regions should be conducted to clarify the complexity of weather-mortality relationships. These research findings can be useful for increasing accuracy of care and warning systems for people, specially elderly ones, who live in city zones of 6, 9 and 12, which are more vulnerable to cold temperature effects.

Based on the results of this study, it is necessary to impose new polices in Tehran as following:

-To increase the percentage of households with air conditioning and heating facilities especially in the regions 6, 9 and 12 of Tehran considering low incomes of their habitants. These people need to be made aware of simple ways they can adapt in their daily routines to prevent death due to cold weather; therefore air conditioned environments should be made readily available and accessible.

-To establish warning system to alert excess weather for vulnerable people to stay in their homes.

-To develop educational programs on TV or radio and establish workshops to present suitable solutions.

-To determine the protective measures for mitigation of the rate of mortality in Tehran.

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