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Original Article

Excess Mortality during Heat Waves, Tehran Iran: An Ecological Time-Series Study

Elham Ahmadnezhad (MD, MPH)[a], Kourosh Holakouie Naieni (PhD)[a*], Ali Ardalan (PhD)[b], Mahmood Mahmoudi (PhD)[a], Masoud Yunesian (PhD)[c], Kazem Naddafi (PhD)[c], Ali Reza Mesdaghinia (PhD)[c]

[a]Department of Epidemiology and Biostatistics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

[b]Department of Disaster & Emergency Health, National Institute of Health Research, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

[c]Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

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*** Correspondence**
Kourosh Holakouie Naieni (MD)
Tel:+989121056029
E-mail1:holakoin@tums.ac.ir
E-mail2:holakoik@hotmail.com

ABSTRACT

Background: In the past three decades, Tehran, capital of Iran, has experienced warmer summers so we need to determine heat-related mortality to establish appropriate public health activities during hot summers. The aim of this study was to detect heat waves during the last decades and then determine excess mortality in immediate and lagged times.

Methods: An ecological study based on time-series model was conducted in Tehran for recent decade using generalized linear lagged model (GLLM) with Poisson regression in 2001-2011. Maximum daily temperature was heat exposure for death outcome on the same day (lag 0), 3 (lag 01) and also 7 (lag 02) day moving average. Relative risk with 95% confidence was reported to quantify for increasing of daily mortalities for 1°C risen exposure. Air pollutants considered as confounders in final model.

Results: Total excess mortality during 17 heat waves was 1069 (8.9 deaths/Heat wave days). All non-external cause of death increased significantly during heat waves (3%-9%) with (RR= 1.03, 95% CI: 1.01, 1.05 and RR=1.09, 95% CI: 1.07, 1.09) and after adjusting for ozone and PM10 raised. Cause-specific deaths (especially circulatory disease) and death among elderly increased during heat waves (especially in the hottest wave). The largest positive lagged effect of hot temperature although seen during hottest waves for all mortalities. Three waves had the most harvest effect for all categories of mortalities.

Conclusion: This study showed excess mortalities resulted from hot temperatures and exacerbated with air pollutants in Tehran in the context of climate change. Forward displacement mortality and lagged mortalities were seen, but our results were not conclusive about the displacement pattern of mortalities.

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Introduction

The latest report of Intergovernmental Panel on Climate Change (IPCC-2007) emphasis that changing in climate over the coming century will be faster [1,2]. Therefore, the human threats of climate change need to be strongly considered as a public health issue and it may be the biggest global health threat in future[3,4]. General tendency was created to assess the mortality attributed to extreme temperatures after famous 5-day Chicago heat wave in 1995, which resulted up to 85% excess mortality [5]. There are the well-known examples, which demonstrated the relation between extreme events, and mortality, such as 50-US cities study [6] and the 2003 European heat wave occurred in 16 Europe countries[7], so this issue has been well documented for long time in developed countries and now has been issued as the preventable public health priority in developing worlds.

This is a known phenomenon in mega-cities, which is responsible for part of further augments increase in regional temperature. Concrete, asphalts, metals in keeping with fewer trees, and people overcrowding, embay the sunlight during day and re-radiated as heat at night. Considering that the structure of Tehran is exactly according to heat island, and then it may be predisposed to the additional risks of climate change [8-10].

Climate-related heat stress is not familiar in public health fields in many developing countries. Temperature/mortality association may depend on climatic zone and latitude and it is necessary studying in different latitudes [11,12].

Thermoregulation system of human body stabilized around 36.7 °C. During long heat wave, the temperature of human body do not able to evacuate the exceeding heat so the resulted stress induced the various health outcomes and the stroke may occur when the body temperature rise up 40 °C. Extreme temperature often has acute effects and the health related outcome may occur as soon but in some cases, it can be displaced [13,14]. The excess mortality is seen immediately or a few days later, so the short-term immediate effect on mortality and lagged effects would be considered in temperature/mortality relation studies.

According to Tehran' climate and structure, it is more likely to experience extreme events especially hot ones. As a critical public health issue, studying the climate risk factors is necessary in Tehran. We conducted this study to detect the possible heat waves by threshold approach and then quantifying short-term immediate and delayed effect on daily mortality the during the study period.

Methods

This was an ecological study based on time-series model for 10-year (21st March 2001-2011). Analysis was conducted for the warm months (May to September).

Data

Daily temperature measures (minimum, maximum and 24-hourly mean temperature) were obtained from major station of Tehran from Iran Meteorological Organization. We computed one predictor for each measure according to much close correlation between recorded temperatures, i.e. the maximum temperature is the average of all maximum temperatures, which recorded for same day in different stations.

Mortality

From Behesht-e Zahra (the principal cemetery which responsible for all deaths occurred in Tehran), individually daily mortality data were obtained. We developed a database according to ICD-10 (Tenth Revision of International Classification of Disease: A00-R99) format. Database was subdivided into age, sex and cause of death. We reported all-non external cause (all mortality minus external cause: V00-Y99 in ICD-10) mortalities, age-specific mortality for age 65+, sex-specific and cause-specific mortality from cardiovascular, cerebrovascular and respiratory disease.

Air Quality

Average daily ozone (O3), PM10 and PM2.5 was obtained from Air Quality Organization. Unfortunately, the air pollutant data were not completed for the whole study period so we analyzed based on available data.

Heat wave Definitions

Since, the universal definition of a heat wave has not been developed and best meteorological predicting measure for health outcomes has not been agreed for each climate zone, different definition may be developed. The first approach obtained from a multiple stud for special latitudes and the relationship between mortality/temperature shapes [15].

In the present study, heat wave was defined based on threshold ranges. So each period with three consecutive days with maximum temperature above 90th percentile (37.8 °C)- called first method- or three consecutive days with minimum temperatures above 90th percentile (25.7 °C) and maximum temperature exceeding monthly mean temperature +5 (both conditions would meet for the second part)- called second method- defined as heat wave during study period. Therefore, we used both daily and nightly temperatures. There is an assumption that the hot night in summer may induce more impacts [15].

Before finalizing above definition, we examined the different thresholds (80th, 90th, 95th and 97th percentiles) for indicators and found that the very hot days arrange when the maximum and the minimum temperature exceeding the 90th percentile. We restricted our definition with adding length for avoiding the overestimation. So we chose the period only when we met a 3-day or more consecutive days. Based on the above definition, Tehran has experienced 17 heat waves for whole study period except two years.

Mortality displacement (Lagged effect and Harvest effects)

Mortality displacement is known as lagged effect of several consecutive previous days of temperatures (positive effect of waves during the lags after waves) and forward displacement (harvest effect as the mortality deficit in the lag periods after waves) which debate the present day' mortality derived from exposure to the same day's temperature and temperatures on several previous days because of the substantial close correlation between consecutive days. It was recognized that the effect of heat waves almost short so lag periods defined up to seventh day [16-19].

Analysis

To examine the impact of heat waves on mortality, we calculated excess mortality as the following manner ($Y_{excess} = Y_{observed} - Y_{expected}$) for heat waves period and lagged time. Y donated the mortality count and analysis repeated for all categories of mortality. Expected mortality donates the reference period mortality. We used the near-real time as the reference period. Several studies used the average mortality of previous years (average mortality in the same times without heat waves) [20,21]. We cannot use this approach due to every previous year had at least one or more waves that in some cases exactly accordant to next year waves or with overlaps in some day. We finally selected the previous months before first wave as the near-real time (there had the same population at risk and similar confounders). Previous month for every heat wave was exactly one month before first heat wave even if multiple heat waves had experienced in one year.

With a time-series regression, we examined the cumulative excess death (Model1) and single day (Model2) approaches (as sensitive analysis). Time series data examined by Generalized linear distributed lag model (GLLM) based on Poisson regression [17,22,23]. Daily scale considered in lag models. For model 1, we determined 3 lags, L0 denotes the same (first or last) day of heat waves, Lag01 denotes +3-day and Lag 02 is the +7-day moving window. For single day approach (Model2), the same scale chosen to consider zero up to seven single lags. So the Lag0 denotes the first day and Lag 01 one day with previous temperature. For the linear estimation, we computed the Relative Risk (RR) corresponding to 1°C increase in temperature with 95% confidence interval.

The potential confounders, ozone, PM10 and PM2.5 also were assessed. Akaike's information Critaration (AIC) for goodness of fit statistical method was used. Based on this method, we found that the maximum daily temperature is the best explanatory variables of daily mortality with cumulative approach (Model1). The general model was:

$\text{Log}\ [E(\text{Death}_t)] = \alpha + \beta_0 X_t + \beta_0 X_{t-1} = L0 + \ldots + \beta_n X_{t-n=Ln} + \text{conf.}$

T= refer to the day of observation, E (Death) denotes estimated daily death counts on day t., L is the lags, conf is confounding factor.

Sensitivity analysis

We carried out sensitivity analyses using single-day lag structure to compare with multi-day analysis, Stata 11.

Results

Historical Comparison

The climate-warming trend in summer months during last 60 years is summarized in Table1. Average temperature rising was seen 1.15 °C for extreme hot indicator. Figure 1 shows the temperature (mean)/mortality relation in summer time in Tehran. Based on our definition, Tehran has experienced 17 heat waves for whole study period except two years. Table 2 summarizes heat waves' characteristics.

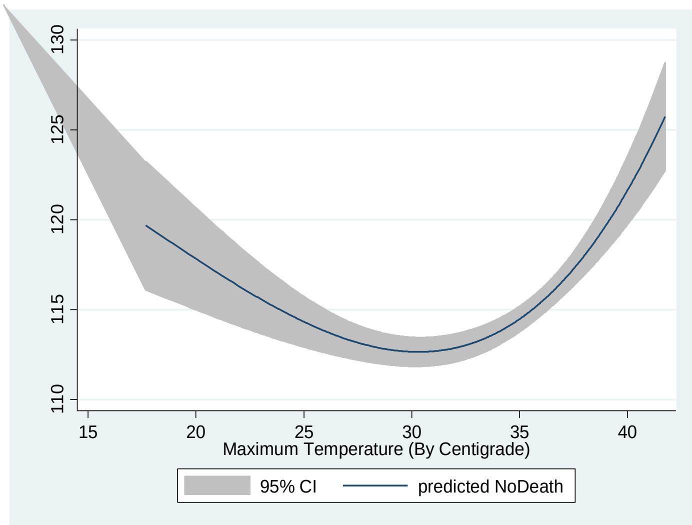

Figure 1: Relationship between mortality/maximum temperatures during for summer time in study period

Table1: Heat Waves' characteristics during 2001-2011

Year	Number of heat (wave per year)	Duration (day)	Date	Time to event (day)	Average temperature	
					Min	Max
2001	1	4	26 June-29 June	56	25.7	39.0
	2	4	07 July-10 July	67	26.8	38.9
	3	3	21 Aug-23 Aug	11	26.8	38.9
2002	1	6	15 July-20 July	75	27.2	38.7
	2	7	14 Aug-20 Aug	105	27.4	39.1
2003	1	1	06 July-19 July	66	27.7	39.4
2005	1	11	09 July-19 July	69	27.8	39.1
	2	5	04 Aug-08 Aug	95	27.4	39.5
2006	1	7	22 June-28 Jun	52	25.5	38.4
	2	5	06 July-10 July	66	27.0	39.8
	3	5	25 July-29 July	85	26.4	39.0
	4	5	02 Aug-08 Aug	94	26.2	39.3
2008	1	7	10 July -16 July	70	27.0	39.8
	2	3	27 July-29 July	87	26.9	39.0
2009	1	8	15 July-22 July	74	27.0	40.0
2010	1	14	28 June-11 July	58	26.5	39.6
2011	1	11	28 June-08 July	58	26.4	39.2
Total	17	119	-	-	-	-

Table 2: Comparison of historical and recent distribution of daily mean temperature (95th Percentile) during summer month in Tehran

Period	May	June	July	August	September	Average temperature (°C)
1951-1980	24.10	28.80	32.29	30.20	26.72	28.42
1981-2010	25.11	30.13	32.23	31.99	28.41	29.57
Trend of temperature	01.01	01.33	-0.06	01.79	01.69	01.15

Excess Mortality

Table 3 shows the results of regression analysis. All non-external mortality during 17 heat waves had the significant excess for all waves. The total excess for all non-external causes were 1096 (average 8.9 deaths/heat wave days) deaths. The largest excess was occurred in 2009' wave with 162 (19.2%), which was the hottest wave (the average of maximum daily temperature was 40 °C). During this wave an increase of 7% (P<0.001) for 1°C increase in maximum temperature was seen. The additive effects of air pollutants showed significant aggravating effect for ozone with 12% (P<0.001) increasing and additive effect of PM10 resulted 8% increase in mortality (P<0.001). We have no data for PM2.5. The air pollution data are not shown in the table.

Table 3: Excess mortality during summer heat waves; N= (Observed - Expected)/Expected, RR=Increase in mortality for 1°C temperature rising

Heat wave	2001 (1)	2001 (2)	2001 (3)	2002 (1)	2002 (2)	2003	2005 (1)	2005 (2)	2006 (1)	2006 (2)	2006 (3)	2006 (4)	2008 (1)	2008 (2)	2009	2010	2011
All Cause																	
N (%)	27 (6.1)	45 (10.0)	34 (11.6)	62 (9.8)	83 (11.6)	14 (0.8)	43 (3.2)	84 (14.6)	120 (15.8)	5.9 (3.9)	63 (11.3)	65 (11.7)	52 (6.4)	21 (5.6)	162 (19.2)	43 (2.7)	111 (8.9)
RR (95% CI)	1.04 (1.03, 1.05)	1.07 (1.05, 1.08)	1.05 (1.00, 1.09)	1.04 (1.00, 1.07)	1.07 (1.05, 1.09)	1.06 (1.03, 1.10)	1.05 (1.03, 1.06)	1.05 (1.04, 1.07)	1.03 (1.01, 1.05)	1.04 (1.03, 1.06)	1.05 (1.01, 1.09)	1.06 (1.02, 1.09)	1.06 (1.02, 1.10)	1.09 (1.07, 1.12)	1.07 (1.06, 1.10)	1.07 (1.04, 1.10)	1.07 (1.04, 1.10)
≥65 yr																	
N (%)	40 (19.3)	44 (21.8)	23 (17.1)	40 (12.3)	49 (13.9)	0 (0.0)	6 (0.8)	60 (19.3)	66 (16.5)	40 (14.3)	46 (16.7)	21 (6.7)	39 (8.8)	11 (5.6)	84 (17.7)	5 (0.5)	74 (11.0)
RR (95% CI)	1.06 (1.04, 1.08)	1.05 (1.04, 1.07)	1.03 (1.0, 1.05)	1.05 (1.02, 1.08)	1.06 (1.05, 1.08)	1.05 (1.02, 1.09)	1.04 (1.02, 1.06)	1.05 (1.03, 1.06)	1.02 (1.00, 1.04)	1.04 (1.03, 1.05)	1.04 (1.01, 1.08)	1.05 (1.02, 1.09)	1.06 (1.02, 1.20)	1.08 (1.04, 1.12)	1.09 (1.07, 1.10)	1.06 (1.03, 1.09)	1.06 (1.02, 1.09)
Male																	
N (%)	-2 (0.8)	6 (2.6)	23 (15.6)	62 (21.7)	70 (20.8)	9 (1.0)	15 (2.1)	44 (15)	37 (9.0)	49 (18.5)	45 (15.8)	35 (12.7)	6 (1.3)	9 (4.5)	77 (16.8)	7 (0.8)	27 (3.9)
RR (95% CI)	1.04 (1.02, 1.06)	1.06 (1.04, 1.09)	1.04 (0.98, 1.10)	1.02 (1.00, 1.05)	1.07 (1.05, 1.09)	1.05 (1.02, 1.09)	1.04 (1.02, 1.05)	1.04 (1.02, 1.06)	1.04 (1.02, 1.06)	1.04 (1.02, 1.06)	1.04 (1.00, 1.08)	1.05 (1.01, 1.09)	1.05 (1.02, 1.08)	1.08 (1.06, 1.11)	1.06 (1.04, 1.09)	1.06 (1.03, 1.09)	1.07 (1.04, 1.11)
Female																	
N (%)	30 (20.2)	34 (21.8)	11 (10.6)	15 (5.9)	24 (8.6)	32 (5.3)	23 (4.7)	38 (16.9)	85 (32.4)	-6 (,2.8)	34 (18.2)	13 (5.8)	53 (16.9)	12 (8.2)	68 (20.9)	26 (4.0)	54 (11.3)
RR (95% CI)	1.04 (1.01, 1.07)	1.05 (1.02, 1.07)	1.03 (1.00, 1.07)	1.04 (1.02, 1.06)	1.06 (1.04, 1.08)	1.04 (1.01, 1.08)	1.05 (1.02, 1.08)	1.06 (1.04, 1.08)	1.02 (0.99, 1.05)	1.03 (1.02, 1.04)	1.05 (1.00, 1.10)	1.06 (1.00, 1.11)	1.04 (0.98, 1.09)	1.10 (1.06, 1.13)	1.08 (1.04, 1.12)	1.05 (1.02, 1.09)	1.03 (1.00, 1.07)
Cardiovascular																	
N (%)	-3 1.4)	26 (14.0)	15 (11.7)	44 (16.7)	20 (6.3)	40 (5.8)	43 (9.3)	32 (15.5)	33 (12.2)	13 (6.8)	-17 (-8.9)	27 (14.4)	12 (0.3)	5 (3.5)	60 (17.5)	-10 (-1.6)	24 (5.3)
RR (95% CI)	1.05 (1.01, 1.08)	1.05 (1.03, 1.07)	1.05 (0.98, 1.12)	1.04 (1.00, 1.08)	1.05 (1.03, 1.08)	1.06 (1.03, 1.09)	1.05 (1.01, 1.09)	1.05 (1.02, 1.08)	1.04 (1.01, 1.06)	1.03 (1.03, 1.04)	1.01 (0.97, 1.05)	1.04 (1.01, 1.07)	1.06 (1.01, 1.12)	1.07 (1.02, 1.12)	1.08 (1.05, 1.10)	1.05 (1.02, 1.08)	1.07 (1.04, 1.11)
Cerebrovascular																	
N (%)	12 (28)	-1 (-2.1)	-2 (-10.0)	11 (35.5)	3 (7.1)	-9 (-5.2)	-7 (-5.1)	5 (8.4)	0 (0. 0)	-8 (-14.2)	22 (52.4)	8 (14.8)	4 (8.9)	-2 (-7.6)	25 (52.0)	3 (2.8)	82 (21.0)
RR (95% CI)	1.03 (0.95, 1.11)	1.03 (0.98, 1.09)	0.90 (0.83, 0.98)	1.02 (0.94, 1.09)	1.01 (0.99, 1.04)	1.11 (1.40, 1.18)	1.0 (0.95, 1.05)	1.06 (1.01, 1.10)	1.07 (1.01, 1.14)	1.03 (1.00, 1.06)	1.10 (1.04, 1.17)	1.10 (1.02, 1.19)	1.04 (0.94, 1.15)	1.03 (0.93, 1.14)	1.06 (1.01, 1.12)	1.01 (0.96, 1.06)	1.03 (0.98, 1.08)
Respiratory																	
N (%)	-3 (16.6)	6 (31.5)	3 (30.0)	-10 (-35)	-3 (-9.4)	1 (1.3)	3 (3.0)	6 (18.7)	-4 (-6.9)	-5 (-11.3)	4 (9.5)	-9 (-20.4)	10 (18.5)	16 (66.7)	19 (33.4)	6 (4.4)	0 (0.0)
RR (95% CI)	1.01 (0.93, 1.11)	1.09 (0.97, 1.21)	1.09 (1.05, 1.12)	0.92 (0.87, 0.98)	1.02 (0.95, 1.10)	0.98 (0.90, 1.08)	1.01 (0.96, 1.07)	1.03 (0.97, 1.10)	0.99 (0.93, 1.05)	1.02 (0.98, 1.06)	0.99 (0.92, 1.07)	0.93 (0.85, 1.01)	1.06 (0.99, 1.13)	1.19 (1.12, 1.27)	1.06 (0.94, 1.20)	0.99 (0.96, 1.02)	1.08 (0.99, 1.13)

Mortality for 65+ years had also significant excess. The largest deaths also happened in heat wave of 2009 were about 84 (17.7%) and total deaths were 648 (average 5.4 deaths/ heat waves days). An increase of 9% (P<0.001) for 1°C was seen for heat wave period and after adjusting of ozone a significant decrease also seen. The PM10 had not an aggregative effect.

Total excess death among males was 519 and females 546 (1.05 more than in male) deaths. The largest excess was seen in also heat wave of 2009 with 77 (16.8%) deaths among male and 9% significant increasing in mortality for 1°C arising in daily temperature occurred. For females, the largest excess happened during the first heat wave of 2006 (the earliest heat wave). The observed mortality were 85 (32.4%) with 2% increasing (P=0.080) for 1°C temperature' arising. After adjusting for ozone, the excess deaths of male had one percent decrease (P<0.001) and for PM10, there was not any change. There was not any record for ozone in 2006 and PM10 did not aggravating factor for increasing mortality among females.

Total excess deaths were 364 (average three deaths/heat wave days), 85 (average 0.7 deaths/heat wave days) and 40 (average 0.3 deaths/ heat wave days), were seen for cardiovascular, cerebrovascular and respiratory diseases, respectively. The 2009' wave had the greater impact on cause-specific mortalities and 8% statistically significant increasing in cardiovascular mortality was seen (P<0.001) and after adjusting for ozone, a significant decrease in mortality (8% to 7%) occurred (P<0.001). PM10 had not additive effect on cardiovascular mortality. The largest excess mortality among cerebrovascular disease were 25 (52%) deaths with 6% increasing for 1°C arising in temperature (P=0.010) and assessing the additive effects of air pollution displayed 2% significantly increase for ozone (P=0.009) and 1% significantly decrease for PM10 (P=0.020). The respiratory disease had the smallest excess deaths compare with others and the largest occurred in 2009' wave with 19 (33.4%) deaths and every 1°C increasing in temperature, death increased 6% (P=0.020).

Sensitivity Analysis

Applying the sensitivity analysis showed the multi-day metrics had robust estimation than single-day approach. Analyses of single-day approach do not show in the article.

Lagged effect

For all non-external cause of mortality, the largest positive displeased deaths occurred during the 2009' wave. Total displeased deaths were 181 (15.5%) in lag 01 with 2% increasing (P=0.060) and 2% (P=0.09) for lag02 with 236 total displeased deaths. The largest displeased deaths for age 65+ mortality occurred in the first wave of 2006 (earliest wave) with 104 (18.2%). The largest displeased mortalities for some categories of mortalities also occurred in 2009 and were the largest counts that included mortalities among age 65+ with 125 excess with 2% increase (P=0.040) in lag01, among male were 74 (11.5%) with 2% increase also in lag01, among cerebrovascular were 35 (36.4%) deaths (P=0.200) and respiratory were 11 excess displeased mortalities in lag02. Table-4 summarized the displaced effects of heat waves.

Harvest effects

Table 4 shows the results of forward displacement of mortality. The first heat wave of 2005, second of 2006 and second of 2008 had some deficit of mortality in the lag periods after waves. The hottest wave (2009) had not any deficit mortality. In addition, it was the same for earliest wave (1^{st} 2006) and only in lag01, there was two deficit mortalities.

Table 4: Positive lagged and deficit mortalities during heat waves on study period (bold figures mean significant); MA: moving average (day)

MA	Heat Wave	2001 (1)	2001 (2)	2001 (3)	2002 (1)	2002 (2)	2003	2005 (1)	2005 (2)	2006 (1)	2006 (2)	2006 (3)	2006 (4)	2008 (1)	2008 (2)	2009	2010	2011
All Cause																		
3	01	**92**	83	28	**103**	**61**	55	**-42**	127	134	**4**	**33**	135	57	-10	181	74	101
7	02	**47**	**163**	**-1**	**62**	**53**	**73**	**-85**	**73**	**196**	**-52**	**162**	**82**	**80**	-6	236	**71**	**142**
≥65 yr																		
3	01	**81**	**55**	**20**	40	34	65	-31	**77**	104	**32**	65	67	54	-5	87	19	64
7	02	**57**	**102**	**-6**	**44**	**35**	**68**	**-48**	**19**	**109**	**16**	**87**	**44**	**75**	-3	125	**38**	**96**
Male																		
3	01	**27**	24	38	**72**	59	14	**-10**	**71**	61	**30**	66	65	9	**1**	74	34	-12
7	02	8	**62**	**38**	45	**81**	**4**	**-54**	**34**	**97**	**15**	93	**40**	**34**	-17	95	**48**	-8
Female																		
3	01	**67**	37	**7**	40	18	65	-13	53	**109**	**-28**	43	55	72	-11	71	32	**77**
7	02	56	**83**	**-19**	**50**	**9**	**96**	**-8**	**49**	**101**	**-33**	64	15	78	-12	101	25	**110**
Cardiovascular																		
3	01	44	71	29	56	**20**	-12	23	58	48	**-2**	-7	31	-4	-38	61	14	-6
7	02	**41**	105	**30**	**49**	**-2**	**-8**	**-20**	**32**	**68**	**-22**	**23**	**19**	**-4**	-38	**84**	**18**	-6
Cerebrovascular																		
3	01	29	-3	0	15	9	**-12**	-17	4	**-2**	-14	26	**-1**	-5	-2	20	11	25
7	02	28	18	**-17**	11	**11**	**-8**	-15	5	**3**	-23	38	-11	-15	-12	35	5	32
Respiratory																		
3	01	-2	7	**0**	-3	-2	1	3	-4	**4**	-10	18	0	4	22	7	**21**	-16
7	02	-9	5	**-2**	**4**	-9	-16	-3	-20	4	-21	10	3	8	**6**	11	-4	-2

Discussion

The acute effect of hot daily temperature on mortality has been well-studied in many western developed countries [7,16,24-26]. The present study investigated the impacts of heat waves on mortalities under the changing climatic conditions in Tehran, which to our knowledge; this is the first report to assess the immediate and lagged effect of hot temperature during heat waves on mortality outcome in this region.

Increasing in observed mortality rates during heat waves period in comparison with reference period was the principle finding of present study, which supports the study hypothesis and compatible with other many literatures [14,16,18,24,26]. Different type of heat waves was seen during the study period, which differs in intensity, time of beginning and length. [16,19,26]. Another main result of our study was that the intensity had more effect than other aspects. As so far, the unusually hottest heat wave of 2009 provided the largest excess and displeased mortalities that it was consistent with other literature [22,27]. However, in the EuroHeat study, the intensity of heat waves only had low effect on mortality [24].

We found a small gender difference, which the females were more vulnerable. It may be related to treatment seeking among male or perhaps the females are more vulnerable to hot temperature physiologically. Gender differences in other studies often assessed for elder groups then they did not find a major difference among two genders [21,28] but we studied all age groups both for male and female.

The results of regression analysis also verified the principle analysis and showed the significant excess total mortality (3-9%). We found also the significant excess mortality among the oldest people (65+), which the health status of this group was expected to be more sensitive to hot weather. There is an interest to assessing the temperature effects based on age categories and many literatures found the positive relation between exposure and outcome of interest [20,27,29]. The 2009' wave provided largest effect on mortality among 65+ years of old. This result confirms that the older people to be more sensitive on very hot temperature. Our results also agree with heat stress studies among elder people during hot periods[27,30].

All causes-specific of mortality were also more than in 2009' wave that supports the relation of mortality with very hot temperature' hypothesis. Cardiovascular mortality especially to be more than others and had the significantly arising during many heat waves in the present study. Cause-Specific mortality relation with temperature studied widely and adverse effects has been found[18,20,28,29]. Respiratory mortalities were a little less affected by hot temperature in our study and population with circulatory disease is more vulnerable. A study among elderly people showed the same results [18].

Respiratory mortalities may be more affected by lower extreme weather than high so we can conclude our results based on this assumption. However, the EuroHeat study [24] and heat wave of July 2006 had different results [20]. We did not categorize the cause-specific mortalities by age groups so the different results may due to this fact.

The longest heat wave (2010' heat wave) has not more effect in comparison other than the waves; however, results of another study were against our results [16,18,19,24] but one study reported that heat waves had only small-added effects sustained more than four days that consistent with our results [17]. This controversy may be due to people behavior which in long heat waves they are doing some preventive actions.

Time of beginning of wave (earlier in summer) has more impacts on mortality [26]. The results of the present study are concurrent.

Ozone and PM10 increased statistically significant all non-external cause of mortality risk in present study during the hottest heat wave. The effect of ozone was more than PM10 and the effects of the two pollutants seem to be independent. Others studied the probable additive effects of air pollutants and showed some positive or negative results [6,18-20]. We assumed that the different results might be due to target group and the concentration of pollutants, which Tehran as a metropolitan area espoused to high concentration of air pollutant. We found that in hottest wave both pollutants had an additive effect that consists with other reports [12,20].

The results of regression analysis showed that in the earliest wave and although the hottest, mortality regardless to classification increased in longest lag (Lag 02). This was agreed with longer positive lag effects which reported by others [23,26]. The deficit mortality assumption also confirmed by this report and was seen in the first heat wave of 2005, second one 2006 and 2008. Deficit mortalities were seen also in cardiovascular and cerebrovascular mortalities that consistent with previous literatures [18].

Our reports depend on heat wave definition and furthermore the reference period so some information bias may influence. In addition, other source of bias is due to classification of disease. Based on methodology, our conclusions may be resulted from ecological fallacy, and then other studies would be considered using the results.

Conclusion

However, Tehran population would adjust to hot temperature, but the growing global warming and urbanization and aging may be faster than adaptation. Then the timely intervention for future probable heat waves would be considered. Accompanying the very hot temperature, ozone and PM10 have additive risk on mortalities in Tehran perhaps due to high concentration of air pollutants.

Totally, the results of displacement mortality due to heat waves of present study were not conclusive. Up to now, health impacts of climate change have not been studied much in details so future studies could focus on understanding the association between current climates with future impacts on health. For that reason the health outcomes interest would collect under routine surveillance data (such as specific mortality and related morbidities' data). According to this fact, Tehran often experiences heat waves around June up to August, establishing a warning system is necessary.

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Conflict of interest statement

Authors declare that present study has no conflict of interest.

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