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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.

Keywords: Diurnal Temperature Range, mortality, 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 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 1,330 meters 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 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 missingdata 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 inthe 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 studydistributed LagNon-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 dfnaturalcubic 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.Asthe effect of DTR may vary between the hot season (from May toOctober) 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 percent 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-hour 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 Figure1 shows the relation between the changes in DTR index vs. mortality. As Figure 1(a) shows NAD risk increases at higher DTR values in the initial lags; and in low levels of DTR in the final lags.

Figure 1(b) is about respiratory mortality shows, at higher DTR values, mortality risk increases in the initial lags; and decreases in the final lags (harvesting effect). But at low DTR levels, the risk of death decreases.

In Figure 1(c) is about cardiovascular mortality risk increases at higher DTR values in the initial lags. But at low DTR levels, no significant change is observed in the risk of death.

DTR index had a nonlinear effect on mortality and at higher levels of the index, especially in the initial lags, the risk of death had the largest increase compared to the DTR median (14°C) (Table 1).

In NAD, at high levels of DTR (all percentiles) and all lags, there was an increase in CRR that significantly increased in 0-6 lags and the highest CRR was observed in the lag (0-6).

In respiratory death, CRR increasedwith increasein DTR,in all percentiles and most lags. But no significant effect was observed in the cardiovascular death.

Table 1-S (Supplementary) shows the relation between the DTR index and NAD in terms of demographic variables. In high values of the DTR index (99th percentile), in over 75 group, CRR significantly increased in the initial lags (0-2).

In low values of the DTR index, in the age group below 65 and in the 5th percentile inlag 0,a significant decrease in CRR was observed.

In high levels of the DTR index (the 99th and 97.5th percentiles), CRR significantly increased on lag 0 among men. But the other results were not significant.

4.3: Seasonal analysis

Figures 2(a, b, and c)show the relation between the DTR index and death in the warm season and Figures 2(d, e, andf)show the relation between the index and death in the cold season.

4.3.1: Warm season

In high DTR, the CRR of NAD significantly increased in the initial lags (0-6), but in low levels of the DTR index, the results were contradictory. In the 1st percentile, in the middle lags,CRR significantly decreased, but in the 5th percentile in the final lags it significantly increased (Table 2).

In regard to respiratory deaths, in high DTR levels a significant increase in CRR was only seen in lag 0 and the 99th percentile. No significant effect was observed at low DTR levels.

In regard to cardiovascular deaths,in high DTR levels (99th and 95th percentiles) in most lags, there was a significant increase in CRR. No significant effect was seenin low DTR levels.

During the warm season, in high DTR levels (all percentiles) and in the initial lags, the relative risk (RR)of NAD increased. RR also increased in the 5th percentile in the middle lags (lag 4 to 18). But in the 1st percentile inlags 1-14, the RR of NAD decreased.

RR increased in respiratory deaths, only in the99th percentile of DTR and in lag 0; and in cardiovascular deaths, in the 99th and 97.5th percentiles of DTR and the initial lags (Tables 2-S and 3-S) (Supplementary).

4.3.2: Cold season

There was a protective effect for NADsin low and high levels of the index (all percentiles) and thisreduced risk was significant in some lags (Table 3). In respiratory death, no significant results were observed in either high and low values of DTR.

CRR of cardiovascular deaths decreasedin high levels of DTRin all lags and was significant in the 97.5th percentile and the final lags. But no significant effect was observed at low levels of DTR.

During the cold season, there was a significant protective effect at high levels of DTR (90th, 95th and 97.5th percentiles) for NAD in the initial and middle lags. In cardiovascular death, there was a significant decreased risk, at high amounts of DTR (97.5th percentile)and in the middle lags.

5. Discussion:

Acute effects of extreme thermal events such as heat waves on mortality has been shown in some studies (Anderson and Bell, 2009; Huynen et al., 2001; Muggeo and Hajat, 2009). However, these studies have used the average and maximum temperature as the temperature index. Recently researchers have suggested that perhaps DTR is a better index for showing the relation between temperature variations and mortality(Kan et al., 2007). Some studies that have addressed the relation between DTR and mortality on a single day (single day model) have reported a linear relationship between DTR and mortality(Kan et al., 2007). And others have reporteda relation between high DTR and NADs, respiratory or cardiovascular deaths(Cao et al., 2009; Chen et al., 2007; Kan et al., 2007; SONG et al., 2008). A study from Hong Kong showed that for each 1°C increase in DTR, the risk of cardiovascular death in lag 0-3 increased 1.7%(Tam et al., 2009). In the present study,in high DTR, in all percentiles, over the year and in the warm season;the CRR of all types of death increased, especially in the initial lags (0-13). But in low DTR levels, depending on the type of death, the study period (whole year, warm or cold seasons) and the percentiles (1th, 2.5th, 5th and 10th) the CRRs were various and no specific trend was observed.

Luo et al(Luo et al., 2013)conducted a study to assess the effect of high and low levels of DTR on death in Guangzhou city, China and the results of their annual analysis showed that high levels of DTR (more than the 99th percentile) increased the risk of NAD (RRNAD lag (0) = 1.06, 95%CI: 1.01-1.11) and RD(RRRD lag (0) = 1.14, 95%CI: 1.001-1.32); and the highest relative risk was at lag 0. In the present study, the highest relative risk for NAD and RD was in lag 0 and in the 99th percentile.

In Luo et al'sstudy at very low DTR levels (less than the1st percentile) and lag 0, the highest significantrelative risk for NAD and CVD and the lowest significant relative risk for respiratory death was seen (Luo et al., 2013)But in this study, the relative risks were not significant in lag 0.

Another result of this study was the non-linear relation between DTR and death which was similar to Luo et al's study. Also in the present study, the immediate effect (zero lag effect) of high DTR levels in the warm season was more than the cold season which was similarto Luo et al'sstudy (table 3-S) (Supplementary).

In the present study, in theseasonalanalysis,in the warm season, at high DTR levels, in all deaths and percentiles,the highest CRR were seen in the initial lags (0-6), which were similar to Luo et al's study. In this study, at low DTR levels (1st percentile) there was a protective effect for NAD,which is not consistent with Luo et al's study in Guangzhou where the risk of death increased at low levels of DTR (less than the 1st percentile), especially in the final lags. However, in the present study, the risk of NAD significantly increased in the5th percentile and in the final lags.

In the present study during the cold season,and at high levels of DTR, in many lags, the CRR of NAD and cardiovascular death decreased. This is not consistent with Luo et al's results. In Guangzhou,in the cold season similar to the warm season,in extreme DTR values (above the 99th and less than 1st percentile), the risk of NAD, RD, and CVD increased especially in the final lags(Luo et al., 2013). In the present study, there was a clear trend at high DTR levels in the annual and warm season analysis,which showedwith increase in DTR from the 90th to 99th percentiles, the risk of death increased which is consistent with Luo et al's study. But at low DTR levels with decrease from the 10th to 1stpercentiles, the the risk of death was different in different lags which is not consistent with Luo et al's report. The different meteorology conditions between Urmia and Guangzhou, and the difference in the people's adoptability can be one of the important reasons for this difference. The maximum DTR in Guangzhou was 16.9°C, but it was 24°C in Urmia.

Chen et al conducted a study to assess DTR changes and sudden infant death (SID) in 2001-2004 in Shanghai, China and used time- stratified case- crossover analysis. The results showed that1°C increase in DTR in one day, increased SID by 1.56%, 95%CI:0.97-2.15(Chen et al., 2011). In the present study, high levels of DTR increased the risk of NAD.

Vutcovici et al conducted a study in 1984-2007 to evaluate the impact of DTR on NAD in the elderly (over 65 years old) in Montreal. In this study, the effects of the DTR index up to lag 30 were analyzed with constrained distributed lag nonlinear models and the results showed that as the DTR index increased from the 25th to 75th percentile,the risk of NAD increased by 5.12%, CI95% 0.02%-10.49%. Also as the DTR index increased from the 25th to the 99th percentile,the CRR of NAD increased by 11.27%,CI 95% 2.28%-21.29%(Vutcovici et al., 2014);these results were consistent with the results of the present study. In the present study,in the elderly (over the age of 75) at high DTR levels,the risk of increased especially in the initial lags.

In Zhou et al's study about the impact of increasing DTR on mortality that was done in 8 cities of China in 2001-2010. First, the relationship between DTR and death was evaluated separately in each city and then using meta-analysis an overall effect was estimated and the results showed that as DTR increases, NAD, RD and CVD in the whole year, warm and cold seasons, increase as well. As per 1°C increase in DTR during the cold season and in lag 1, RD, CVD and NAD increased by 0.81, 0.46 and 0.42% respectively(Zhou et al., 2014). In the present study, the risk of death increased in the whole year and warm season as DTR increased; and the risk of RD also increased in the cold season. The important difference between the present study and Zhou et al's results are in the cold season, and NAD and CVD. However, in Zhou et al, the reduced risk of NAD was reported in some cities, in the cold season. In both studies,as DTR increased, the risk of NAD in the elderly, compared to under 65 years,increased as well.

In Iran, few studies have addressed the relationship between temperature changes and health. In Dadbakhsh and et al's study the relation between temperature and respiratory diseases mortality was evaluated in the city of Shiraz (southern Iran) and the results showed that there was a statistically significant association between mean daily temperature and RD; and as it got colder, the number of RD increased(Dadbakhsh et al., 2016). In this study, no significant association was observed between low levels of DTR,and death.However, at high DTR levels the risk of the RD increased significantly in the whole year and warm season and non-significantly in the cold season.

Khanjani and et al's study in Kerman (South East of Iran), showed that the risk of CVD and RD increased significantly with decreasing temperature(Khanjani and Bahrampour, 2013). The results of this study were consistent with the present study,and in the cold city of Urmia there was an increase in NAD, CVD and RD risk in the warm season, but the risk of CVD and NAD decreased in the cold period.Both studies indicated people's adaptation with the dominant temperature. These results were also consistent with the studies conducted in Europe(Keatinge et al., 2000)and America(Curriero et al., 2002) and showed that in the countries with low annual mean temperature, heat had a greater impact on mortality.

The mean temperature in the world has increased by 0.5°C over the last century. This is partly due to the faster-increasing trend or slower declining trend of the minimum daily temperature in comparison to the maximum daily temperature that has reduced DTR in many parts of the world(Zhou et al., 2014). DTR changes are different and complex in various parts of the world; for example, despite the reducing DTR trend observed in some developed and developing parts of the world, the DTR index has had an increasing trend in India, Russia and the northern parts of China due to decrease in minimum daily temperature(Li and Chen, 2009). In the recent decades, DTR has had a reducing trend in most parts of Iran, the including Northwest(Rahimzadeh et al., 2009). This may be due to different demographic characteristics, adaptability with the climate, type of housing, heating and cooling methods.

Previous studies have shown that these factors affect the relation between temperature and health(Basu and Samet, 2002).

6. Conclusion:

High levels of DTR increase the risk of NAD, RD and CVD especially in warmer seasons and may have aprotective effect on NAD and CVD in the cold seasons. No clear relation was observed between low values of DTR and mortality in the northwest of Iran which is a region with a cold and mountainous climate.

Conflicts of interest: none

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Fig. 1 Relative risks of Non Accidental Death (a), Respiratory Death (b) and cardiovascular Death (c) by Diurnal temperature range (°C), using a natural cubic spline-natural cubic spline DLNM with 5 df for DTR and 2 df for lag in full year.

Fig. 2 Relative risks of Non Accidental Death (a-d),Respiratory Death (b-e) and cardiovascular death (c-f) by Diurnal temperature range (°C), using a natural cubic spline-natural cubic spline DLNM with 5 df for DTR and 2 df for lag in the seasonal analysis. a,b,c (hot season) and d,e,f (cold season).

Table 1: The cumulative relative risks (CRR, mortality in low and high DTR* values relative to mortality in DTR=14°C) stratified by cause –specific mortality in the full year.

Death type	DTR value(°C)		Lag0	Lag 0-2	Lag 0-6	Lag 0-13	Lag 0-20	Lag 0-27
NAD•	H**	99^{th} (22)	**1.06(1.01-1.11)**	**1.16(1.03-1.31)**	**1.25(1.005-1.55)**	1.17(0.83-1.62)	1.07(0.68-1.68)	1.15(0.65-2.02)
		97.5^{th} (20)	**1.05(1.01-1.09)**	**1.13(1.03-1.24)**	**1.19(1.02-1.41)**	1.11(0.89-1.40)	1.02(0.78-1.35)	1.04(0.74-1.48)
		95^{th} (19)	**1.04(1.007-1.07)**	**1.11(1.01-1.21)**	1.15(0.99-1.34)	1.09(0.88-1.35)	1.01(0.77-1.32)	1.02(0.73-1.42)
		90^{th}(18)	**1.03(1.003-1.05)**	**1.07(1.002-1.15)**	1.11(0.98-1.26)	1.08(0.91-1.28)	1.02(0.82-1.26)	1.003(0.76-1.32)
	L***	10^{th} (7)	1.00(0.97-1.04)	1.02(0.92-1.11)	1.03(0.86-1.23)	1.04(0.78-1.37)	1.01(0.69-1.48)	0.96(0.59-1.54)
		5^{th} (4)	0.99(0.96-1.03)	0.99(0.90-1.09)	1.01(0.85-1.19)	1.06(0.83-1.36)	1.08(0.78-1.49)	1.02(0.68-1.52)
		2.5^{th} (3)	0.99(0.95-1.04)	0.98(0.88-1.10)	0.99(0.80-1.22)	1.02(0.75-1.40)	1.06(0.71-1.59)	1.08(0.66-1.78)
		1^{th}(2)	0.99(0.93-1.06)	0.98(0.82-1.17)	0.97(0.70-1.34)	0.97(0.57-1.64)	1.03(0.51-2.09)	1.17(0.55-2.81)
RD••	H	99^{th} (22)	**1.15(1.001-1.32)**	1.39(0.97-1.99)	1.54(0.81-2.93)	1.05(0.38-2.88)	0.57(0.14-2.25)	0.35(0.06-1.95)
		97.5^{th} (20)	**1.14(1.02-1.26)**	**1.40(1.07-1.83)**	**1.77(1.11-2.82)**	1.85(0.96-3.58)	1.66(0.72-3.80)	1.57(0.56-4.36)
		95^{th} (19)	**1.11(1.009-1.22)**	**1.32(1.03-1.69)**	**1.65(1.07-2.55)**	**1.91(1.03-3.53)**	1.94(0.89-4.24)	2.02(0.77-5.32)
		90^{th} (18)	1.07(0.99-1.16)	1.21(0.99-1.49)	**1.45(1.02-2.07)**	**1.70(1.02-2.83)**	1.84(0.96-3.51)	1.97(0.88-4.40)
	L	10^{th} (7)	1.03(0.93-1.14)	1.06(0.82-1.39)	1.02(0.62-1.65)	0.78(0.36-1.72)	0.62(0.21-1.83)	0.62(0.16-2.36)
		5^{th} (4)	0.97(0.88-1.07)	0.92(0.71-1.19)	0.81(0.50-1.29)	0.64(0.32-1.27)	0.50(0.21-1.23)	0.41(0.14-1.25)
		2.5^{th} (3)	0.96(0.85-1.09)	0.91(0.65-1.27)	0.83(0.46-1.50)	0.72(0.29-1.75)	0.60(0.19-1.89)	0.46(0.11-1.89)
		1^{th}(2)	0.96(0.79-1.17)	0.92(0.55-1.53)	0.88(0.34-2.26)	0.87(0.19-3.93)	0.78(0.10-5.95)	0.56(0.05-6.92)
CVD•••	H	99^{th} (22)	1.06(0.98-1.14)	1.15(0.95-1.40)	1.22(0.87-1.75)	1.09(0.65-1.88)	0.92(0.45-1.95)	0.83(0.35-2.20)
		97.5^{th} (20)	1.03(0.97-1.08)	1.07(0.92-1.24)	1.10(0.85-1.42)	1.06(0.74-1.50)	0.99(0.64-1.55)	0.98(0.57-1.70)
		95^{th} (19)	1.01(0.96-1.07)	1.04(0.91-1.18)	1.05(0.83-1.33)	1.03(0.74-1.43)	0.99(0.65-1.51)	0.99(0.59-1.66)
		90^{th}	1.004(0.96-1.05)	1.01(0.90-	1.01(0.83-	0.99(0.76-	0.98(0.69-	0.96(0.63-

	(18)		1.13)	1.22)	1.31)	1.38)	1.47)
L	10th (7)	1.01(0.95-1.07)	1.03(0.89 - 1.12)	1.08(0.83- 1.42)	1.16(0.75- 1.80)	1.12(0.62 - 2.04)	0.96(0.46 - 2.01)
	5th (4)	1.001(0.95-1.06)	1.01(0.87- 1.17)	1.06(0.82 - 1.38)	1.16(0.80- 1.71)	1.14(0.70- 1.87)	0.91(0.49- 1.70)
	2.5th (3)	1.009(0.94-1.08)	1.03(0.86- 1.23)	1.09(0.80- 1.51)	1.2(0.74- 1.97)	1.23(0.65- 2.32)	1.09(0.50- 2.40)
	1th(2)	1.02(0.92-1.13)	1.06(0.80- 1.40)	1.14(0.74- 1.90)	1.27(0.56- 2.90)	1.37(0.45- 4.18)	1.41(0.35- 5.64)

* Diurnal Temperature Range (°C)

**High Extreme DTR effect: The cumulative effects of99th, 97.5th, 95th and 90th percentile of DTRon mortality categories, relative to 50th percentile of DTR (14°C)

***Low Extreme DTR effect: The cumulative effects of10th, 5th, 2.5th and1th percentile of DTRon mortality categories, relative to 50th percentile of DTR (14°C)

• Non-Accidental Death

•• Respiratory Death

••• Cardiovascular Death

Table 2: The cumulative relative risks (CRR, mortality in low and high DTR* values relative to mortality in DTR=14°C) stratified by cause –specific mortality in the hot season.

Death type	DTR value(°C)		Lag0	Lag 0-2	Lag 0-6	Lag 0-13	Lag 0-20	Lag 0-27
NAD•	H**	99th (22)	**1.09(1.03-1.16)**	**1.27(1.08-1.48)**	**1.46(1.08 - 1.98)**	1.41(0.83-2.37)	1.23(0.58-2.59)	1.19(0.46-3.08)
		97.5th (21)	**1.09(1.03-1.15)**	**1.25(1.09-1.45)**	**1.44(1.09-1.89)**	1.39(0.87-2.12)	1.23(0.64-2.33)	1.18((0.53-2.64)
		,95th (20)	**1.08(1.03-1.14)**	**1.23(1.07-1.42)**	**1.41(1.07-1.85)**	1.39(0.87-2.22)	1.25(0.0.65-2.40)	1.21 (0.54-2.73)
		,90th (19)	**1.07(1.02-1.12)**	**1.20(1.05-1.36)**	**1.36(1.06-1.75)**	1.40(0.91-2.16)	1.32(0.72-2.40)	1.28(0.61-2.71)
	L***	10th (10)	0.99(0.94-1.05)	0.99(0.85-1.15)	0.97(0.71-1.33)	0.95(0.53-1.71)	0.94(0.40-2.21)	0.96(0.33-2.81)
		5th (7)	1.03(0.92-1.14)	1.15(0.85-1.54)	1.67(0.90-3.10)	**3.86(1.19-12.49)**	**7.16(1.34-38.08)**	**7.72(1.03-57.70)**
		2.5th (4)	0.96(0.87-1.07)	0.93(0.70-1.23)	0.93(0.51-1.68)	1.05 (0.34-3.23)	1.19 (0.25-5.76)	1.19(0.18-7.83)
		1th(3)	0.92(0.82-1.01)	**0.75(0.57-0.99)**	**0.49(0.27-0.87)**	**0.23(0.07-0.71)**	**0.14(0.03-0.73)**	0.13(0.01-1.05)
RD••	H	99th (22)	**1.20(1.006-1.44)**	1.59(0.98-2.58)	1.99(0.78-5.08)	1.49(0.29-7.51)	0.79(0.08-7.85)	0.44(0.02-7.94)
		97.5th (21)	1.15(0.98-1.35)	1.44(0.93-2.21)	1.73(0.76-3.96)	1.42(0.35-5.67)	0.87(0.13-5.98)	0.54(0.05-5.99)
		,95th (20)	1.12(0.95-1.31)	1.33(0.87-2.03)	1.56(0.70-3.55)	1.40(0.35-2.62)	0.98(0.14-6.84)	0.66(0.06-7.51)
		,90th (19)	1.09(0.95-1.26)	1.26(0.86-1.86)	1.48(0.70-3.14)	1.43(0.39-5.17)	1.12(0.18-6.74)	0.81(0.88-7.70)
	L	10th (10)	0.98 (0.83-1.16)	0.95(0.59-1.50)	0.86(0.34-2.17)	0.68(0.12-3.86)	0.51(0.04-6.33)	0.35(0.01-8.40)
		5th (7)	1.27(0.91-1.75)	1.89(0.77-4.60)	3.14(0.48-20.00)	3.35(0.09-120.34)	1.43(0.008-238.00)	0.27(0.00-132.72)
		2.5th (4)	1.11(0.81-1.53)	1.34(0.56-3.21)	1.71(0.27-10.56)	1.61(0.05-50.10)	0.80(0.006-105.60)	0.19(0.00-70.72)
		1th(3)	0.91(0.64-1.28)	0.77(0.30-1.97)	0.61(0.08-4.21)	0.45(0.01-17.66)	0.30(0.001-67.84)	0.15(0.00-174.30)
CVD•••	H	99th (22)	**1.12(1.02-1.23)**	**1.36(1.05-1.76)**	1.22(0.87-1.75)	**1.76(1.06-2.91)**	2.08(0.87- 4.95)	1.93(0.39-9.50)
		97.5th (21)	**1.10(1.01-1.20)**	**1.30(1.03-1.64)**	**1.64(1.05-2.58)**	2.01(0.94-4.29)	2.16(0.75-6.22)	2.28(0.60-8.65)
		,95th (20)	1.08(0.99-1.17)	1.23(0.98-1.55)	1.51(0.96-2.36)	1.84(0.85-3.98)	2.08(0.71-6.09)	2.33 (0.60-8.98)
		,90th (19)	1.05(0.97-1.14)	1.16(0.94-1.43)	1.35(0.89-2.03)	1.60(0.80-3.25)	1.80(0.67-4.85)	2.01(0.60-6.97)
	L	10th (10)	1.04(0.95-1.14)	1.13(0.89 - 1.46)	1.35(0.81-2.28)	1.87(0.70-4.98)	2.56(0.62 - 10.75)	3.45(0.56 - 21.00)
		5th (7)	0.95(0.80-1.14)	0.93(0.57-1.50)	1.05(0.38 - 2.89)	1.68(0.24-11.60)	2.38(0.15-37.36)	2.17(0.08-60.00)
		2.5th (4)	0.92(0.77-1.08)	0.80(0.50-1.25)	0.63(0.24-1.67)	0.48(0.07-3.00)	0.36(0.03-4.75)	0.24(0.11-5.21)
		1th(3)	0.93(0.80-1.09)	0.80(0.50-1.24)	0.53(0.20-1.37)	0.24(0.04-1.54)	0.12(0.008-1.89)	0.08(0.003-2.67)

*Diurnal Temperature Range (°C)

**High Extreme DTR effect: The cumulative effects of99th, 97.5th, 95th and 90th percentile of DTRon mortality categories, relative to 50th percentile of DTR (14°C)

***Low Extreme DTR effect: The cumulative effects of10th, 5th, 2.5th and1th percentile of DTRon mortality categories, relative to 50th percentile of DTR (14°C)

• Non-Accidental Death

•• Respiratory Death

••• Cardiovascular Death

Table 3: The Cumulative relative risks (CRR, mortality in low and high DTR* values relative to mortality in DTR=14°C) stratified by cause –specific mortality the cold season.

Death type		DTR value(°C)	Lag0	Lag 0-2	Lag 0-6	Lag 0-13	Lag 0-20	Lag 0-27
NAD•	H**	99^{th}(19°)	0.99(0.92-1.06)	0.96(0.78-1.17)	0.86(0.60-1.24)	0.67(0.37-1.23)	0.57(0.26-1.26)	0.58(0.22-1.51)
		97.5^{th} (18)	0.97(0.92-1.02)	0.90(0.78-1.04)	0.78(0.60-1.03)	**0.61(0.40-0.95)**	**0.50(0.27-0.92)**	**0.45(0.22-0.94)**
		95^{th} (17)	0.96(0.92-1.005)	0.88(0.78-1.006)	**0.76(0.59-0.98)**	**0.61(0.40-0.95)**	**0.50(0.23-0.95)**	**0.43(0.19-0.94)**
		90^{th} (16)	0.96(0.93-1.001)	**0.90(0.82-0.99)**	**0.80(0.66-0.98)**	0.68(0.47-1.00)	0.59(0.35-1.00)	0.51(0.26-1.00)
	L***	10^{th} (5)	0.97(0.92-1.02)	0.93(0.80-1.06)	0.87(0.66-1.15)	0.83(0.51-1.34)	0.77(0.40-1.51)	0.66(0.30-1.50)
		5^{th} (4)	0.97(0.93-1.02)	0.92(0.81-1.05)	0.85(0.67-1.10)	0.78(0.50-1.19)	0.69(0.38-1.25)	0.58(0.27-1.23)
		2.5^{th} (2)	0.97(0.89-1.07)	0.92(0.72-1.18)	0.78(0.47-1.30)	0.57(0.22-1.48)	0.44(0.10-1.82)	0.40(0.06-2.52)
		1^{h} (1)	0.98(0.85-1.12)	0.92(0.64-1.34)	0.75(0.34-1.60)	0.47(0.10-2.01)	0.33(0.04-2.91)	0.32(0.02-5.30)
RD••	H	99^{th}(19°)	1.09(0.88-1.34)	1.25(0.72-2.18)	1.48(0.52-4.24)	1.57(0.28-8.66)	1.48(0.15-14.31)	1.41(0.08-22.70)
		97.5^{th} (18)	1.05(0.90-1.22)	1.16(0.78-1.73)	1.36(0.63-2.94)	1.68(0.47-3.03)	1.95(0.35-10.72)	2.17(0.28-17.00)
		95^{th} (17)	1.03(0.90-1.16)	1.09(0.77-1.55)	1.25(0.62-2.55)	1.66(0.46-5.99)	2.14(0.35-13.08)	2.60(0.28-23.89)
		90^{th} (16)	1.00(0.91-1.11)	1.04(0.78-1.37)	1.15(0.65-2.04)	1.47(0.50-4.28)	1.89(0.41-8.70)	2.27(0.34-15.12)
	L	10^{th} (5)	0.99(0.86-1.15)	0.98(0.67-1.45)	0.96(0.44-2.09)	0.92(0.23-3.70)	0.91(0.13-6.40)	0.95(0.08-10.39)
		5^{th} (4)	0.99(0.87-1.14)	0.99(0.68-1.42)	0.95(0.46-1.94)	0.85(0.25-2.93)	0.74(0.13-4.15)	0.64(0.07-5.56)
		2.5^{th} (2)	1.03(0.80-1.34)	1.06(0.52-2.17)	0.99(0.23-4.23)	0.64(0.04-10.00)	0.34(0.006-19.80)	0.16(0.00-32)
		1^{h} (1)	1.06(0.72-1.56)	1.12(0.40-3.23)	1.03(0.11-9.05)	0.55(0.008-35.36)	0.21(0.00-105.00)	0.07(0.00-226)
CVD•••	H	99^{th}(19°)	0.97(0.86-1.07)	0.88(0.65-1.18)	0.71(0.41-1.22)	0.47(0.19-1.11)	0.33(0.10-1.06)	0.28(0.07-1.18)
		97.5^{th} (18)	0.95(0.87-1.02)	0.85(0.69-1.06)	0.68(0.45-1.03)	**0.47(0.24-0.92)**	**0.35(0.14-0.85)**	**0.30(0.10-0.88)**
		95^{th} (17)	0.95(0.88-1.01)	0.85(0.71-1.03)	0.70(0.48-1.02)	0.52(0.26-1.02)	0.41(0.16-1.06)	0.35(0.11-1.14)
		90^{th} (16)	0.95(0.91-1.01)	0.88(0.76-1.02)	0.77(0.56-1.04)	0.63(0.36-1.10)	0.54(0.24-1.20)	0.47(0.17-1.30)
	L	10^{th} (5)	0.99(0.92-1.07)	0.99(0.80-1.22)	1.04(0.70-1.57)	1.21(0.58-2.50)	1.24(0.45-3.43)	0.98(0.28-3.43)
		5^{th} (4)	0.99(0.93-1.07)	1.00(0.82-1.22)	1.06(0.72-1.55)	1.21(0.62-2.34)	1.22(0.48-3.06)	0.96(0.30-3.06)
		2.5^{th} (2)	1.02(0.90-1.17)	1.06(0.73-1.55)	1.08(0.50-2.35)	1.01(0.23-4.41)	0.89(0.10-8.03)	0.82(0.05-13.81)
		1^{h} (1)	1.04(0.85-1.29)	1.10(0.63-1.93)	1.09(0.34-3.45)	0.88(0.09-8.26)	0.75(0.03-20.27)	0.72(0.00-53.10)

*Diurnal Temperature Range (°C)

**High Extreme DTR effect: The cumulative effects of99th, 97.5th, 95th and 90th percentile of DTR on mortality categories, relative to 50th percentile of DTR (14°C)

***Low Extreme DTR effect: The cumulative effects of10th, 5th, 2.5th and1th percentile of DTR on mortality categories, relative to 50th percentile of DTR (14°C)

• Non-Accidental Death

•• Respiratory Death

••• Cardiovascular Death

Highlights

- In the city of Urmia, in the hot season and full year, high values of DTR increased the risk of mortality.
- In the cold season, high values of DTR decreased the risk of Non-AccidentalDeath and Cardiovascular Death.
- In low DTR levels, the risk of mortality was various and no specific effect was observed.

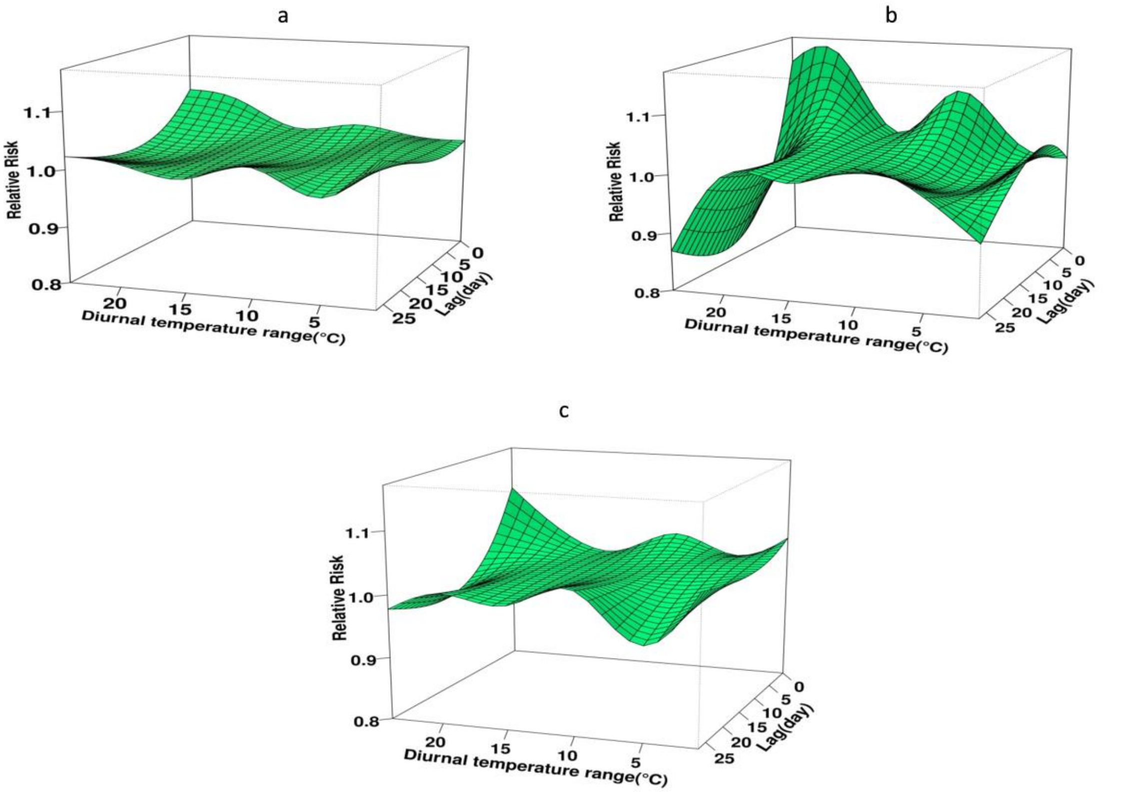

Fig1: Relative risks of Non Accidental Death (a), Respiratory Death (b) and cardiovascular Death (c) by Diurnal temperature range (°C), using a natural cubic spline–natural cubic spline DLNM with 5 df for DTR and 2 df for lag in full year.

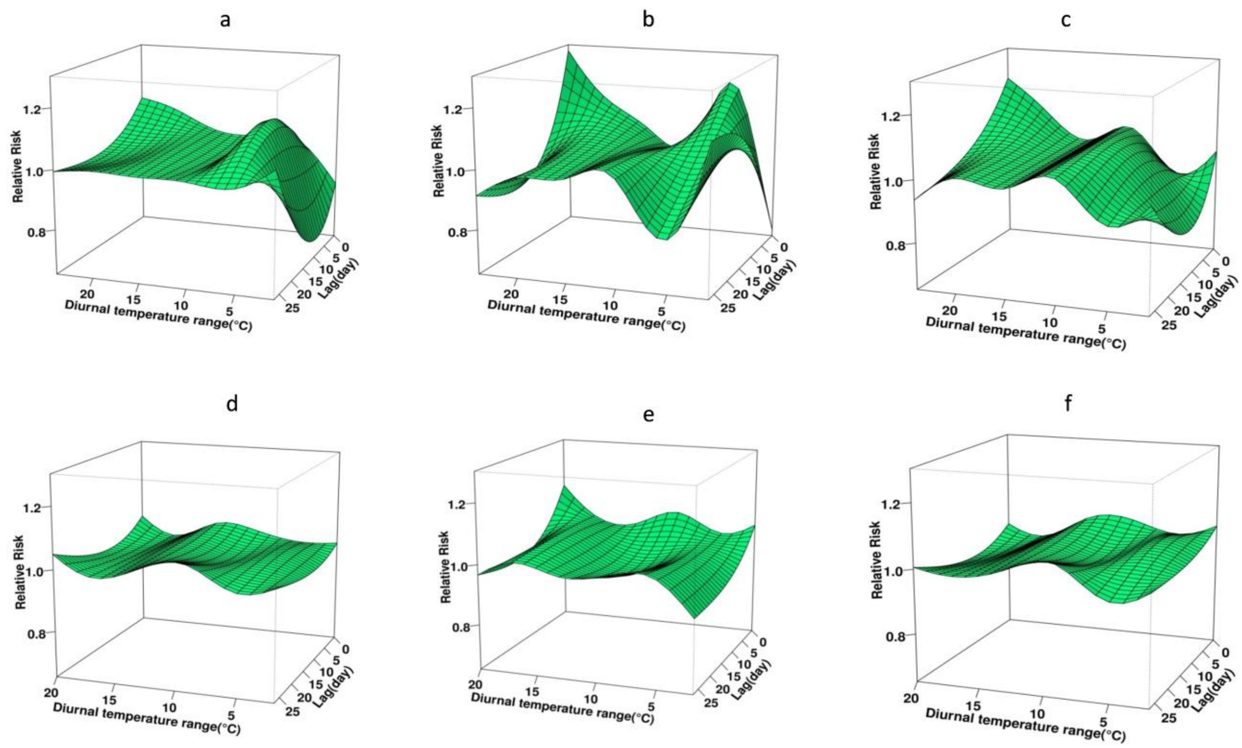

Fig2: Relative risks of Non Accidental Death (a-d), Respiratory Death (b-e) and cardiovascular death (c-f) by Diurnal temperature range (°C), using a natural cubic spline–natural cubic spline DLNM with 5 df for DTR and 2 df for lag in the seasonal analysis. a,b,c (hot season) and d,e,f (cold season)