RESEARCH ARTICLE

Physiological equivalent temperature (PET) index and respiratory hospital admissions in Ahvaz, southwest of Iran

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Abstract
Although Ahvaz is considered as one of the warmest cities around the world, few epidemiological studies have been conducted on the adverse effects of temperature on human health using thermal indices in this city. This study investigates the relation between physiologically equivalent temperature (PET) and respiratory hospital admissions in Ahvaz. Distributed lag non-linear models (DLNMs) combined with quasi-Poisson regression models were used to investigate the relation between PET and respiratory disease hospital admissions, adjusted for the effect of time trend, air pollutants (NO_2, SO_2, and PM_{10}), and weekdays. The analysis was performed by utilizing R software. Low PET values significantly decreased the risk of hospital admissions for total respiratory diseases, respiratory diseases in men and women, chronic obstructive pulmonary diseases (COPD), and bronchiectasis. However, low PET (16.9°C) in all lags except lag 0–30 significantly increased the risk of hospital admissions for asthma. The results indicate that in Ahvaz, which has a warm climate, cold weather decreased overall respiratory hospital admissions, except for asthma.

Introduction

The hypothesis that meteorological variables can affect human health has been around since the middle of the twentieth century. Due to the intense heat events in the last 30 years, this period is considered to be the warmest period since 1880 (Guha-Sapir et al. 2016; NOAA 2017). According to credible evidence, both extreme temperatures (cold and heat) play a role in creating considerable physiological pressure on the human body that can cause a range of complications and

mortality (Gasparrini et al. 2010; Gasparrini et al. 2015; Zhang et al. 2017). With increasing environmental changes, most industrialized and developing countries have seen an increase in the number of respiratory diseases in recent decades (D'Amato et al. 2015a; Haines and Ebi 2019). Some researchers think that respiratory diseases are closely related to high and low temperatures (Bunker et al. 2016).

So far, several studies around the world have reported a link between exposure to extreme ambient temperature and an increase in hospital admissions for respiratory diseases. For example, a study in Hong Kong during 2000–2016 indicated increased respiratory hospitalizations after hot weather, but decreased respiratory hospitalizations after cold weather (Sun et al. 2019). Also, a recent research showed that heat waves increased the number of outpatient hospital visits for respiratory diseases in Cangnan, China (Zhang et al. 2019). Moreover, in rural China, only low temperatures had a strong impact on increasing clinic visits due to respiratory illnesses (Zhao et al. 2018).

Thermal indices are used to estimate human comfort or thermal stress (Fröhlich et al. 2019). Human thermal comfort has been an important topic in academic discussions since the middle of the twentieth century on which different

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comparisons have been made (Abdel-Ghany et al. 2013). This suggests that the assessment and interpretation of heat stress is complex in terms of physiological and psychological stress. The proposed indicators for heat stress can be divided into three groups: "reasoning indicators," "experimental indicators," and "direct indicators." Unlike the first two groups, which are complex indicators and cannot be used routinely, the last group includes simple indices based on the measurement of basic environmental variables (Epstein and Moran 2006). One of the most popular of these indicators is the physiological equivalent temperature (PET), which is a measure of human thermal comfort outdoors, and is estimated by considering the integral effects of meteorological parameters and other personal conditions related to heat exchange between the human body and its environment (Lai et al. 2018).

Observations clearly show that Iran has been warming rapidly in recent decades, resulting in a wide range of climatic effects. Meteorological records of several ground stations throughout Iran demonstrate that Iran's temperature in 2013 was 1.3 °C warmer than in 1951(Alizadeh-Choobari and Najafi 2018; Lai et al. 2018; Saboohi et al. 2012). Although Ahvaz is one of the hottest cities in the world, no study has been done about ambient temperature and respiratory disease admissions in this city. The present study examined the impact of PET index changes on respiratory hospital admissions in Ahvaz which is located in the southwest of Iran. The findings of this study may help to plan strategies to mitigate the adverse effects of extreme weather conditions.

Materials and methods

Study site

Ahvaz is one of the metropolises of Iran, and the capital of Khuzestan province. It is the seventh most populous city in Iran. Ahvaz is located at 31° 20′ N and 48° 40′ E, with an area of 185 km^2 and altitude of 12 m above sea level. According to the 2016 census, the city's population was approximately 1,300,000 people (Statistical-Centre-of-Iran 2016).

Outcomes and exposures

Respiratory hospital admission data were obtained from the two main referral hospitals of Ahvaz, from 2008 to 2018, for 10 years. Outcomes data was classified according to the International Classification of Diseases (ICD-10) and included total respiratory diseases (J00-J99), asthma (J45.9), COPD (J44.1, J44.9), and bronchiectasis (J47).

Meteorological parameters including average daily temperature, maximum daily temperature, minimum daily temperature, average wind speed, relative humidity, and cloudiness were obtained from the Khuzestan Meteorological Department. The pollutants routinely measured in Ahvaz were NO_2, PM_{10}, and SO_2 and were inquired from the Ahvaz Environmental Protection Organization.

PET index

The equations for calculating the PET index have been explained in our previous publications (Sharafkhani et al. 2018).

The no stress, thermal comfort zone for PET, similar to our previous studies (Sharafkhani et al. 2018), was assumed to be between 17.8 and 27 °C, which means there is no thermal stress for humans in this range. The median of PET in the no thermal stress zone (22.5 °C) was used as the basis for comparison. PET index analysis was performed using RayMan software. Details about this software can be found elsewhere (Lee and Mayer 2016).

The association of low values (1st, 5th, and 25th percentiles relative to no thermal stress) and high values (90th, 95th, and 99th percentiles relative to no thermal stress) of PET with risk of respiratory hospital admissions was calculated in cumulative models of 0, 0–2, 0–6, 0–13, 0–20, and 0–30 day lags. Also, similar to other studies (Lin et al. 2012; Luo et al. 2013; Sharafkhani et al. 2018; Sharafkhani et al. 2019), the association of cold thermal stress (1st percentile relative to 25th percentile) and hot thermal stress (75th percentile relative to 99th percentile) of the PET index with outcomes was evaluated in cumulative models of 0, 0–2, 0–6, 0–13, 0–20, and 0–30 day lags.

In order to investigate the effect of PET on respiratory outcomes, distributed lag non-linear models (DLNMs) combined with quasi-Poisson regression models were used (Gasparrini et al. 2010). A natural cubic spline DLNM was used to determine the non-linear relation of the PET index as well as the cumulative lag effects up to a maximum of 30 days, with respiratory hospital admission. Spline knots were set at equally spaced values on the log scale of lags. The long-term seasonal trend of the outcomes was adjusted by a natural cubic spline function of time with 7 degrees of freedom. PM_{10}, SO_2, and NO_2 were controlled using the stratified distributed lag model for up to 7 days lag with 3 degrees of freedom, as done in previous studies (Sharafkhani et al. 2018). Also, the variable of holidays and weekdays was adjusted as a categorical variable in the final model (Sharafkhani et al. 2018). Akaike information criterion (AIC) models were used to select the most appropriate model and degrees of freedom (knots) for PET index and lags (Gasparrini et al. 2010). The risk ratio and 95% confidence intervals were reported. The analysis was performed by utilizing R software version 3.5.3 with the dlnm package.

Results

The descriptive statistics of respiratory hospital admissions, air pollutants, PET index, temperature, and humidity factors are presented in Table 1. During the 10-year study period, the total number of respiratory admissions was 28,041 cases with an average of 8 cases per day. More than half of the respiratory (59.2%) patients admitted were male. The daily mean of PET, temperature, and humidity were 27.6 °C, 27.0 °C, and 42.3%, respectively. The mean concentrations of PM_{10}, NO_2, and SO_2 were 216.9, 46.4, and 48.8 μg/m³, respectively (Table 1).

The association between the PET index and respiratory hospital admissions in the 1st (6.4 °C), 5th (9.9 °C), 25th (16.9 °C), 90th (42.5 °C), 95th (43.6 °C), and 99th (45.4 °C) percentiles relative to the no thermal stress point (22.5°C) is presented in Table 2.

The results showed that low PET in the 1st percentile in lags 0–2 and 0–6 caused a decrease in total respiratory admissions and among the male population. In terms of specific respiratory disease, low PET in the 1st percentile in lags 0–6, 0–13, 0–20, and 0–30 significantly reduced bronchiectasis hospital admissions. Also, low PET in the 1st and 5th percentiles in lags 0–2 and 0–6 caused a significant reduction in COPD hospital admissions, while low PET in the 25th percentile in lags 0, 0–2, 0–6, 0–13, and 0–20 increased the risk of asthma hospital admissions. Also, low PET values in the 5th percentile in lags 0–20 and 0–30 increased respiratory admissions among women.

Table 3 and Fig. 1 illustrate the effects of intensified thermal stress, comparing the value of PET index in the first percentile to the 25th percentile (cold thermal stress) and comparing the value of PET index in the 99th percentile to the 75th percentile (hot thermal stress) in cumulative lags.

The results show that cold thermal stress significantly reduced the risk of total respiratory admissions in lags 0–2, 0–6, and 0–13; respiratory admissions in the male population in lags 0–2, 0–6, and 0–13; respiratory admissions in the female population in lag 0–6; and in the population < 65 years in lags 0–2, 0–6, 0–13, and 0–20. In terms of specific respiratory outcomes, cold thermal stress also significantly decreased the risk of bronchiectasis admissions in lags 0–6, 0–13, 0–20, and 0–30, and COPD hospital admissions in lags 0–2 and 0–6 (Table 3 and Fig. 1).

Discussion

Ahvaz is one of the hottest cities in the world; however, no study had been conducted on ambient temperature and respiratory hospital admission rates in this city.

The results of this study showed that the low values of PET index (1st, 10th, and 25th percentiles) affect hospital admissions more than the high values of PET (95th and 99th percentiles), and low levels of PET (cold weather) significantly decreased the risk of hospital admissions, due to total respiratory diseases, COPD, respiratory diseases, and bronchiectasis in most lags. But, low PET levels significantly increased the risk of asthma in all lags except 0–30, and in females in long lags.

Few studies have been conducted on the association between different temperature indices and respiratory disease incidence. There are studies that show warm weather can cause the release of inflammatory factors, increase ventilation,

Table 1 Descriptive statistics of respiratory hospital admissions, air pollutants, PET, and climate factors in Ahvaz city, 2008–2018

Variable (mean per day)	N	Mean	SD	Min	Max	Q1	Median	Q3
Respiratory diseases (RD)	28,041	7.7	4.9	0	37	4	7	10
Men	16,550	4.5	3.3	0	22	2	4	6
Women	11,491	3.2	2.6	0	16	1	3	4
<65 years	21,050	5.8	4.1	0	36	3	5	8
65–74 years	3111	0.8	1.1	0	9	0	1	1
≥75 years	3880	1.1	1.3	0	9	0	1	2
Asthma	3090	0.8	1.8	0	29	0	0	1
COPD	4534	1.2	1.7	0	12	0	1	2
Bronchiectasis	1994	0.6	1.0	0	8	0	0	1
PM_{10} (μg/m³)	---	216.9	278.3	1.8	4324.2	105.8	149.2	222.4
NO_2 (μg/m³)	---	46.4	43.1	1.5	443.8	17.8	35.6	60.7
SO_2 (μg/m³)	---	48.8	57.0	0.0	907.4	19.3	35.9	59.3
PET	----	27.6	11.6	0.8	47.3	16.9	27.9	39.1
Temperature (°C)	---	27.0	9.4	1.4	47.8	18.4	27.7	36.0
Relative humidity (%)	---	42.3	17.9	7.0	96.0	27.5	40.0	54.5

Table 2 The cumulative relative risks of respiratory hospital admissions in high and low PET values relative to PET=22.5 °C

Admissions	PET values (°C)		Lag 0	Lag 0–2	Lag 0–6	Lag 0–13	Lag 0–20	Lag 0–30
Total respiratory	H	45.4	0.924 (0.745–1.146)	1.024 (0.789–1.328)	0.890 (0.630–1.259)	0.759 (0.461–1.250)	1.023 (0.539–1.943)	1.308 (0.537–3.188)
		43.6	0.898 (0.735–1.095)	0.998 (0.787–1.267)	0.894 (0.655–1.222)	0.777 (0.500–1.208)	1.038 (0.594–1.813)	1.250 (0.579–2.700)
	L	16.9	1.041 (0.980–1.107)	0.993 (0.925–1.067)	1.008 (0.918–1.106)	1.119 (0.981–1.276)	1.131 (0.960–1.333)	1.118 (0.897–1.395)
		9.9	1.029 (0.921–1.151)	0.957 (0.839–1.091)	0.970 (0.818–1.15)	1.167 (0.917–1.484)	1.301 (0.960–1.764)	1.425 (0.937–2.168)
		6.4	0.980 (0.866–1.109)	0.846 (0.738–0.970)*	0.773 (0.650–0.919)*	0.840 (0.656–1.076)	0.877 (0.64–1.201)	0.840 (0.547–1.292)
Males	H	45.4	0.949 (0.730–1.235)	1.039 (0.756–1.429)	0.863 (0.566–1.318)	0.690 (0.375–1.269)	0.916 (0.419–2.004)	1.381 (0.465–4.103)
		43.6	0.911 (0.715–1.161)	1.017 (0.76–1.36)	0.874 (0.597–1.279)	0.709 (0.414–1.214)	0.949 (0.480–1.876)	1.333 (0.520–3.418)
	L	16.9	1.010 (0.937–1.087)	0.960 (0.88–1.048)	0.998 (0.891–1.118)	1.092 (0.929–1.283)	1.046 (0.855–1.281)	0.995 (0.759–1.305)
		9.9	0.957 (0.834–1.098)	0.895 (0.762–1.051)	0.949 (0.771–1.168)	1.104 (0.821–1.483)	1.137 (0.782–1.654)	1.141 (0.681–1.910)
		6.4	1.308 (0.537–3.188)	0.813 (0.688–0.960)*	0.772 (0.625–0.953)*	0.822 (0.608–1.113)	0.843 (0.574–1.236)	0.751 (0.445–1.267)
Females	H	45.4	0.889 (0.652–1.211)	1.000 (0.688–1.453)	0.932 (0.568–1.531)	0.868 (0.424–1.776)	1.177 (0.469–2.954)	1.178 (0.328–4.224)
		43.6	0.879 (0.660–1.170)	0.971 (0.690–1.367)	0.927 (0.592–1.451)	0.887 (0.471–1.671)	1.165 (0.523–2.594)	1.119 (0.371–3.375)
	L	16.9	1.088 (0.998–1.187)	1.042 (0.941–1.154)	1.017 (0.889–1.162)	1.149 (0.952–1.386)	1.255 (0.994–1.586)	1.307 (0.954–1.790)
		9.9	1.142 (0.973–1.340)	1.052 (0.871–1.269)	0.992 (0.777–1.265)	1.239 (0.879–1.745)	1.547 (1.005–2.384)*	1.903 (1.047–3.460)*
		6.4	1.076 (0.901–1.284)	0.893 (0.733–1.088)	0.769 (0.599–0.987)*	0.853 (0.598–1.217)	0.913 (0.58–1.437)	0.966 (0.519–1.798)
Under 65 years	H	45.4	0.938 (0.730–1.205)	1.010 (0.747–1.367)	0.913 (0.611–1.363)	0.787 (0.442–1.402)	0.953 (0.454–2.000)	1.218 (0.435–3.414)
		43.6	0.919 (0.729–1.158)	1.007 (0.764–1.328)	0.940 (0.654–1.349)	0.826 (0.496–1.377)	0.997 (0.523–1.902)	1.178 (0.483–2.874)
	L	16.9	1.06 (0.987–1.138)	1.029 (0.946–1.119)	1.042 (0.934–1.163)	1.145 (0.98–1.337)	1.157 (0.953–1.404)	1.127 (0.868–1.462)
		9.9	1.019 (0.893–1.163)	0.961 (0.823–1.122)	0.978 (0.8–1.196)	1.154 (0.868–1.532)	1.288 (0.899–1.844)	1.447 (0.882–2.375)
		6.4	0.948 (0.819–1.097)	0.832 (0.707–0.979)*	0.756 (0.615–0.928)	0.762 (0.568–1.022)	0.77 (0.53–1.118)	0.764 (0.459–1.272)
65–74 years	H	45.4	0.814 (0.478–1.386)	0.984 (0.515–1.880)	0.779 (0.326–1.863)	0.686 (0.193–2.438)	1.331 (0.26–6.813)	1.09 (0.115–10.348)
		43.6	0.768 (0.471–1.251)	0.899 (0.499–1.620)	0.729 (0.334–1.593)	0.664 (0.218–2.021)	1.289 (0.314–5.299)	1.092 (0.158–7.555)
	L	16.9	0.989 (0.857–1.143)	0.938 (0.802–1.096)	0.836 (0.671–1.041)	0.986 (0.723–1.345)	1.039 (0.704–1.534)	1.123 (0.667–1.891)
		9.9	1.111 (0.872–1.415)	1.021 (0.77–1.355)	1.037 (0.718–1.497)	1.062 (0.597–1.887)	1.250 (0.604–2.585)	1.505 (0.555–4.083)
		6.4	1.071 (0.823–1.394)	0.91 (0.68–1.217)	0.857 (0.594–1.238)	0.952 (0.529–1.714)	1.068 (0.504–2.261)	1.188 (0.423–3.335)
≥75 years	H	45.4	0.937 (0.572–1.536)	1.154 (0.633–2.103)	0.924 (0.416–2.055)	0.834 (0.263–2.645)	1.802 (0.407–7.985)	3.590 (0.452–28.498)
		43.6	0.893 (0.566–1.41)	1.047 (0.605–1.812)	0.845 (0.412–1.735)	0.760 (0.274–2.104)	1.533 (0.42–5.591)	2.965 (0.495–17.759)
	L	16.9	0.989 (0.865–1.132)	0.938 (0.802–1.096)	0.985 (0.803–1.208)	1.085 (0.812–1.449)	1.048 (0.729–1.505)	1.033 (0.635–1.679)
		9.9	1.111 (0.872–1.415)	1.021 (0.77–1.355)	1.037 (0.718–1.497)	1.285 (0.763–2.165)	1.323 (0.683–2.564)	1.136 (0.456–2.831)
		6.4	1.071 (0.823–1.394)	0.91 (0.68–1.217)	0.857 (0.594–1.238)	1.132 (0.67–1.912)	1.270 (0.653–2.47)	0.908 (0.364–2.27)
Asthma	H	45.4	0.460 (0.199–1.061)	0.379 (0.135–1.06)	0.314 (0.078–1.258)	0.236 (0.031–1.797)	0.299 (0.021–4.184)	0.377 (0.01–14.188)
		43.6	0.568 (0.268–1.203)	0.443 (0.177–1.107)	0.323 (0.095–1.098)	0.240 (0.042–1.386)	0.293 (0.031–2.799)	0.343 (0.015–7.63)
	L	16.9	1.388 (1.136–1.697)*	1.314 (1.033–1.671)*	1.362 (1.003–1.851)*	1.791 (1.175–2.73)*	1.724 (1.022–2.908)*	1.536 (0.751–3.142)
		9.9	1.114 (0.779–1.593)	1.146 (0.749–1.753)	1.378 (0.806–2.354)	2.087 (0.996–4.374)	2.507 (0.99–6.349)	2.136 (0.582–7.846)
		6.4	1.066 (0.716–1.588)	0.935 (0.600–1.455)	1.014 (0.587–1.752)	1.546 (0.719–3.323)	1.808 (0.679–4.812)	1.626 (0.421–6.281)

Table 2 (continued)

Admissions	PET values (°C)	Lag 0	Lag 0–2	Lag 0–6	Lag 0–13	Lag 0–20	Lag 0–30
Bronchiectasis	H	45.4	1.369 (0.660–2.841)	1.477 (0.604–3.610)	1.535 (0.452–5.206)	2.849 (0.460–17.630)	6.493 (0.595–70.843)	13.488 (0.475–382.772)
		43.6	1.226 (0.631–2.381)	1.351 (0.603–3.024)	1.418 (0.478–4.207)	2.561 (0.521–12.595)	6.029 (0.769–47.281)	11.032 (0.626–194.435)
	L	16.9	1.005 (0.816–1.238)	1.039 (0.814–1.326)	0.878 (0.636–1.214)	0.727 (0.456–1.159)	0.776 (0.432–1.394)	0.689 (0.314–1.512)
		9.9	1.080 (0.724–1.611)	1.142 (0.715–1.824)	0.857 (0.461–1.592)	0.619 (0.255–1.504)	0.637 (0.209–1.945)	0.454 (0.097–2.115)
		6.4	0.949 (0.61–1.478)	0.833 (0.509–1.364)	0.501 (0.267–0.942)*	0.242 (0.098–0.597)*	0.162 (0.052–0.507)*	0.082 (0.017–0.386)*
COPD	H	45.4	0.423 (0.249–0.718)*	0.643 (0.333–1.243)	0.989 (0.407–2.404)	0.822 (0.225–2.998)	1.136 (0.211–6.101)	1.364 (0.131–14.242)
		43.6	0.444 (0.275–0.718)*	0.630 (0.349–1.139)	0.943 (0.428–2.074)	0.837 (0.271–2.588)	1.143 (0.268–4.869)	1.350 (0.18–10.103)
	L	16.9	1.039 (0.908–1.189)	0.866 (0.738–1.017)	0.830 (0.672–1.025)	1.032 (0.767–1.389)	1.078 (0.744–1.561)	1.008 (0.609–1.668)
		9.9	0.955 (0.742–1.227)	0.705 (0.524–0.950)*	0.684 (0.465–1.008)	0.984 (0.572–1.692)	1.028 (0.519–2.037)	0.767 (0.296–1.986)
		6.4	0.910 (0.689–1.203)	0.619 (0.454–0.844)*	0.602 (0.408–0.889)*	0.943 (0.544–1.635)	0.980 (0.486–1.974)	0.651 (0.247–1.718)

* Statistically significant

and exacerbate chronic obstructive pulmonary disease, which is common in the elderly (Anderson et al. 2013; Leon and Helwig 2010; Malik et al. 1983; Mannino 2011; White 2006). Anderson et al. noted that a few minutes of hot air inhalation can cause undesirable airway responses in the elderly (Anderson et al. 2013). However, one of the main reasons that hot weather did not show adverse effects in the present study was that due to the very hot weather in Ahvaz, most people stay at home or work under the cooling system especially in the middle of the day.

Contrary to our results, a study from New York City found a 2.7–3.1% increase in hospital admissions due to respiratory diseases for every 1 °C above the threshold temperature (29–36 °C) (Lin et al. 2009). Jenkins et al. (2012) reported that during the winter months, the severity of symptoms and hospital admissions due to COPD are almost doubled in the northern and southern regions of the world (Jenkins et al. 2012). In the extreme northern and southern parts of the world with more cold weather, the rate of exacerbation of COPD symptoms in the cold conditions of the year is higher than the warm months. However, no significant differences in COPD rates in different seasons were observed in tropical areas. Therefore, the climatic condition of an area seems to be influential in this regard (Jenkins et al. 2012). The study by Hansel (2016) also showed that COPD patients are more vulnerable, if cold weather persists for a week or more. Therefore, people with COPD should take necessary steps to minimize the effects of cold and reduce the risk of exacerbation. Extreme heat may also be associated with increased respiratory complications in COPD patients, because high temperatures can modify the effects of air pollution (Hansel 2016).

Our results showed that cold stress significantly reduced the risk of hospital admissions due to total respiratory diseases, bronchiectasis, and COPD in Ahvaz. In contrary to the present study, the results of a study by Chen et al. (2019) showed that cold weather generally increased respiratory hospital admissions, especially in the elderly over 75 years of age (Chen et al. 2019). And Tseng et al. showed in Taiwan that with a decrease of 5 °C at moderate temperatures, the exacerbation of COPD increases, especially in the elderly (Tseng et al. 2013). The reason for the differences between our results and the aforementioned studies is that the cold weather which has been reported to exacerbate diseases and increase hospital admissions is below 0 °C which is rarely experienced in Ahvaz.

However, in the present study, in colder weather, hospital admissions increased for asthma and among women. Likewise, Son et al., in eight major cities in Korea (2003–2008), reported that an absolute decrease in ambient temperature (comparing 2 °C to 15 °C) significantly increased hospital admissions due to respiratory disease, allergies, and asthma especially among women (Son et al. 2014). In Italy, D'Amato et al. reported that weather may directly affect

Table 3 The cumulative relative risks of respiratory hospital admissions in intensified thermal stress of PET

| Cold effect	Lag 0	Lag 0–2	Lag 0–6	Lag 0–13	Lag 0–20	Lag 0–30
Total respiratory	0.941 (0.853–1.039)	**0.852 (0.764–0.950)***	**0.767 (0.666–0.884)***	**0.751 (0.609–0.926)***	**0.775 (0.591–1.018)***	**0.751 (0.517–1.092)***
Males	0.909 (0.807–1.025)	**0.846 (0.742–0.966)***	**0.773 (0.651–0.918)***	**0.753 (0.584–0.972)***	0.805 (0.580–1.118)	0.755 (0.481–1.185)
Females	0.989 (0.858–1.139)	0.857 (0.731–1.005)	0.756 (0.616–0.929)	0.743 (0.548–1.007)	0.727 (0.489–1.082)	0.739 (0.428–1.277)
Under 65 years	0.895 (0.795–1.006)	**0.809 (0.710–0.921)***	**0.725 (0.612–0.858)***	**0.666 (0.518–0.856)***	**0.665 (0.481–0.921)***	0.679 (0.435–1.058)
65–74 years	1.059 (0.843–1.329)	0.980 (0.76–1.264)	0.908 (0.65–1.268)	0.966 (0.59–1.582)	1.027 (0.539–1.959)	1.058 (0.431–2.600)
≥75 years	1.082 (0.881–1.33)	0.970 (0.773–1.219)	0.870 (0.648–1.168)	1.043 (0.676–1.612)	1.212 (0.691–2.125)	0.879 (0.402–1.924)
Asthma	0.768 (0.560–1.054)	0.711 (0.498–1.016)	0.745 (0.468–1.186)	0.863 (0.436–1.707)	1.049 (0.428–2.57)	1.058 (0.308–3.632)
Bronchiectasis	0.945 (0.661–1.349)	0.802 (0.538–1.194)	**0.571 (0.342–0.953)***	**0.334 (0.159–0.701)***	**0.209 (0.080–0.543)***	**0.119 (0.033–0.433)***
COPD	0.876 (0.700–1.095)	**0.714 (0.557–0.915)***	**0.725 (0.529–0.994)***	0.914 (0.577–1.447)	0.909 (0.499–1.657)	0.646 (0.281–1.489)
Hot effect	**Lag 0**	**Lag 0–2**	**Lag 0–6**	**Lag 0–13**	**Lag 0–20**	**Lag 0–30**
Total respiratory	1.078 (0.956–1.215)	1.064 (0.921–1.230)	0.966 (0.802–1.164)	0.907 (0.698–1.178)	0.943 (0.674–1.319)	1.099 (0.684–1.767)
Males	1.117 (0.964–1.294)	1.055 (0.884–1.260)	0.944 (0.751–1.187)	0.893 (0.648–1.230)	0.881 (0.584–1.328)	1.074 (0.602–1.918)
Females	1.027 (0.866–1.218)	1.075 (0.875–1.320)	0.995 (0.763–1.296)	0.921 (0.634–1.339)	1.021 (0.630–1.653)	1.110 (0.561–2.193)
Under 65 years	1.063 (0.925–1.221)	1.013 (0.857–1.197)	0.913 (0.737–1.132)	0.855 (0.632–1.157)	0.862 (0.585–1.270)	1.050 (0.607–1.817)
65–74 years	1.149 (0.847–1.558)	1.224 (0.849–1.766)	1.110 (0.69–1.786)	1.032 (0.526–2.023)	1.087 (0.459–2.576)	0.974 (0.289–3.281)
≥75 years	1.108 (0.843–1.457)	1.270 (0.912–1.769)	1.230 (0.801–1.888)	1.242 (0.678–2.277)	1.587 (0.728–3.46)	1.829 (0.613–5.453)
Asthma	**0.581 (0.350–0.967)***	0.636 (0.343–1.18)	0.866 (0.391–1.918)	0.901 (0.289–2.814)	0.984 (0.232–4.174)	1.216 (0.171–8.617)
Bronchiectasis	1.356 (0.883–2.082)	1.278 (0.762–2.141)	1.199 (0.608–2.363)	1.292 (0.485–3.446)	1.255 (0.348–4.522)	1.835 (0.301–11.190)
COPD	0.822 (0.598–1.130)	1.00 (0.680–1.472)	1.109 (0.676–1.819)	0.945 (0.471–1.896)	1.013 (0.415–2.47)	1.081 (0.309–3.784)

* Statistically significant
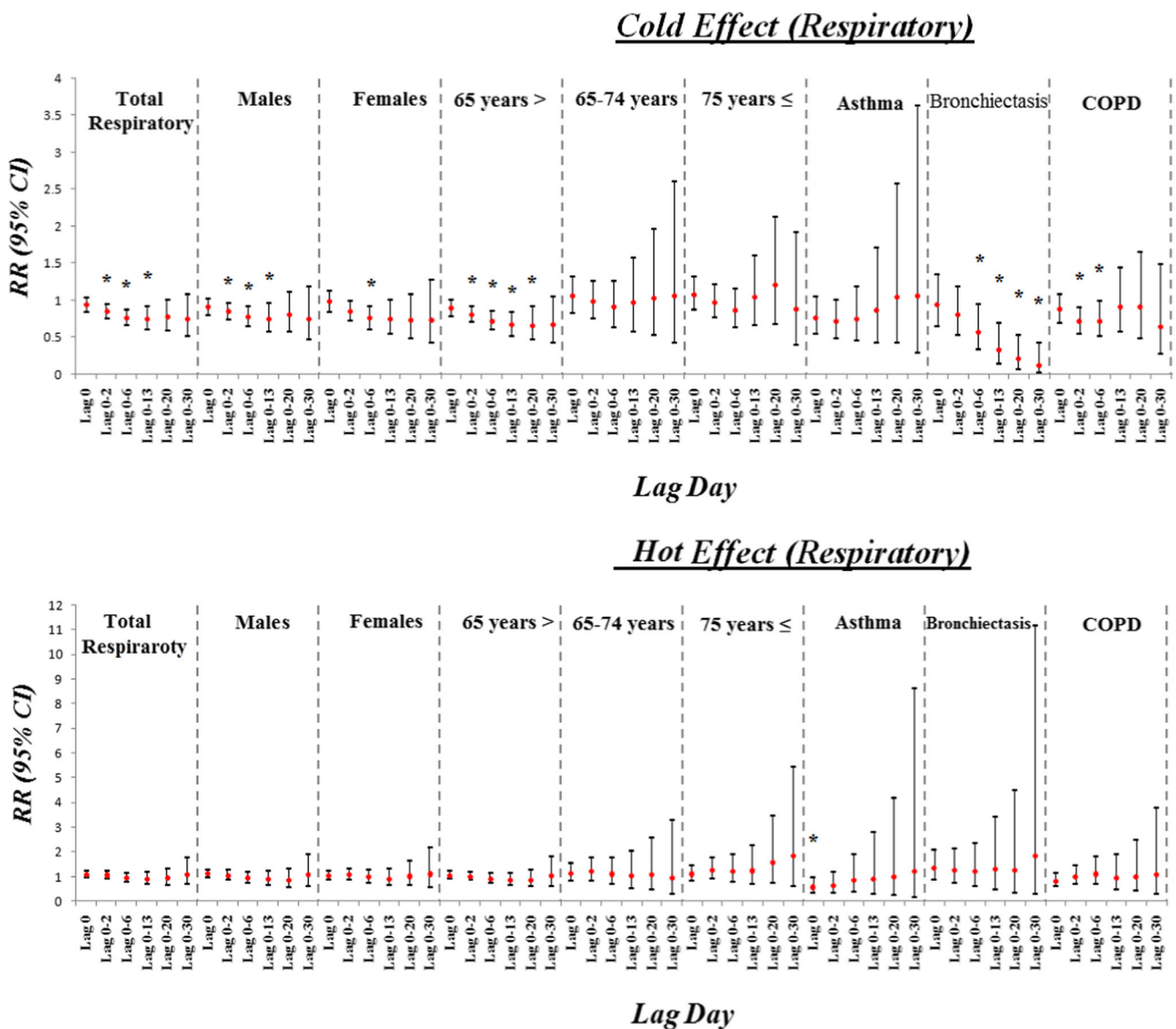
Fig. 1 The relative risks (95% CIs) of hot and cold thermal stress of PET respiratory hospital admissions at different lag days. *Statistically significant

irritability and cause asthma and airway diseases, or indirectly affect the respiratory system by its effect on the level of air allergens, air pollutants, or people's exposure to viral illnesses (Buckley and Richardson 2012; D'amato et al. 2015b). Researchers think regardless of geographical and climatic conditions decreased temperature is a factor that exacerbates asthma symptoms (D'amato et al. 2015b). Studies have also shown that cold air can provoke obstruction of the respiratory tract and airways, lead to asthma (Giesbrecht 1995), and cause sensitivity to infection, with reduced mucosal discharge (Eccles 2002). Decreased temperature also contributes to lung dysfunction and exacerbation of cold-related illnesses, including chronic obstructive pulmonary diseases (Donaldson et al. 1999).

It seems that the relation between cold weather and increased hospital admissions due to asthma in the city of

Ahvaz can be related to the seasonal effects and the density of allergens and pollen in the autumn, and respiratory infections and influenza (especially in recent years) in the winter. In the recent years, there have been several outbreaks of thunderstorm asthma in the autumn in Ahvaz (Idani et al. 2016).

In this present study, heat stress reduced the risk of asthma hospital admissions. However, in the research conducted by Lin et al, in New York City, the number of hospitalizations for asthma and chronic airway obstruction increased in high temperatures (Lin et al. 2009). Michelozzi et al. (2009) found a significant relation for high temperature and admission for respiratory disease especially in the European elderly over 75 years, as well; and, for every 1 °C increase in the apparent maximum temperature above the threshold, respiratory admissions increased by 4.5% and 3.1% in the Mediterranean and northern cities of Europe, respectively (Michelozzi et al.

2009). Different climatic conditions and avoiding staying outdoors in very hot temperatures in Ahvaz may be the main reason for these inconsistent results.

Overall, in the present study, heat stress and cold stress were associated with changes in hospital admissions due to respiratory diseases; and in both situations, hospital admissions in most types of respiratory diseases decreased, except for asthma and female respiratory hospital admissions which increased.

Conclusion

The results of the present study indicate that cold stress significantly decreased overall respiratory hospital admissions in Ahvaz, Iran, which has a warm climate.

Availability of data and materials   Not applicable

Declarations

Ethics approval and consent to participate   The proposal of this study was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (IR.AJUMS.REC.1399.866).

Consent for publication   Not applicable

Competing interests   The authors declare no competing interests.

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