The effect of human bioclimatic conditions on acute cardiovascular problems in Heraklion, Crete Island, Greece

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Abstract

The aim of this study is to quantify the association between bioclimatic conditions and daily counts of admissions for non-fatal acute cardiovascular (acute coronary syndrome, arrhythmia, decompensation of heart failure) syndromes (ACS) registered by the two main hospitals in Heraklion, Crete Island, during a five-year period 2008-2012. The bioclimatic conditions analyzed are based on human thermal bioclimatic indices such as the Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI).

Mean daily meteorological parameters, such as air temperature, relative humidity, wind speed and cloudiness, were acquired from the meteorological station of Heraklion (Hellenic National Meteorological Service). These parameters were used as input variables in modeling the aforementioned thermal indices, in order to interpret the grade of the thermo-physiological stress. The PET and UTCI analysis was performed by the use of the radiation and bioclimate model, “RayMan”, which is well-suited to calculate radiation fluxes and human biometeorological indices.

Generalized linear models (GLM) were applied to time series of daily numbers of outpatients with ACS against bioclimatic variations, after controlling for possible confounders and adjustment for season and trends.

The interpretation of the results of this analysis suggests a significant association between cold weather and increased coronary heart disease incidence, especially in the elderly and males. Additionally, heat stress plays an important role in the configuration of daily ACS outpatients, even in temperate climate, as that in Crete Island. In this point it is worth mentioning that Crete Island is frequently affected by Saharan outbreaks, which are associated in many cases with miscellaneous phenomena, such as Föhn winds - hot and dry winds - causing extreme bioclimatic conditions (strong heat stress). Taking into consideration the projected increased ambient temperature in the future, ACS exacerbation is very likely to happen during the warm period, against mitigation during the cold period of the year.

Keywords: Bioclimatic conditions, PET and UTCI Index, cardiovascular diseases, Crete

Introduction

Human biometeorology research highlights the increasing importance being placed on environment and human health, and their interrelationships (Oliveira and Andrade, 2007). The influence of weather on human health has a very broad range, specifically many biometeorological research indicating the impact of urban bioclimate on human morbidity (Schwartz et al. 2004, Nastos and Matzarakis 2006, Michelozzi et al. 2007). More specific studies have investigated the association between temperature and human mortality (Baccini et al., 2008, McMichael et al., 2008, Basu et al., 2009, Nastos and Matzarakis, 2012). The interdisciplinary field of Human Biometeorology continues to be an increasingly prominent and fascinating topic in the literature, with a great deal of research needed in all aspects of the discipline. The possible benefits to society of such research have been successfully documented, with the health and overall well-being of urban dwellers of prime importance (Vanos et al. 2010).

Under certain weather conditions a higher frequency of coronary heart disease and chronic heart failure is recorded (Schneider et al. 2008, Morabito et al. 2005). The seasonal variation in meteorological parameters has been associated in different parts of the world with the occurrence of cardiovascular diseases. Cold causes an increase in heart rate, systemic vascular resistance, plasma norepinephrine, levels of vasoconstrictor peptides, and blood pressure (Mäkinen and Hassi 2009). Cold also induces myocardial ischaemia, may precipitate arrhythmias and lead to heart failure decompensation (Stefanadis, 2007). However, effects on morbidity would also be anticipated given the present understanding of underlying mechanisms of temperature effects. Cold temperatures could lead to thrombosis through hemoconcentration (The Eurowinter Group, 1997) and physical activity during cold weather can precipitate angina pectoris and myocardial infarction. Human bodies adapt to heat by increasing cardiac output to increase skin surface blood circulation, which facilitates heat loss. The association of environmental temperature with cerebral vascular accidents is somewhat similar to that found of coronary heart disease, the numbers of deaths and incident cases increasing with declining temperature (Donaldson et al, 1998). The pattern is often U-shaped, with some increase in numbers at warmer temperatures (Ohno 1969, Pan et al, 1995). The effect of cold on cardiovascular diseases has been addressed mostly in terms of short-term temporal effects,i.e. days or weeks (Näyhä et al. 2002). However, a few investigators have analyzed the long-term association between cold and cardiovascular conditions in a geographical context, in an effort to understand regional variations in diseases (Law et al. 1998)

Crete Island is located in the south most border of East Mediterranean basin, facing exacerbating atmospheric conditions (mainly concentrations of particulates) due to Saharan dust outbreaks. It is worth to note that these episodes are more frequent during spring and autumn (Kaskaoutis et al. 2008), when mild climatic conditions become intolerable due to the synergy of the so called Föhn winds. Cretan mountains, especially Psiloritis Mt. (summit at 2456 m), are orientated perpendicularly to the south-west air mass flow, generating the Föhn winds. Furthermore, the topography of the island and the consequent Föhn winds develop worse bioclimatic conditions (Nastos et al. 2011, Bleta et al. 2013), which are exacerbated due to atmospheric pollution in urban agglomerations and strongly impact public health.

Materials and Methods

The climatic data used in this study concern mean daily values of air temperature, relative humidity, cloudiness, and wind speed, acquired from the archives of the Hellenic National Meteorological Service (HNMS) concerning the meteorological stations in Heraklion, Crete, during the period 2008-2012. The data sets have been tested for homogeneity in previous studies (Matzarakis and Nastos 2011, Nastos et al. 2002) and were used for the calculation of PET and UTCI in order to assess the level of the thermo-physiological stress. The medical data were obtained from the two main hospitals in Heraklion city, Crete, during 2008 – 2012, and concern daily counts of admissions for cardiovascular syndromes (acute coronary syndrome, arrhythmia, myocardial infarction etc).

For bioclimatic purposes, the wind velocity for Heraklion station was adjusted according to the following formula (Kuttler 2000):

$$WS_{1.1} = WS_h * (1.1/h)^a \qquad a=0.12*z_0+0.18$$

where WS_h is the wind speed (m s^{-1}) at the station's height (h, usually 10 m), a is an empirical exponent, depending on the surface roughness, and z_0 is the roughness length (z_0=0.8 for Heraklion). Wind velocity was estimated at 1.1 m, which is the center of gravity of the human body, and builds the reference level for human biometeorological studies.

In the last years many attempts have been carried out to formulate a reliable and user-friendly index for the assessment of the physiological thermal response of the human body to the climatic conditions (d'Ambrosio Alfano et al. 2011), but only the Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI) seem to meet these requirements.

The physiological equivalent temperature (PET) is based on the Munich Energy-balance Model for Individuals. PET is very effective, as a single thermal index, to evaluate the thermal component of any given microclimate (Chirag Deb et. al 2010). It is equivalent to the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat balance of the human body (work metabolic rate 80 W of light activity, that should be added to the basic metabolic rate (heat resistance of clothing 0.9 clo, which is the reference clothing insulation value used for the formulation of PET) is maintained with core and skin temperatures equal to those of the under assessment conditions (reference environment: temperature 20^0C, humidity 50%) (Mayer and Höppe 1987 and Höppe P., 1999). The PET assessment scale (Tab. 1) is derived by calculating Fanger's (1972) PMV for varying air temperatures in the reference environment using the settings for the PET reference person (height: 1.75m, weight: 75kg, age: 35 yrs and sex: male; work metabolic rate 80 W of light activity, that should be added to the basic metabolic rate and heat resistance of clothing 0.9 clo,) (Matzarakis et al. 1999).

The UTCI assessment scale is presented in Table 2 (Bröde et al., 2012). The assessment scale is based on different combinations of rectal and skin temperatures, sweat rate, shivering, etc. that might indicate "identical" strain causing non-unique values for single variables like rectal or mean skin temperature in different climatic conditions with the same value of UTCI (Havenith G. et al. 2012)

Table 1. Physiological Equivalent Temperature (PET) for different grades of thermal sensation and physiological stress on human beings (Matzarakis et al. 1999)

PET (°C)	Thermal sensation	Physiological stress level
<4	very cold	extreme cold stress
4-8	cold	strong cold stress
8-13	cool	moderate cold stress
13-18	slightly cool	slight cold stress
18-23	comfortable	no thermal stress
23-29	slightly warm	slight heat stress
29-35	warm	moderate heat stress
35-41	hot	strong heat stress

Table 2. UTCI Assessment Scale: UTCI categorized in terms of thermal stress (Bröde et al. 2012).

UTCI (°C)	Stress Category
> +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
+9 to 0	slight cold stress
0 to -13	moderate cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
< -40	extreme cold stress

The input variables in modeling mean daily PET and UTCI are mean daily values of air temperature, relative humidity, wind speed, and radiant temperature. The input variable of mean daily radiant temperature (the uniform temperature of a surrounding surface that results in the same radiation energy gain on a human body as the prevailing radiation fluxes) is modeled based on mean daily cloud coverage. In the study, both PET and UTCI were calculated using ‘‘RayMan’’ model, appropriate to calculate radiative heat transfer and human biometeorological indices (Matzarakis et al. 1999, 2010). The ‘‘RayMan’’ model, developed according to Guideline 3787 of the German Engineering Society (VDI 1998), calculates the radiative heat transfer in both simple and complex environments. The main feature and advantage of ‘‘RayMan’’ compared to other similar models is the calculation of short- and long-wave radiation fluxes, the possibility to evaluate the thermal environment throughout the year for both cold and hot seasons, and the use of a common unit (°C).

Results and Discussion

We produced a bioclimate diagram for the PET-based and UTCI-based analysis of the general bioclimate conditions. Ten-day frequencies of the daily PET and UTCI values are illustrated for the period 2008 to 2012 respectively (Fig. 1 and 2). The bars appeared in each interval represent the percentages of cardiovascular admissions associated with the particular PET and UTCI Index.

Figure 1 depicts that the days in spring (middle of April) and fall (beginning of November) are within the PET classes of 8°C – 12.9°C (moderate cold stress) while from the end of June to the end of August, moderate (23°C <PET<28.9°C) and strong (29°C <PET<34.9°C) heat stress can also be observed for the study region.

It is shown that the PET between 23°C - 28.9°C (red colour) is associated with lower admissions and PET between 8°C - 12.9°C (green color) are mainly related with higher admissions for cardiovascular diseases.
On the other hand in Figure 2 is shown that only the days in the beginning of June to the beginning of September are within the UTCI classes 9°C – 25.99°C (no thermal stress). In others seasons the UTCI index is between -13°C – 0°C (moderate cold stress) and 0°C – 8.99°C (slight cold stress), classes related with high admissions for cardiovascular diseases.

A decrease of 10^0C in air temperature results in 9% increase of ACS, a decrease 10m/s in wind speed is related to 6% increase of ACS, while 50% increase in cloudiness is related to 7% increase in ACS. We found similar results concerning lag effects up to 3-days.

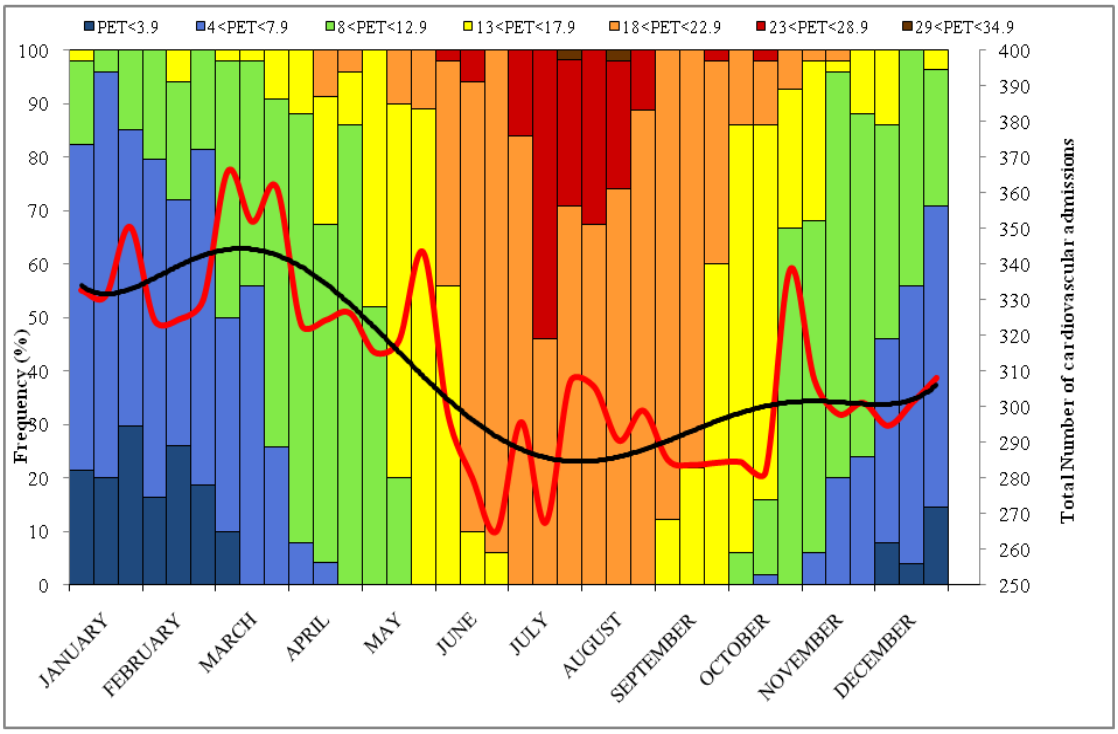

Figure 1 Frequency (%) of the cardiovascular admissions per 10-Days Intervals (2008-2012) in Heraklion as a function of the bioclimatic indices of PET Index, along with the variation of the total number of cardiovascular admissions per 10-Days Interval (red line) and the polynomial fitting (black line).

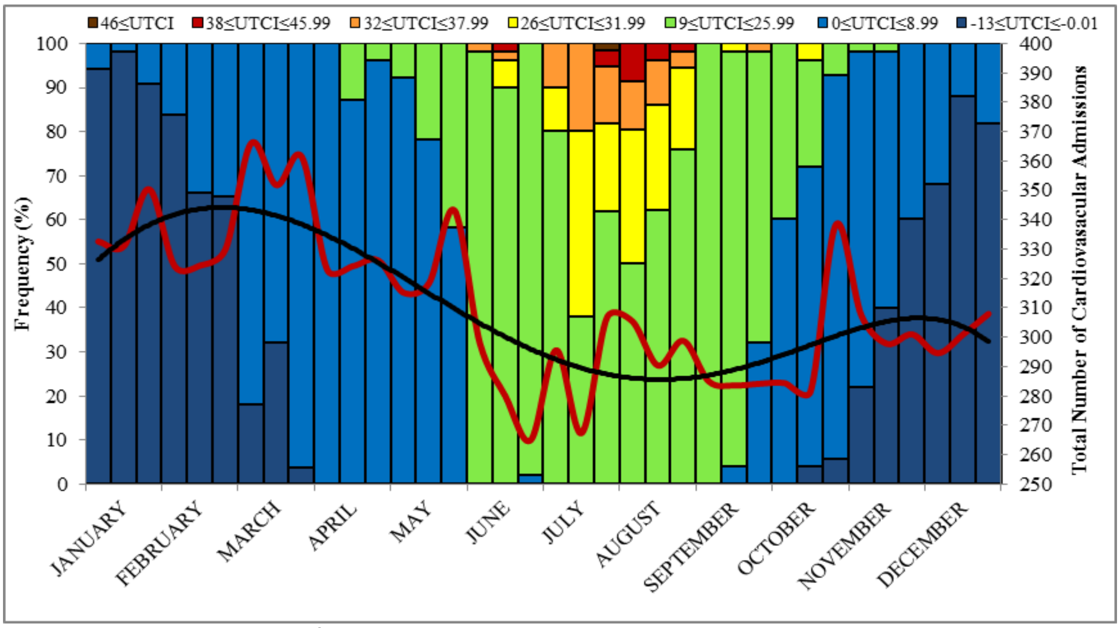

Figure 2 Frequency (%) of the cardiovascular admissions per 10-Days Intervals (2008-2012) in Heraklion as a function of the bioclimatic indices of UTCI Index, along with the variation of the total number of cardiovascular admissions per 10-Days Interval (red line) and the polynomial fitting (black line).

Table 3. Results of Applied Generalized Linear Models

Meteorological Parameters	Estimate	p
Temperature	-0.0093	0.000
Relative Humidity	0.0008	0.069
Wind Speed	-0.0060	0.002
Cloudiness	0.0109	0.000
PET	0.000	0.2805
UTCI	0.000	0.3068

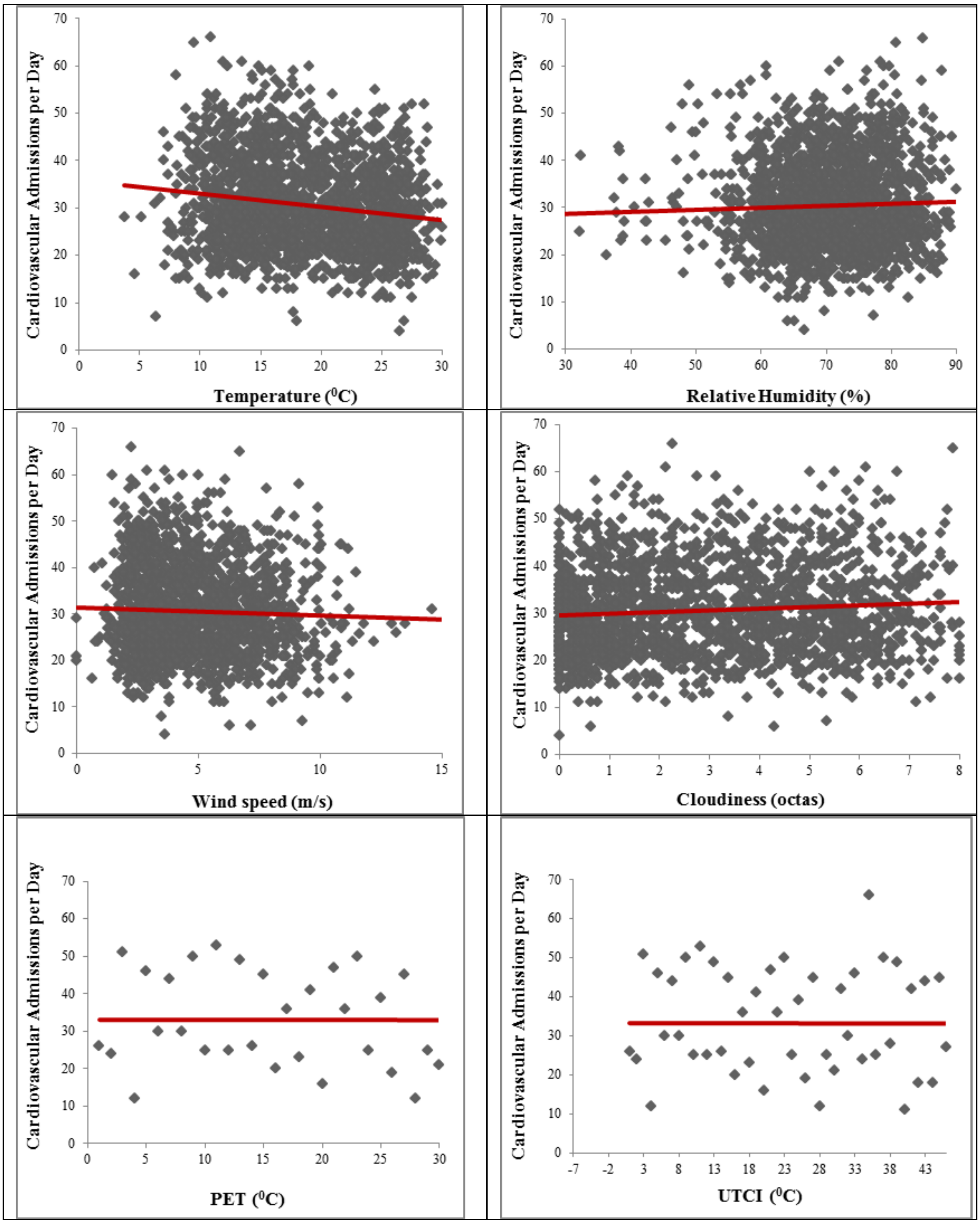

Figure 3 Scatter plot between air temperature (a), relative humidity (b), wind speed (c), cloudiness (d), PET (e) and UTCI (f) and cardiovascular syndromes.

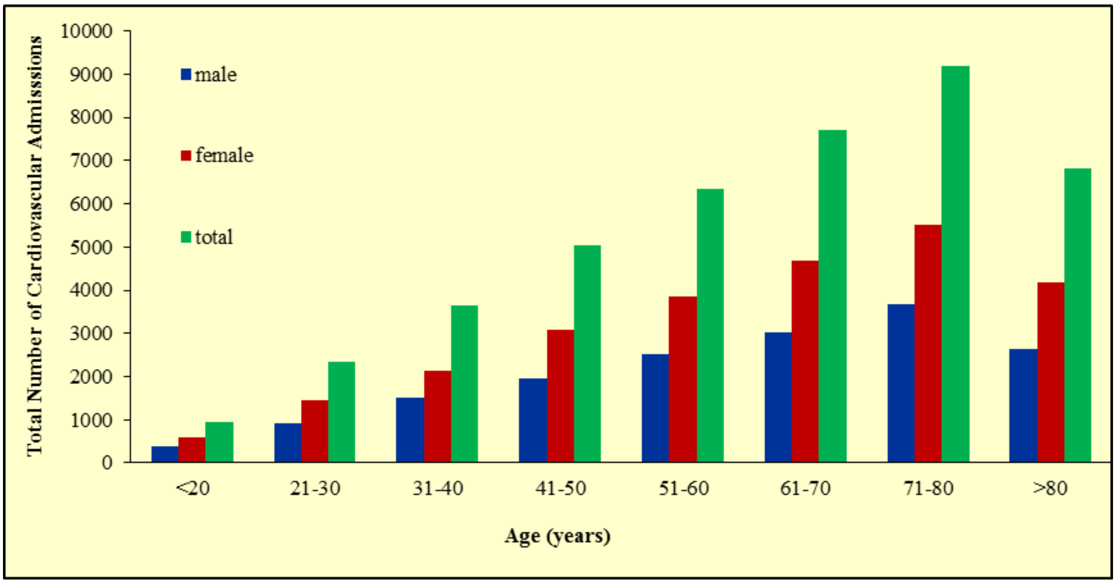

Figure 4 Age and sex distribution of the patient with cardiovascular problems in Heraklion.

Conclusions

The interpretation of the results of this analysis suggests a significant association between cold weather and increased coronary heart disease incidence, especially in the elderly and females. Our findings revealed that the bioclimatic indices did not affect daily ACS significantly against seasonal impacts. The day to day variability of independent variables is associated with ACS; namely a decrease of 10^0C in air temperature results in 9% increase of ACS, a decrease 10m/s in wind speed is related to 6% increase of ACS, while 50% increase in cloudiness is related to 7% increase in ACS. We found similar results concerning lag effects up to 3-days.

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