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The accuracy of the heat index to explain the excess of mortality and morbidity during heat waves – a case study in a mediterranean climate

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Abstract. The aim of this contribution was to evaluate the accuracy of a well known human comfort index, the heat index, to anticipate the effects of the July 2006 heat wave in mortality (all causes) and morbidity (all causes, respiratory and circulatory disease). Our assessment was done to all citizens, to people of the 75+ cohort and to each gender, in Porto. For further statistical analysis, we calculated an expected number of admissions by averaging the admissions recorded during the comparison period. The 95% confidence interval was calculated, using a standard method based on the t-distribution, for differences between independent means with different population variances, using the Leveane test to evaluate the variance's homogeneity. During the 2006 heat wave, a 52% mortality excess was registered relatively to the expected mortality ($p < 0.001$), for all cohorts of the population. The admissions excess for all ages included the admissions due to respiratory diseases ($p < 0.029$), pneumonia ($p < 0.001$) and chronic obstructive pulmonary disease ($p < 0.001$). For the 75+ cohort, the admissions due to respiratory diseases ($p < 0.017$), pneumonia ($p < 0.001$) and heart failure ($p < 0.610$) were also statistically high. The obtained results confirm that the heat index is a truthful method to anticipate the negative impacts of heat waves in human health even in climate contexts adapted to hot summers like at Porto – a Mediterranean tempered climate. The impacts of July 2006's heat wave in the increase of mortality (all causes) and in respiratory morbidity (all population and 75+cohort) was evident.

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Contents:

1. Introduction

All 21st climate scenarios produced by several global climate models anticipate a frequency increase in the duration and intensity of the heat waves (Planton et al., 2008; Monteiro et al., 2012a, 2012b, 2012c) for temperate zone and in special for Mediterranean regions like Porto (Dessai, 2002, 2003; Díaz et al., 2002a, 2002b, 2006; Meehl, Tebaldi, 2004; Monteiro et al., 2012c).

Having this climate projections in mind, the negative impacts in human health caused by heat waves have been highly investigated either by climatologists or public health experts (Monteiro et al., 2011, 2012a, 2012b, 2012c) because the human adaptation capacity to adapt to this extreme events is still considerably low. The consequences of the several heat waves that occurred after the 90's in Europe (Rooney et al., 1998; Calado et al., 2004; Grize et al., 2005; Fouillet et al., 2006; D'lppoliti et al., 2010; Monteiro et al., 2012a, 2012c), in United States (Semenza et al., 1999; Weisskopf et al., 2002) and in other places (Tan et al., 2007) in mortality and morbidity were highly investigated and all the conclusions claim for a greater concern with the need of innovative tools to anticipate the human health risks during extreme climatic episodes.

The research carried out on this particularly problematic had roughly two different approaches: i) use of temperature as an isolated climatic variable and its effects in mortality and morbidity (Saez et al., 1995; Ballester et al., 1997; Hajat et al., 2002); ii) use of some climatic elements combination, such as temperature and relative humidity (Michelozzi et al., 2006; Schiffano et al., 2009; Almeida et al., 2010; Monteiro et al., 2012a, 2012c) and its consequences in human health deterioration. Steadman (1979a, 1979b, 1984) was an important example of these last ones, which constituted a remarkable starting point for the creation of the heat index, later on adjusted by the United States National Weather Service as an anticipation warning system for extreme heat events.

One subjacent concern to the majority of this type of investigation lies in the identification of the main vulnerable groups, namely, the elderly population (Díaz et al., 2002a), as it has a limited adaptation ability towards thermal stress factors (Jendritzky, 1993), requiring the creation of adequate preventive measures against heat waves. The negative impacts of intense heat in the elderly people by rising already existing physical weaknesses and sometimes leading even to death is recognised by several studies done in France 2006's heat wave (Fouillet et al., 2006; Rey et al., 2007), in Vienna (Hutter et al., 2007), in Holland (Huynen et al., 2001), in Spain (Borrel et al., 2006) and at Porto (Monteiro et al., 2011, 2012a, 2012b, 2012c). In the majority of the studied cases the presence of chronic diseases are triggered and aggravated by the existing thermal discomfort during heat waves (Fouillet et al., 2006). Moreover, the individual vulnerability during extreme hot events is a composite equation where the age and the pre-existing diseases should be considered in combination with a vast list of other variables like gender (McGeehin, Mirabelli, 2001; Monteiro et al., 2012a).

During heat waves events the effects in the health of individuals living in Mediterranean climates of Europe, special in cities where the Urban Heat Island effect is strong (Rooney et al., 1998; Gaffin et al., 2008; Metzger et al., 2010) and the ageing of the population is increasing like at Portugal (Almeida et al., 2010), it is very important to give also a sp ecial focus to the individual vulnerability, which means: (a) to estimate the impacts of the 2006 heat wave, according to the heat index, in terms of total mortality, total morbidity and morbidity due to circulatory and respiratory causes, in the Great Metropolitan Area of Porto (Portugal); (b) to identify the most vulnerable groups to the heat wave impacts, comparing the excess of mortality and morbidity for the total population, for the population by gender and for the population of the 75+ cohort.

2. Materials and methods

Study areas: Porto city, the hub of a Great Metropolitan Area (GAMP), represents the second larger Portuguese urbanized area. The location in the North-Western area of the Iberian Peninsula (41°N) close to the Atlantic Ocean and well exposed to the arrival of the zonal westerly's after a long journey over the ocean from the east coast of the USA, explains the Mediterranean tempered climate context with mild and rainy winters and hot and dry summers. The GAMP has, approximately, 1.6 million people who, spatially distributed, represent the population density of 1,115 inhabitants per 1 km^2 (Instituto Nacional de Estatística, 2001).

Health and climate data: The health data analysed was obtained in Instituto Nacional de Estatística databases (mortality for January to December 2002–2007) and in Biostatistics and Medical Informatics and Health System's Central Administration databases (daily admissions due to all causes, to circulatory diseases and to respiratory diseases using All Patient Diagnosis Related Groups – Version 21 (ACSS, 2011). The morbidity data were explored in four perspectives: i) all ages; ii) all ages by gender; iii) the cohort 75+; iv) the cohort 75+ by gender.

The heat index calculation, defined as an individually perceived air temperature given the humidity, was done with Porto's daily meteorological variables (Meteorological Observatory of Porto Serra do Pilar). The heat index measures the evaporative heat between a typical human and the environment, one of the appropriate measures to determine the effect of heat in the body, and better than temperature itself. The original estimation of the human-perceived equivalent temperature, proposed by Steadman (1979), comprised a group of parameters' calculations that were considerably simplified by Rothfusz' model (1990), assuming several fixed magnitudes to some parameters like vapour pressure or dimensions of a human skin surface or clothing cover or clothing resistance to heat transfer or activity, etc.

$$HI = -42.379 + \left(2.04901523 \times T\right) + \left(10.14333127 \times R\right) - \left(0.22475541 \times T \times R\right) - \\ -\left(6.83783 \times 10^{-3} \times T^2\right) - \left(5.4481717 \times 10^{-2} \times R^2\right) + \left(1.22874 \times 10^{-3} \times T^2 \times R\right) + \\ +\left(8.5282 \times 10^{-4} \times T \times R^2\right) - \left(1.99 \times 10^{-6} \times T^2 \times R^2\right)$$

Where:
T = air temperature °C;
R = relative humidity %.

The calculation of the HI allows the classification of temperature (°C) according to four different dangerousness levels, to which possible physical symptoms correspond (National Weather Service

Weather Forecast Office Summer Weather Safety and Survival Heat Index, 2011): (a) extreme danger (HI ≥ 54ºC) – heat stroke or sunstroke; (b) danger (41 < HI < 54) – sunstroke, muscle cramps, and/or heat exhaustion; heatstroke due to prolonged exposure and/or physical activity; (c) extreme caution (32 < HI <41) – sunstroke, muscle cramps, and/or heat exhaustion due to possible prolonged exposure and/or physical activity; (d) caution (27 < HI < 32) – possible fatigue due to prolonged exposure and/or physical activity.

Statistical methods: An *expected number of admissions* was calculated by determining the average number of admissions (2002 to 2007, except for 2006) recorded during three comparison weeks: the week previous to the heat wave (from July 3 to 10), the week of the heat wave (from July 11 to 18) and the following week (from July 19 to 26). From the *number of admissions observed* during the heat wave (from 11 to 18 July 2006) the *expected number of admissions* was subtracted to determine an excess of deficit in hospital admissions during the heat wave.

The 95% confidence interval was calculated, using the standard method based on the *t*-distribution for differences between independent means with different population variances, using the Leveane test to evaluate the variance's homogeneity.

3. Research Results

3.1. Total mortality and morbidity excess

During the July 2006 heat wave, Porto registered an excess of 107 deaths which corresponds to an increase of 52% ($p < 0.026$) relatively to the expected mortality. At that time, the morbidity data due to all-causes did not evidence a statistically significant increase ($p < 0.938$).

The morbidity results due to circulatory and respiratory disease during the heat wave were fairly different. Morbidity due to all circulatory diseases did not reveal any statistical significant admission excess ($p < 0.562$). From the studied circulatory pathologies, the admissions due to myocardial infarction ($p < 0.353$) and heart failure ($p < 0.331$) did not reveal the admission excess during the studied extreme climatic episode.

The four hospitals admissions with respiratory diseases during the 2006 July heat wave show an excess of 67 admissions ($p < 0.029$), corresponding to an increase of 49% relatively to the expected respiratory morbidity. Moreover, some respiratory diseases evidence an even higher excess, namely the increase in pneumonia by 86% ($p < 0.001$) and chronic obstructive pulmonary disease by 100% ($p < 0.001$).

3.2. Excess morbidity by gender

Morbidity due to all-causes, like morbidity due to all circulatory causes, myocardial infarction, heart failure and chronic obstructive pulmonary disease did not present the admission excess by gender.

Morbidity due to all respiratory causes presented the admissions excess for the masculine gender by 43% ($p < 0.001$) and for the feminine gender by 58% ($p < 0.036$).

For admissions due to specific respiratory causes, only pneumonia revealed a statistically significant admission excess for the masculine gender ($p < 0.001$).

3.3. Excess morbidity for the 75+ cohort

The total morbidity of individuals from the 75+ cohort, despite revealing a slight increase during the heat wave period (22%), is not statistically significant ($p < 0.156$) for a confidence interval of 95%.

The admission excess in the population of the elderly group during the studied extreme climatic episode occurred for the generality of respiratory (59%, $p < 0.017$), pneumonia (127%, $p < 0.001$), and chronic obstructive pulmonary disease (100%, $p < 0.013$).

Morbidity due to the generality of circulatory diseases, in elderly individuals, during the heat wave remained constant, with just a slight increase by 2%, statistically meaningless (p 0.875). The total circulatory morbidity due to some specific causes, namely, due to acute myocardial infarction (-38%) and heart failure (-15%) decreased during the heat wave period. Morbidity due to vascular accident revealed a slight increase of 8%, however, statistically meaningless ($p < 0.665$).

Table 1. Mortality and internments excess during the heat wave from 11/07/2006 to 18/07/2006, calculated according to the heat index

Diagnosis	A	B	C	D	E
Mortality [a]	All–causes	313	206	107 (52%)	0.026
All–Causes Morbidity (Total)	All–causes	2,395	2,370	25 (1%)	0.938
All–Causes Morbidity (Men)		1,034	1,072	−38 (−4%)	0.813
All–Causes Morbidity (Women)		1,361	1,266	95 (8%)	0.567
Respiratory Disease (Total)	GDC4	204	137	67 (49%)	0.029
Respiratory Disease (Men)		117	82	35 (43%)	0.000
Respiratory Disease (Women)		87	55	32 (58%)	0.036
Pneumonia (Total)	HDG 89;90	41	22	19 (86%)	0.000
Pneumonia (Men)		24	12	12 (100%)	0.001
Pneumonia (Women)		17	11	6 (55%)	0.064
Chronic Obstructive Pulmonary Disease (Total)	HDG 88	24	12	12 (100%)	0.001
Chronic Obstructive Pulmonary Disease (Men)		13	8	5 (63%)	0.089
Chronic Obstructive Pulmonary Disease (Women)		11	4	7 (175%)	0.070
Circulatory Disease (Total)	GDC5	232	218	14 (6%)	0.562
Circulatory Disease (Men)		111	110	1 (1%)	0.933
Circulatory Disease (Women)		121	108	13 (12%)	0.384
Acute Myocardial Infarction (Total)	HDG 121;122;123	15	19	−4 (−21%)	0.353
Acute Myocardial Infarction (Men)		8	10	−2 (−20%)	0.484
Acute Myocardial Infarction (Women)		7	9	−2 (−22%)	0.542
Heart Failure (Total)	HDG 127	16	20	−4 (−20%)	0.331
Heart Failure (Men)		11	9	2 (22%)	0.461
Heart Failure (Women)		5	12	−7 (−58%)	0.068
Cerebral Vascular Accident (Total)	HDG 14;15	31	28	3 (11%)	0.614
Cerebral Vascular Accident (Men)		17	14	3 (21%)	0.415
Cerebral Vascular Accident (Women)		14	14	0 (0%)	0.960

Explanation: [a] Mortality data by gender not available; GDC – Great Diagnostic Category; HDG – Homogeneous Diagnostic Groups; A – code; B – observed; C – expected; D – excess (95% CI); E – p-value

Source: PTDC/SAU-ESA/73016/2006

Table 2. Mortality and Internments excess in individuals from the 75+ cohort during the heat wave from 11/07/2006 to 18/07/2006, calculated according to the heat index

Diagnosis	A	B	C	D	E
Mortality[b]	All-causes	b	b	b	b
All-Causes Morbidity (Total)	All-causes	484	397	87 (22%)	0.156
All-Causes Morbidity (Men)		187	172	15 (9%)	0.660
All-Causes Morbidity (Women)		297	224	73 (33%)	0.000
Respiratory Disease (Total)	GDC4	113	54	59 (109%)	0.017
Respiratory Disease (Men)		53	28	25 (89%)	0.068
Respiratory Disease (Women)		60	25	35 (140%)	0.006
Pneumonia (Total)	HDG 89;90	25	11	14 (127%)	0.000
Pneumonia (Men)		12	5	7 (140%)	0.001
Pneumonia (Women)		13	6	7 (117%)	0.011
Chronic Obstructive Pulmonary Disease (Total)	HGD 88	12	6	6 (100%)	0.013
Chronic Obstructive Pulmonary Disease (Men)		5	4	1 (20%)	0.488
Chronic Obstructive Pulmonary Disease (Women)		7	2	5 (250%)	0.153
Circulatory Disease (Total)	GDC5	63	62	1 (2%)	0.875
Circulatory Disease (Men)		27	25	2 (13%)	0.678
Circulatory Disease (Women)		36	37	-1 (-3%)	0.893
Acute Myocardial Infarction (Total)	HDG	5	8	-3 (-38%)	0.352
Acute Myocardial Infarction (Men)	121;122;123	1	3	-2 (-67%)	0.149
Acute Myocardial Infarction (Women)		4	5	-1 (-20%)	0.638
Insuficiência Cardíaca (Total)	HDG 127	11	13	-2 (-15%)	0.610
Insuficiência Cardíaca (Men)		7	4	3 (75%)	0.042
Insuficiência Cardíaca (Women)		4	8	-4 (-50%)	0.146
Cerebral Vascular Accident (Total)	HDG 14;15	14	13	1 (8%)	0.665
Cerebral Vascular Accident (Men)		7	5	2 (40%)	0.273
Cerebral Vascular Accident (Women)		7	8	-1 (-13%)	0.774

Explanation: [a] Mortality data by gender not available; GDC – Great Diagnostic Category; HDG – Homogeneous Diagnostic Groups; A – code; B – observed; C – expected; D – excess (95% CI); E – p-value

Source: PTDC/SAU-ESA/73016/2006

3.4. Excess morbidity the 75+ cohort by gender

During the July 2006 heat wave, the admission excess due to all causes was observed, having a statistical significance of only 33% ($p < 0.001$) for the feminine gender.

The increase in the number of admissions for the generality of respiratory causes from individuals of the 75+ cohort was observed only for the feminine gender (140%, $p < 0.006$) during the July 2006 hot period.

This admission excess due to pneumonia in the eldest group occurred, for both genders, of

140% ($p < 0.001$) for men and 117% for women ($p < 0.011$).

In the case of the total number of admissions due to heart failure, in this age group a significant increase for men was observed ($p < 0.042$).

The total of admissions due to circulatory causes, acute myocardial infarction and cerebral vascular accident did not reveal significant increases between genders.

4. Discussion

4.1. Number of heat wave days and daily temperatures

The high heat index values seems to be well correlated with the mortality and respiratory admission excess during a heat wave episode, as in July 2006, characterised by the combination of very high temperatures (from 29ºC to 37ºC) and relative humidity moderate values (42% to 71%). Besides knowing that thermal sensation in man depends on much more factors than the only two considered here – temperature and relative humidity – we concluded that they are adequate to start a thermal discomfort evaluation. Thermal discomfort, which is liable of being observed (3 days of level II and 5 days of level III) can be explained by the combination of both climatic elements, from which the oscillating apparent temperature between 33 to 47ºC resulted. The physiological symptoms associated to the level II of the heat index are sunstroke, muscle cramps, heat exhaustion due to possible prolonged exposure and physical activity, while those from the level III are similar to those from the previous level, with the possibility for the occurrence of heat stroke due to prolonged exposure and/or physical activity. In this study, the use of the heat index constituted an important criterion for the anticipation of respiratory morbidity. It is a warning system that combines temperature with humidity, generating the apparent temperature and respective physiological limits (Kovats, Ebi, 2006). Nevertheless, the human *susceptibility* to extreme events involves a puzzle of local bio-geophysical, social and economic variables that modifies considerably the accuracy of an index to a specific place. Sometimes those who predicts better the negative impacts in human health are the simpler ones that use only pre-established temperature thresholds (Koppe et al., 2003; Monteiro et al., 2012a, 2012c), while in other examples may be those that include synoptic methods associated to specific air masses or those presenting temporal series models (Kyselý, 2004).

4.2. Mortality/morbidity excess (all-ages)

The mortality excess of 52% (107 admissions) and the all causes morbidity excess of 1% (25 admissions), as well as the respiratory morbidity excess of 49% (67 admissions) and circulatory morbidity excess of 6% (14 admissions) that occurred at the Great Metropolitan Area of Porto during the July 2006 heat wave, confirm previous results obtained in other places, namely, in chronic obstructive pulmonary disease and pneumonia (Mastrangelo et al., 2007; Monteiro et al., 2011, 2012b). It referred that the ideal conditions for increasing hospital admissions are gathered in the presence of a sequence of at least four consecutive hot and humid days, with humidex index above 40ºC. As the author refers, from the physiological point of view, a respiratory difficulty occurs in result of the accumulation of heat and humidity during time. Simultaneously, the evaporative capacity becomes more reduced, making the organism's sudation and cooling function more difficult. Simultaneously, the evaporation capacity becomes smaller, making it difficult for the sudation and organism's cooling functions to occur (Frota, Schiffer, 1987).

Our results are also consistent with previous studies relating heat waves and mortality due to respiratory diseases (Monteiro et al., 2011, 2012a, 2012c). Some authors showed similar results while revealing the mortality excess due to respiratory causes, during heat wave episodes (Kilbourne, 1999; Rey et al., 2007). Similarly, Huynen et al. (2001) showed a clear relation between the respiratory mortality increase and different heat waves registered in Holland and Hertel et al. (2009) during the 2003 heat wave in Germany. Almeida et al. (2010), while studying the effect of apparent temperature in daily mortality, verified that during a hot season the increase of 1ºC in daily average apparent temperature corresponded to the increase of 2.7% in respiratory causes mortality.

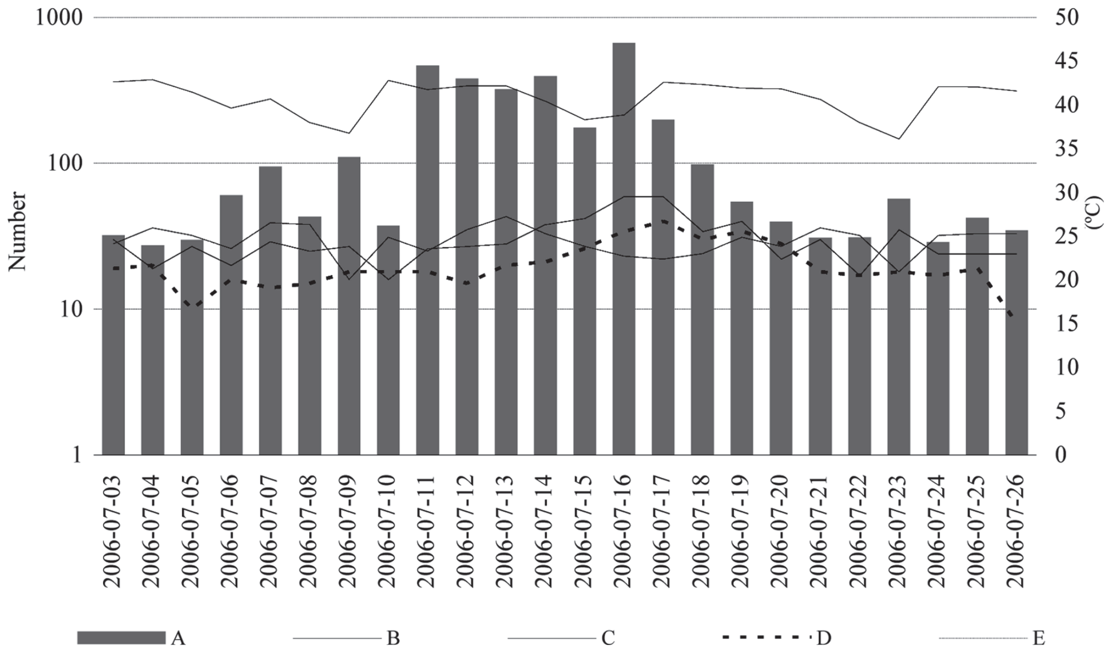

Fig. 1. Number of deaths and admissions for the total population occurred during the extreme heat event (from 11 to 18 July 2006), during the previous week (from 03 to 10 July 2006) and the following week (from 19 July to 26 July 2006)

Explanation: A – heat index; B – deaths, C – admissions (all-causes); D – respiratory admissions; E – circulatory admissions

Source: PTDC/SAU-ESA/73016/2006

4.3. Morbidity excess by gender (all-ages)

The significant admission excess for both genders during the 2006 heat wave, characterised by a high apparent temperature, was perceptive for the generality of the respiratory diseases. In pneumonia admissions, only the masculine gender revealed the hospital admission increase in relation to what would have been expected.

In the generality of circulatory diseases and admissions due to cerebral vascular accidents, a significant increase was observed neither for the total of admissions nor for admissions by gender, relatively to the expected admissions during the heat wave. The admissions due to myocardial infarction and heart failure suffered a decrease. These results seem to agree with other works which highlight a sub-dimensioning of circulatory causes. Studies made in London (Kovats, Ebi, 2006), Veneto (Mastrangelo et al., 2007), Chicago (Semenza et al., 1996; Whitman et al., 1997), Madrid (Linares, Díaz, 2007) and Holland (Huynen et al., 2001) suggest that there is a short time gap between the exposure to heat and the death due to circulatory diseases. Therefore, the immediate effect of the heat in the human organism will contribute towards the reduction of the individual's hospitalisation.

Our results do not allow a clear distinction between the heat wave's effects by gender and for the generality of the population independently of age, except for the admission excess due to pneumonia for the masculine gender. Other studies (Ellis, Nelson, 1975, Ellis et al., 1975) regarding the evaluation of the effects in mortality in New York in the decade of the 1970s, do also refer the non-observance of differences between genders. However, the mortality excess in France during the 2003 heat wave (Pirard et al., 2005) and in Chicago during the 2005 heat wave (Whitman et al., 1997) were higher among women. Taking into account the differences between the results, the study's consensuality about the effects of heat waves by gender is still not recognised (Basu, Samet, 2002).

4.4. Morbidity excess in the 75+ cohort

Morbidity due to all causes presents an observed admission increase of 22% relatively to the expected in this age group, even though its significance level is reduced.

The results from this study also revealed a significant admission increase for the generality of respiratory diseases (109%), pneumonia (127%) and chronic obstructive pulmonary disease (100%) in the 75+ cohort during the heat wave period.

The hospital admission excess for individuals in this age group due to all circulatory causes, myocardial infarction, heart failure and cerebral vascular accident was not observed. The number of myocardial infarctions and heart failure during the July 2006 heat episode revealed a decrease. This morbidity behaviour in the most fragile individuals, such as the elderly, contributes to corroborate the idea that the intense heat will potentiate immediate death in individuals susceptible to the development of circulatory diseases (Mastrangelo et al., 2007). The heat wave episodes negative effects are more evident in the aged groups, due especially to the impact of temperature in the increase of the blood viscosity, which may produce thrombosis and a deficit in the thermoregulation function (Keatinge et al., 1986). However, other admission causes, such as the respiratory causes, characterised by a larger lag period between the development of the extreme heat episode and the effect produced in the human body evidence a higher vulnerability in individuals from the 75+ cohort.

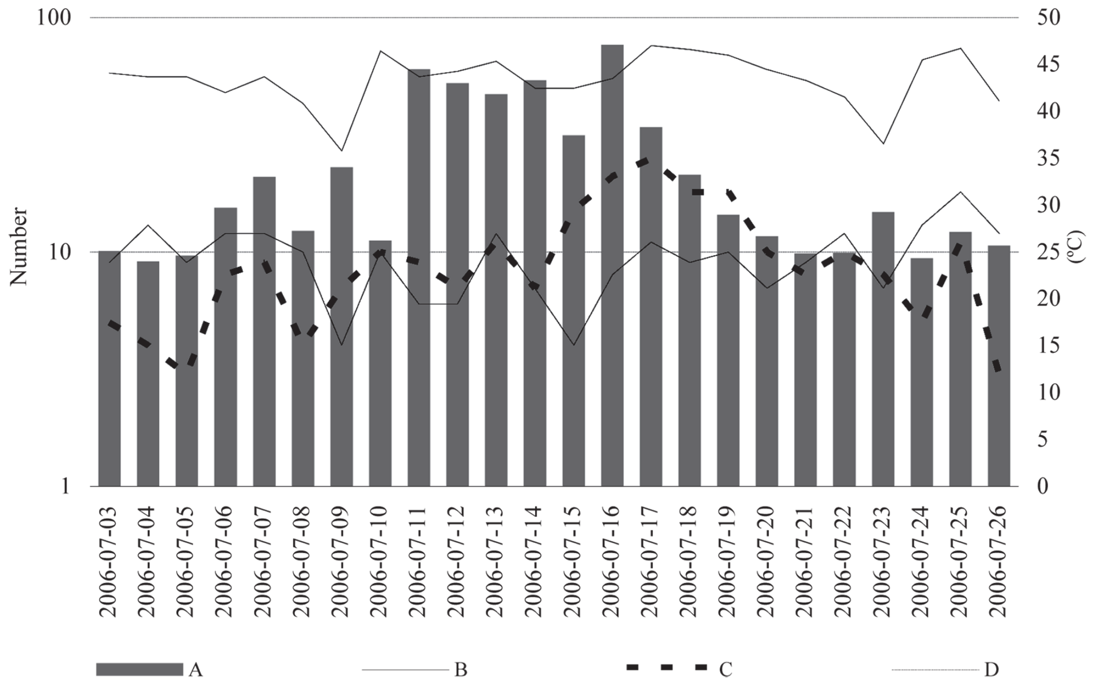

Fig. 2. Number of deaths and admissions in the population with age equal and above 75 years, occurred during the extreme heat event (from 11 to 18 July 2006), during the previous week (from 03 to 10 July 2006) and the following week (from 19 July to 26 July 2006)

Explanation: A – heat index; B – admissions (all-causes); C – respiratory admissions; D – circulatory admissions

Source: PTDC/SAU-ESA/73016/2006

4.5. Morbidity excess in the 75+ cohort by gender

The aged (75+ cohort) morbidity due to all causes is statistically significant for females. Numerous studies show also that the elderly women are the group with the highest mortality proportion in extreme heat situations (Klinenberg, 2002; Whitman et al., 1997). However, the women higher life expectancy than men may be one possible explanation for their higher mortality (Fouillet et al., 2006). Nevertheless, in our analysis this argument is not plausible, once we standardized the population by gender. Women from the 75+ cohort registered a significant increase in admissions for the generality of respiratory diseases and pneumonia. The masculine admission excess for this age group was only significant for admissions due to pneumonia and cardiac failure. One possible explanation for the cardiac failure excess in individuals with advanced age can be the fact that the filling during the left ventricular diastole decreases with age, limiting the cardiac debt and the cardiac frequency during a rest or during physical exercise (Schulman et al., 1992; Kenney, 1997). Other possibility is based on the fact that the age also contributes to the smaller activity of cutaneous vessels, limiting the body's capacity to deviate heat from the centre to the skin in moments of intense heat (Rooke et al., 1994). The risk for heart failure in the elderly from the masculine gender can be due to the fact that this group presents inadequate water consumption during high thermal stress conditions due to heat, which contributes towards a lower adaptation (Semenza et al., 1999).

5. Conclusions

The use of the heat index in the Mediterranean tempered climate, reflected similar effects to the extreme heat episodes in the behaviour of mortality and respiratory morbidity (Monteiro et al., 2012c). However, the circulatory morbidity was decreasing, unlike the respiratory mortality and morbidity. This fact suggests the necessity to investigate the consequences of these events according to their pathological causes, even for mortality or morbidity simultaneously, once they might demand diversified intervention strategies.

This study still allowed the comprehension of some aspects which characterise the populations' individual vulnerability, namely, the differences observed between general population and the elderly population, as well as between men and women.

One of the constraints in this study results from the fact that it did not include mortality data specified by causes, what complicates the comprehension if the statistical insignificance relative to the admissions due to circulatory causes resulted in the mortality increase due to this type of cause. Accordingly, forward studies could try to understand the influence of high apparent days' temperature in the simultaneous behaviour for morbidity and mortality due to circulatory causes.

In conclusion, this study has demonstrated that, in the context of the Mediterranean tempered climate during high apparent temperature days, the mortality due to all causes and the morbidity due to all respiratory causes, pneumonia and chronic obstructive pulmonary disease significantly increased, not only for the 75+ cohort but also for the general population.

For the group including all ages, the differences between genders were not significant, with the exception for the masculine admission superiority in pneumonia.

Women from the 75+ cohort seem to be the population's most vulnerable group during these days, once morbidity due to all causes increased significantly. However, for this age group some significant differences between genders were registered. Women were the most affected by respiratory diseases as men were by heart failure.

The minimisation of vulnerability must include preventive measures which attribute a special importance to risk groups, which implies the knowledge of the local population's characteristics (Michelozzi et al., 2006). The information transmitted to public in general, and to the risk age groups in particular, assumes high importance. Naughton et al. (2002) suggest the necessity of informing the population about the main symptoms of heat in health. In the case of the population's most vulnerable groups, such as the elderly people and patients, it is fundamental to have daily surveillance to their physical conditions and their environmental context, by family, neighbours or social assistants. The recognition of the effects of heat in health could contribute towards the modification of risk behaviours, as well as the awareness of physical symptoms in relation to heat could contribute to activate faster intervention mechanisms when emergency situations occur.

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