



Air conditioning and intrahospital mortality during the 2003 heatwave in Portugal: evidence of a protective effect

Baltazar Nunes, Eleonora Paixão, Carlos Matias Dias, et al.

Occup Environ Med published online October 4, 2010
doi: 10.1136/oem.2010.058396

Updated information and services can be found at:
<http://oem.bmj.com/content/early/2010/10/04/oem.2010.058396.full.html>

These include:

- | | |
|-------------------------------|--|
| References | This article cites 19 articles, 8 of which can be accessed free at:
http://oem.bmj.com/content/early/2010/10/04/oem.2010.058396.full.html#ref-list-1 |
| P<P | Published online October 4, 2010 in advance of the print journal. |
| Email alerting service | Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article. |
-

Notes

Advance online articles have been peer reviewed and accepted for publication but have not yet appeared in the paper journal (edited, typeset versions may be posted when available prior to final publication). Advance online articles are citable and establish publication priority; they are indexed by PubMed from initial publication. Citations to Advance online articles must include the digital object identifier (DOIs) and date of initial publication.

To request permissions go to:
<http://group.bmj.com/group/rights-licensing/permissions>

To order reprints go to:
<http://journals.bmj.com/cgi/reprintform>

To subscribe to BMJ go to:
<http://journals.bmj.com/cgi/ep>

Air conditioning and intrahospital mortality during the 2003 heatwave in Portugal: evidence of a protective effect

Baltazar Nunes, Eleonora Paixão, Carlos Matias Dias, Paulo Nogueira, José Marinho Falcão

► Additional tables and figures are published online only. To view these files please visit the journal online (<http://oem.bmj.com>).

Department of Epidemiology, Instituto Nacional de Saúde Dr Ricardo Jorge, Lisboa, Portugal

Correspondence to

Mr Baltazar Nunes, Instituto Nacional de Saúde Dr Ricardo Jorge, Department of Epidemiology, Av. Padre Cruz P-1649-016 Lisboa, Portugal; baltazar.nunes@insa.min-saude.pt

For author footnote see end of the article.

Accepted 23 June 2010

ABSTRACT

Objectives The objective of the study was to analyse the association between the presence of air conditioning in hospital wards and the intrahospital mortality during the 2003 heatwave, in mainland Portugal.

Methods Historical cohort study design including all patients aged 45 or more who were hospitalised in the 7 days before the heatwave. The outcome was survival during the 18 days the heatwave lasted and during the 2 days after the end of the heatwave. A comparison group was also selected in four analogous periods without any heatwave event during January to May 2003. Data were obtained from the 2003 hospital discharges database. Air conditioning presence in hospital wards was determined using a survey sent to hospital administrations. A Cox-regression model was used to estimate the confounder-adjusted HR of death, during the heatwave and the comparison period, in patients in wards with air conditioning (AC+) versus patients in wards without air conditioning (AC-).

Results 41 hospitals of mainland Portugal (49% of all hospitals in mainland Portugal) participated, and 2093 patients were enrolled. The overall confounder-adjusted HR of death in AC+ patients versus AC- patients was 0.60 (95% CI 0.37 to 0.97) for the heatwave period and 1.05 (95% CI 0.84 to 1.32) for the comparison group.

Conclusions The study found strong evidence that, during the August 2003 heatwave, the presence of air conditioning in hospital wards was associated with an increased survival of patients admitted before the beginning of the climate event. The reduction of the risk of dying is estimated to be 40% (95% CI 3% to 63%).

INTRODUCTION

In Portugal, the consequences of heatwaves in mortality have been studied since 1988,¹ leading to the recognition of the magnitude and importance of this problem and to the development of a national Contingency Plan for Heatwaves, in operation since 2004.²

These studies also led to the observation that more than half of the excess deaths occurred in hospitalised patients, especially during the 2003 heatwave in Portugal,³ raising the discussion about the role that absent or insufficient air conditioning of many hospital wards could have played in intrahospital mortality during heatwaves.

Since then, Health Ministry directives were issued, and efforts have been made by hospital administration boards to install air conditioning equipments in hospital wards.

What this paper adds

- A significant proportion of excess deaths during heatwaves occurs in hospitals.
- The health consequences of inhospital exposure to heat can be considered to be of a true nosocomial nature.
- The benefit of air conditioning has been demonstrated for patients admitted to intensive care units with heatstroke during heatwaves.
- Health authorities need to quantify the benefit of physical changes introduced in hospitals and health centres, namely air conditioning, as mitigating measures for health effects of heatwaves.
- The study found strong evidence that during the August 2003 heatwave, the presence of air conditioning in hospital wards was associated with an increased survival of patients admitted before the beginning of this climatic event for any type of ward (intensive care units were not included in the study).
- Air conditioning in hospitals is an effective measure for health and life protection in extreme summer conditions.

International literature shows that the risk of death associated with excess heat is higher in patients with pre-existing cardiovascular and respiratory diseases than in the general population.^{4,5} The occurrence of heatwaves can increase mortality in patients with chronic diseases, namely pre-existing cardiovascular and respiratory diseases, older people, children and individuals from a low socio-economical background.⁴⁻⁶

Studies in several countries show that, as for mortality, the probability of hospital admission increases during periods of heatwave, affecting especially individuals with pre-existing cardiovascular and respiratory diseases.⁷⁻¹¹ The main direct causes of hospital admissions identified were dehydration, heat stroke and renal failure.^{8,9,12-14}

In hospital settings, heat-associated mortality is higher among patients admitted before the onset of a heatwave, especially older people and those in General Medicine wards. Acute cardiac failure, stroke, acute episodes of chronic respiratory diseases, chronic infections and psychotropic medication are also associated with an increase in heat-related mortality of hospitalised patients.^{15,16}

In hospitalised psychiatric patients, the observed heat associated risk of death is twice as high as that in the general population, probably due to the prescription of antipsychotic and anticholinergic medications.^{17 18}

Two possible explanations for this excess intrahospital mortality during heatwaves are: (1) admission of individuals who became severely ill due to high temperatures; (2) intrahospital worsening of the health status of patients already admitted suffering the effects of the heatwave inside the hospital.

It should be noted that the role of age in the increase of the risk of intrahospital death associated with heat exposure is complemented by other factors which also increase the probability of death, namely: hyperthermia caused by the condition that led to hospital admission, the level of dependency of the patient and the floor level of the building where the ward is situated.⁴

A decrease in body temperature, especially through exposure to air conditioning, is an important factor for the control of health problems associated with environmental heat. Staying in rooms with air conditioning has been described as the strongest predictor of death associated with heat.^{4 12 19}

Some authors²⁰ have also stated that the American population is more prepared to face cold temperatures than extreme heat, and that is due to the near universality of central heating in contrast to the low coverage of central air conditioning.

As controlled environments, health services, especially hospitals, provide access to populations for epidemiological studies with unique characteristics as they are generally composed of frail or diseased individuals, more prone to suffering the consequences of high environmental temperatures.

The possible protective effect on mortality and morbidity of air conditioning in hospital wards has been studied less frequently, namely the relationship between the benefit on heat-related diseases and the risk of diseases associated with air-quality parameters such as the transmission of infectious agents.¹⁷ Air conditioning in intensive care units has been shown to be associated with improved outcomes of patients.²¹

In Portugal, a more recent heatwave with a documented impact on human mortality occurred in July 2006. As a result of the report prepared by the National Health Observatory (Observatório Nacional de Saúde), a Centre of the National Institute of Health (Instituto Nacional de Saúde Dr Ricardo Jorge—INSA) with preliminary estimates of its effects,²² the Minister of Health asked for further studies aimed at: (1) describing the effects of the heat-related warnings in the media; and (2) quantifying the effect of the physical modifications introduced in hospitals and health centres on mitigating the health effects of heatwaves.

This study aimed to verify if there was any association between the existence of air conditioning in the hospital wards and the intrahospital mortality, during the 2003 heatwave, using available data.

METHODS

To accomplish the aforementioned objective, the intrahospital mortality of patients hospitalised in wards with air conditioning (AC+) was compared with the intrahospital mortality of patients in wards without air conditioning (AC-) during the period of the 2003 heatwave in Portugal.

A historical cohort study was designed to assess the association between exposure to intrahospital air conditioning and intrahospital mortality during the period of the 2003 heatwave (period of exposure: 18 days, from 29 July to 15 August in 2003).

This group of patients was exposed to the heatwave, exclusively during hospitalisation, that is they were admitted before the beginning of the heatwave. The heatwave period was defined according to the Portuguese Heat Health Warning System,²³ that is two or more consecutive days with maximum temperature above 32°C. It is also important here to note that excess mortality associated with the 2003 heatwave was observed in all 18 districts of Portugal mainland.³

The cohort 'study group' (SG) included all patients who were admitted to hospital during the 7 days (22 July 2003 to 28 July 2003) before the beginning of the heatwave and who were not discharged before 30 July 2003. Staying in hospital in 29 July 2003 was also a selection criterion because it was considered that one intrahospital death could be attributable to excess heat if the patient was exposed to heat at least 1 day. Therefore, as it is documented that the heatwave ended, nationally, by 15 August, all intrahospital deaths occurring until 17 August (2 days after the end of the heatwave) were included in this study. This decision was based on the fact that in the community, excess deaths were observed until 2 days after the heatwave ended.³

A potential bias could result from the protective association hypothesised, due to the fact that AC- wards already had a higher intrahospital mortality than AC+ wards due for example to less favourable characteristics of hospital conditions, patients or illnesses. To account for this potential bias, a 'Comparison Group' (CG) was also selected. This included four subcohorts of patients admitted during four periods in the winter and spring of 2003 (previous periods when there was no excess heat, as documented by reports from the National Institute of Meteorology).

The CG included patients belonging to four subcohorts admitted to hospital during the winter and spring of 2003 and were designed to be as independent as possible in time from each other. By analogy with the SG, the four cohorts included patients admitted to hospital during the 7 days preceding the first 20 days of February (subcohort January: 25 January 2003 to 31 January 2003), March (subcohort February: 22 February 2003 to 28 February 2003), April (subcohort March: 25 March 2003 to 31 March 2003) and May (subcohort April: 24 April 2003 to 30 April 2003). All patients in each of the four cohorts were not discharged before day 2 of each following month. The period for observations of events lasted from day 2 to day 20 of each month (figure S1). Therefore, the endpoint was death occurring in each 19-day period.

Air conditioning in hospital wards

Data on the presence of air conditioning in hospital wards of the National Health Service (NHS) during the July–August 2003 period were obtained through a special telephone survey of hospital administration boards of NHS hospitals, preceded by direct telephone contact with all Regional Health Administrations. The methodology of this ad hoc survey was tested in a pilot study conducted in two hospitals (Hospital Distrital de Beja and Hospital de Santa Maria, Lisboa). Given the success of the pilot study in obtaining data on the presence of air conditioning in pilot hospitals wards, the survey was extended to all NHS hospitals in Portugal mainland. The survey consisted in sending to each hospital administration board a preliminary list of the hospital wards according to the official list of the Ministry of Health.²⁴ The administration boards were asked to: (1) confirm or update the list of wards in their hospital, (2) provide for each ward the unique hospital discharge database code and (3) provide information on the presence or absence of air conditioning in the June–August 2003 period.

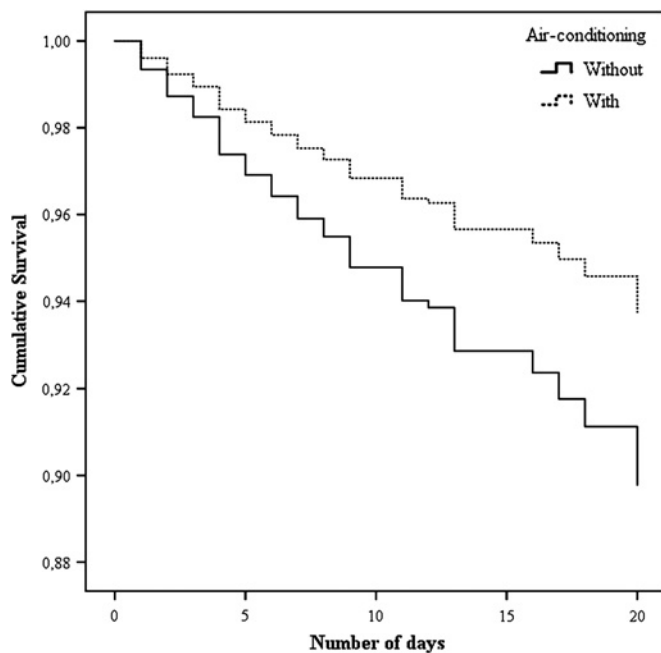


Figure 1 Study group (heatwave): survival of patients in wards with air conditioning and in wards without air conditioning, during the observation period, after adjustment for confounding variables (Cox regression).

Hospital admissions

Patient data were obtained from the 2003 hospital discharge database. This database contains data on all admission episodes occurring in all NHS hospitals of Portugal mainland with discharge in 2003. Patients aged 45 years or more, staying in only one ward, were selected for the study. Patients admitted to more than one ward in the same episode were excluded, given the impossibility of determining the overall level of exposure to air conditioning in different wards. This decision was taken because

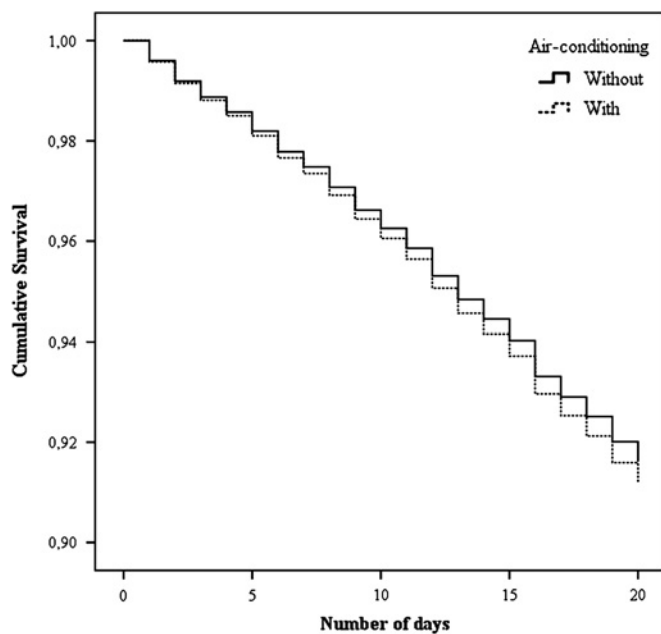


Figure 2 Comparison group (winter/spring): survival of patients in wards with air conditioning and in wards without air conditioning, during the observation period, after adjustment for confounding variables (Cox regression).

the hospital discharge database does not show clearly the sequence of transfers between wards. Patients in intensive care and obstetric wards were also excluded from the study.

For each episode of hospitalisation, the exposure to air conditioning was defined as the presence or absence of air conditioning in the ward where the patient stayed, according to the results of the survey of hospital administrations.

The variables collected for the study included gender, age group, health region where the hospital is located, type of ward (internal medicine, surgery, orthopaedics, neurology, oncology, urology and others) main diagnosis at discharge (coded by ICD-9-CM²⁵: Neoplasm: 140–239; Diseases of the circulatory system: 390–459; Diseases of the respiratory system: 460–519; Diseases of the digestive system: 520–579; External causes: E800-E999; Others: other all codes), discharge status (live or death) and duration of hospital stay (until discharge, death or end of the period defined for observation of events in this study).

Statistical analysis

Intrahospital mortalities were computed, dividing the number of deaths occurring during the period of observation by the sum of the number of days of hospitalisation for each patient in the same period (number of person.days of hospitalisation). Statistical significance of the differences between these rates was tested using an approximation to the Poisson distribution.²⁶

Pearson χ^2 tests were used to compare proportions.

Confounder adjusted HRs of dying in hospital during the observation period were computed for patients staying in wards with air conditioning (AC+) versus patients staying in wards without air conditioning (AC-). With this purpose, a Cox regression model was fitted to time until the death, containing as covariables the indicator of exposure to air conditioning and the confounding factor gender, age group, health region of the hospital, type of ward and main diagnosis. Model adjusted for the confounding variables were build for each group in the study (SG and CG).

The condition of proportional hazards was assessed by the Harrell and Lee test based on the Schoenfeld's residuals as described by Kleinbaum and Klein.²⁷

All results were obtained using the statistical package SPSS 15.0.

RESULTS

AC survey participant and non-participant hospitals

The study encompassed 49% (41) of the hospitals in the NHS. The distribution of participant and non-participant hospitals was different across the Health Regions, mainly because of the Lisbon and Tagus Valley which contributed only 4% (1) of the eligible hospitals (table S1). Otherwise, the distribution of hospitals by type showed no significant differences between participant and non-participant hospitals.

Characteristics of patients in AC survey participant and non-participant hospitals

The AC survey provided information on the presence or absence of AC for 2093 patients from the SG and 8904 for the CG, representing 54% and 53% respectively of the total number of patients hospitalised in these periods. In both SGs, differences were found on the distribution of the AC survey participants by the Health Region where the hospital was located. In fact, hospitals located in southern Portugal are under-represented in this study, especially due to the low participation of hospitals located in the Lisbon and Tagus Valley (tables S2, S3).

Characteristics of participant patients in AC+ and AC– wards

In the SG, 30.2% of patients stayed in AC+ wards.

Statistically significant differences were found in the percentage distribution through the categories of all other characteristics under study: age group, health region, main diagnosis at discharge and type of ward (table S4).

In the CG, the percentage of patients staying in AC+ wards was 30.0%, and with the exception of gender and age group, statistically significant differences were found in the percentage distribution by the categories of all other characteristics under study: health region, main diagnosis at discharge and type of ward (table S5).

Intrahospital crude death rate ratio and survival of patients in AC+ and AC– wards

During the August 2003 heatwave, the intrahospital death rate of patients in AC+ wards (5.8/1000 person.days) was lower than the rate of patients in AC– wards (9.0/1000 person.days). The crude death rate ratio (0.64; 95% CI 0.40 to 1.01) was marginally significant.

During that period (figure 1), survival of patients in AC+ wards was significantly higher than survival of patients in AC– wards (confounder adjusted HR=0.60; 95% CI 0.37 to 0.97) (table 1) suggesting a protective effect of air conditioning of about 40%. This result was obtained by the Cox regression model adjusted for gender, age groups, type of ward, main diagnosis and health region.

During this comparison period, the intrahospital death rate of patients in AC+ wards was 6.5 deaths by 1000 person.days, slightly higher than the death rate of AC– patients (5.8 deaths by 1000 person.days). The crude death rate ratio (1.10; 95% CI 0.89 to 1.36) was not statistically significant.

No significant differences were found between the survival of AC+ and AC– patients during this period (confounder-adjusted HR=1.05; 95% CI 0.84 to 1.32) (table 1). These findings strongly suggest that the higher rate of survival found in AC+ patients during the 2003 heatwave is not associated with an usually higher survival rate in the group of AC+ patients, even in winter and spring when heatwaves do not occur. This shows, as expected, that no difference in survival existed in comparable AC+ and AC– patients outside the heatwave period (figure 2).

DISCUSSION

Patients in hospitals are strongly dependent on these institutions where they are expected not only to receive appropriate care but to be protected from threatening exposures to their health, namely environmental exposures. The occurrence of nosocomial infections, as a consequence of microbiological exposures, is a good example where this is not always the case. In a different situation, patients being exposed to heatwaves in hospital wards suffer the consequences of that exposure and have an increased probability of dying.

The health consequences of inhospital exposure to heat can be considered to be of a true nosocomial nature.¹¹ Under these circumstances, the use of air conditioning in wards should have, intuitively, a relevant role in protecting patients from the effects of heat. This benefit has also been demonstrated for patients admitted to intensive care units with heatstroke during heatwaves.²¹

During the heatwave that occurred in Portugal and other European countries in August 2003, many wards in Portuguese hospitals were not equipped with air conditioning. Therefore, this study was aimed at estimating the expected protective

Table 1 Confounder-adjusted HRs of intrahospital death during the 19 days after the beginning of the 2003 heatwave (study group) and during the first 19 days of four periods in winter/spring of 2003 (comparison group), according to the presence of air conditioning (AC) in the hospital ward, gender, age group, type of ward, main diagnosis at discharge and health region of the hospital location

	Study group Confounder- adjusted HRs (95% CI)	Comparison group Confounder- adjusted HRs (95% CI)
Presence of AC in wards		
Patients in AC+	0.60 (0.37 to 0.97)	1.05 (0.84 to 1.32)
Patients in AC–	1	1
Gender		
Females	0.73 (0.50 to 1.06)	0.94 (0.77 to 1.15)
Males	1	1
Age groups		
45–54	1	1
55–64	1.48 (0.59 to 3.73)	1.11 (0.68 to 1.82)
65–74	1.22 (0.51 to 2.90)	1.55 (1.00 to 2.40)
75–84	3.52 (1.58 to 7.84)	2.25 (1.47 to 3.45)
≥85	2.68 (1.09 to 6.61)	3.92 (2.50 to 6.20)
Type of ward		
Orthopaedics	1	1
Internal medicine	4.61 (1.16 to 18.32)	5.76 (2.84 to 11.71)
Surgery	1.05 (0.25 to 4.73)	2.64 (1.28 to 5.43)
Neurology	3.57 (0.80 to 16.00)	2.80 (1.19 to 6.58)
Oncology	2.26 (0.41 to 12.56)	4.54 (1.99 to 10.35)
Urology	1.09 (0.21 to 5.90)	1.78 (0.71 to 4.44)
Others	1.35 (0.32 to 5.64)	2.04 (0.98 to 4.23)
Main diagnosis		
External causes	1	1
Diseases of the circulatory system	1.04 (0.29 to 3.78)	1.21 (0.67 to 2.17)
Diseases of the respiratory system	1.35 (0.37 to 4.93)	1.07 (0.59 to 1.95)
Diseases of the digestive system	0.83 (0.20 to 3.49)	1.37 (0.74 to 2.54)
Neoplasm	2.83 (0.81 to 9.92)	2.30 (1.30 to 4.08)
Others	1.03 (0.29 to 3.60)	0.73 (0.40 to 1.32)
Health region		
North	1	1
Centre	1.38 (0.91 to 2.10)	1.35 (1.08 to 1.68)
Lisbon and Tagus Valley+Alentejo +Algarve	1.26 (0.68 to 2.34)	0.91 (0.61 to 1.33)

effect associated with the existence of air conditioning in hospital wards, during the 2003 heatwave in Portugal.

The results strongly suggest that a protective effect of air conditioning on intrahospital mortality existed and was statistically significant. The survival function adjusted for the confounder variables by Cox regression shows that survival of AC+ patients was clearly higher than survival of AC– patients during the 2003 heatwave in Portugal. The estimate of the reduction of risk of intrahospital death during the heatwave was 40% (HR 0.60; 95% CI 0.37 to 0.97) (figure 2).

Four relevant aspects related to the study design should be discussed.

The selection of participants included only patients 45+ years old. The reason for excluding younger patients was that the number of patients included in the hospital discharge database was small. Additionally, studies conducted in the community show that the effect of heatwaves in mortality spared individuals younger than 45 years old.³ Accordingly, the estimated protective effect observed in this study must be applied only to persons aged 45+ years inside hospital wards during heatwaves.

The study included patients who were in only one ward during their hospital stay (85% of eligible patients). In fact, the

hospital-discharge database does not clearly show the sequence of transfers between wards, thus precluding the correct classification of exposure to air conditioning of patients transferred between wards during the period of the heatwave.

Patients in intensive, intermediate, recovery and other equivalent units were excluded, as all those types of units have air conditioning as shown by the ad hoc survey to hospital administrations. Additionally, these specialised wards usually receive patients with poorer prognosis coming from other hospital specialist wards. The inclusion of those patients would thus bias the estimates of survival towards the null hypothesis.

A significant bias could also occur if the usual level of survival (for instance in winter and spring) was, on average, higher in AC+ than in AC- groups of wards. Therefore, a higher survival of patients in AC+ wards in comparison with those in AC- wards, during the heatwave period, could be explained by the fact that AC+ wards would usually be associated with a higher survival and not by an effect of the presence of air conditioning.

To test the existence of such a bias, survival of patients in AC+ and AC- wards was also studied in the winter and spring of 2003, the same year of the heatwave under scrutiny. The absence of heatwaves in those seasons makes it unnecessary to use air conditioning for cooling, and differences in survival would have been explained by other reasons than the use of air conditioning.

The survival analysis in the CG showed that, after adjustment for the same confounders as in the study period, the HR was not significantly different from 1 (HR=1.05, 95% CI 0.84 to 1.32; $p=0.644$), demonstrating no evidence of differences in survival in AC+ and AC- patients, when the same analysis was conducted in the winter/spring period. Differences in survival found during the heatwave period (figure 2) cannot thus be explained by differences in the nature and characteristics of the AC+ and AC- groups of wards, and such potential bias does not influence the results of this study.

Assuming that the protective effect of air conditioning varies positively with the level of temperature in each hospital, the overall value obtained (HR=0.60) should be different from equivalent wards of different hospitals. However, the number of hospital admissions and intrahospital deaths was not enough to allow the estimation of the effect of air conditioning in each hospital, or even in groups of hospitals.

The classification of each patient in relation to exposure to air conditioning was based on the existence/non-existence of this equipment in the ward where the patient was hospitalised. Two situations may lead to misclassification of patients: (1) some wards could be equipped only in some rooms, thus making it impossible to identify the room where the patient stayed; (2) there was no information on the use of AC and the duration of this use during the 2003 heatwave. However, it is unlikely that existing AC devices were not used by hospitals in a situation of severe excess heat, as occurred during that heatwave.

However, in any of these cases, a possible misclassification of patients concerning exposure to AC would lead to classifying as exposed to AC, patients who in fact, were not exposed. Therefore, this possible bias would tend to underestimate the protective effect of AC.

Three important aspects related to the conduction of the study should be emphasised.

Forty-one hospitals participated, corresponding to 49% of all NHS hospitals in Portugal mainland. Although non-participating hospitals are located in all five health regions, only one hospital from the Lisbon and Tagus Valley Region participated. This hospital (St^a Maria) is the largest in the region, covers

a large population and offers specialist care in all medical areas. It was also included in the pilot survey. At the time of the study, NHS hospitals in the Lisbon and Tagus Valley were under considerable stress, caused by a lack of medical and nursing staff, which may explain the lack of response of the other hospitals in the region to this study.

There is no reason to consider that NHS hospitals in this health region did not participate in the study for reasons related to different exposure to air conditioning in hospital wards other than what happens in NHS hospitals in other health regions.

Given the fact that the main comparison was made between patients in AC+ and AC- wards and not between patients in different types of hospitals, one can assume that the participation of only about half of all eligible hospitals did not induce relevant bias in the estimates. It should also be emphasised that the distribution of participating and non-participating hospitals by type of hospital showed no significant differences, and this is against a selection bias of patients according to the severity of their health condition (table S1).

The distribution of the characteristics of participating patients in the SG (patients in the heatwave period) showed no significant differences from non-participating patients, except for the Health Region where the hospital is located. This fact is an argument in favour of the non-existence of relevant selection bias induced by these characteristics (table S2).

However, in the CG (winter and spring period), significant differences were found between patients in participating and non-participating wards concerning 'Main diagnosis' and 'type of ward.' This finding suggests that equivalent differences could exist in the SG patients but could not be shown because of the lack of power of the sample of this Group (table S2) when compared with the sample of the CG (table S3). However, adjustment for both 'Main diagnosis' and 'type of ward' was made in the final analysis.

As stressed before, it is reasonable to assume that these differences have not induced relevant bias on the evaluated estimates, as the study design was aimed only at comparisons between patients in AC+ and AC- wards.

It is interesting to note that the 'All causes' mortality was lower in the participating wards than in the non-participating wards. This fact occurred both in the SG—heatwave period (participating wards=8.1/10³ person.days; non-participating wards=10.2/10³ person.days) and in the CG (participating wards=6.1/10³ person.days; non-participating wards=7.1/10³ person.days). It should also be stressed that the highest values of mortality were observed in SG, in both participant and non-participant wards, when compared with the mortalities observed in the CG, suggesting a probable effect of the heatwave affecting patients in both types of wards.

In the SG, patients in AC+ and AC- showed significant differences in several of the characteristics under study: age group, region, main diagnosis, type of ward, but also gender, although with borderline significance. Such differences would be able to generate relevant bias, given the fact that survival could be associated with these variables. Therefore, the confounder-adjusted HRs and the survival curves were adjusted for all of the above-mentioned variables, eliminating or minimising their possible confounding effects.

The study found strong evidence that, during the August 2003 heatwave, the presence of air conditioning in hospital wards was associated with an increased survival of patients admitted before the beginning of this climatic event. This association was probably causal. The reduction of the risk of dying was estimated to be 40% (95% CI 3% to 63%).

This estimate is naturally influenced by the intensity and duration of the heatwave, which was very high in August 2003. Therefore, extrapolation of this estimate to situations of different intensity and duration should be made with caution.

To be rigorous, extension of the results from this study should be restricted to patients 45 years of age or older who were not in intensive care or equivalent wards. It should also be limited to patients who were exposed to the heatwave exclusively in hospital and not to those who were exposed to the heatwave in the community before being admitted to a hospital. It should also be emphasised that the results of this study support the measures included in the Portuguese Contingency Plan for Heatwaves, which recommends the installation of air conditioning equipment in unequipped hospitals and wards.²

Author footnote

List of participating hospitals: Centro Hospitalar Caldas da Rainha, Centro Hospitalar Vale do Sousa, Centro Hospitalar de Coimbra, Centro Hospitalar Vila Nova de Gaia, Hospital Distrital de Águeda, Hospital Distrital de Alcobaça, Hospital Distrital de Amarante, Hospital Distrital de Barcelos, Hospital Distrital de Beja, Hospital Distrital de Bragança, Hospital Distrital de Castelo Branco, Hospital Distrital de Chaves, Hospital Distrital de Covilhã, Hospital Distrital de Elvas, Hospital Distrital de Estarreja, Hospital Distrital de Fafe, Hospital Distrital de Foz, Hospital Distrital do Fundão, Hospital Distrital da Guarda, Hospital Distrital de Guimarães, Hospital Distrital de Leiria, Hospital Distrital de Matosinhos, Hospital Distrital de Macedo de Cavaleiros, Hospital Distrital de Mirandela, Hospital Distrital de Peniche, Hospital Distrital do Pombal, Hospital Distrital de Portalegre, Hospital Distrital de Portimão, Hospital Distrital da Povoia do Varzim, Hospital Distrital de Santo Tirso, Hospital Distrital de São João da Madeira, Hospital Distrital de Tondela, Hospital Distrital de Valongo, Hospital Distrital de Viana do Castelo, Hospital Distrital de Vila Nova Famalicão, Hospital Distrital de Viseu, Hospital de Santo António, Hospital Universidade Coimbra, Hospital da Feira, Hospital de Santa Maria, Hospital de São João, Hospital Joaquim Urbano, Hospital São Marcos, Instituto Português de Oncologia de Coimbra and Instituto Português de Oncologia do Porto.

Acknowledgements The authors wish to acknowledge the support of: R Sousa Santos, president of the Hospital Distrital de Beja, and J Correia da Cunha, deputy director of the administration board of the Hospital Santa Maria, namely during the pilot study; F Araújo, deputy director of the administration council of the Administração Regional do Norte (North Region Health Administration); J Pedro Pimentel, president of the administration council of the Administração Regional do Centro (Centre Region Health Administration); R Valente Matos president of the administration council of the Administração Regional do Alentejo (Alentejo Region Health Administration) and R Eugénio Lourenço president of the administration council of the Administração Regional do Algarve (Algarve Region Health Administration); and all members of the administration board and technicians of the participating hospital centres, hospitals and institutions, for their support and collaboration on the data collection. Finally, we acknowledge the paper referees for the constructive comments and suggestions.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Falcão J**, Castro M, Falcão M. Efeitos de uma onda de calor na mortalidade da população de Lisboa. *Saúde em Números* 1988;**3**:3.
2. **Ministério da Saúde, Direcção-Geral da Saúde**. *Plano de Contigência para ondas de calor 2004*. Lisbon: Ministério da Saúde, Direcção-Geral da Saúde, 2004.
3. **Calado R**, Nogueira P, Catarino J, *et al*. A onda de calor de Agosto de 2003 e os seus efeitos sobre a mortalidade da população portuguesa. *Revista Portuguesa de Saúde Pública* 2004;**22**:7–20.
4. **Basu R**, Samet JM. Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol Rev* 2002;**24**:190–202.
5. **Centre for Disease Control**. *Extreme Heat*. Atlanta, GA: Centre for Disease Control, US Department of Health and Human Services, 1996.
6. **Lugo-Amador NM**, Rothenhaus T, Moyer P. Heat-related illness. *Emerg Med Clin North Am* 2004;**22**:315–27.
7. **Mastrangelo G**, Fedeli U, Visentin C, *et al*. Pattern and determinants of hospitalization during heat waves: an ecologic study. *BMC Public Health* 2007;**7**:200.
8. **Kovats RS**, Hajat S, Wilkinson P. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. *Occup Environ Med* 2004;**61**:893–8.
9. **Johnson H**, Kovats S, McGregor G, *et al*. The impact of the 2003 heat wave on mortality and hospital admissions in England [abstract]. *Epidemiology* 2004;**15**:S126.
10. **Rydman RJ**, Rumoro DP, Silva JC, *et al*. The rate and risk of heat-related illness in hospital emergency departments during 1995 Chicago heat disaster. *J Med Syst* 1999;**23**:41–56.
11. **Hausfater P**. Coup de chaleur nosocomial: signal d'alerte ou oubliés de la vague de chaleur d'août 2003 en France? *Presse Med* 2006;**35**:194–5.
12. **Semenza JC**, Rubin CH, Falter KH, *et al*. Heat-related deaths during the July 1995 heat wave in Chicago. *N Engl J Med* 1996;**335**:84–90.
13. **Semenza JC**, McCullough JE, Flanders WD, *et al*. Excess hospital admissions during the July 1995 heat wave in Chicago. *Am J Prev Med* 1999;**16**:269–77.
14. **Nogueira PJ**, Nunes AR, Nunes B, *et al*. Internamentos hospitalares durante a onda de calor de Agosto de 2003: evidências de associação entre morbilidade e ocorrência de calor. *Revista Portuguesa de Saúde Pública* 2009;**27**:87–102.
15. **Stafoggia M**, Forastiere F, Agostini D, *et al*. Factors affecting in-hospital heat-related mortality: a multi-city case-crossover analysis. *J Epidemiol Community Health* 2008;**62**:209–15.
16. **Davidó A**, Patzak A, Dart T, *et al*. Risk factors for heat related death during the August 2003 heat wave in Paris, France, in patients evaluated at the emergency department of the Hôpital Européen Georges Pompidou. *Emerg Med J* 2006;**23**:515–18.
17. **Bark N**. Deaths of psychiatric patients during heat waves. *Psychiatr Serv* 1998;**49**:1088–90.
18. **Mann SC**, Boger WP. Psychotropic-drugs, summer heat and humidity, and hyper-pyrexia—danger restated. *Am J Psychiatry* 1978;**135**:1097–100.
19. **Sathyavagiswaran L**, Fielding JE, Dassy D. Heat-related deaths—Los Angeles County, California, 1999–2000, and United States, 1979–1998. (Reprinted from *MMWR*, vol 50, pp 623–626, 2001). *JAMA* 2001;**286**:911–12.
20. **Medina-Ramon M**, Schwartz J. Temperature, temperature extremes, and mortality: a study of acclimatization and effect modification in 50 US cities. *Occup Environ Med* 2007;**64**:827–33.
21. **Misset B**, De Jonghe B, Bastuji-Garin S, *et al*. Mortality of patients with heatstroke admitted to intensive care units during the 2003 heat wave in France: A national multiple-center risk-factor study. *Crit Care Med* 2006;**34**:6.
22. **Paixão E**, Nogueira P, Nunes A, *et al*. *Onda de calor de Julho de 2006: efeitos na mortalidade. Estimativas preliminares para Portugal Continental*. Lisbon: Observatório Nacional de Saúde—Instituto Nacional de Saúde Dr Ricardo Jorge, 2006.
23. **Nogueira PJ**. Examples of heat health warning systems: Lisbon's ICARO's surveillance system, summer of 2003. In: Kirch W, Menne B, Bertolini R, eds. *Extreme Weather Events and Public Health Responses*. European Union: World Health Organization Regional Office for Europe. Springer, 2005:141–59.
24. **Ministério da Saúde**. *Anuário 2006*. Lisbon: Ministério da Saúde, 2006.
25. **Organização Mundial de Saúde**. *Classificação Internacional de Doenças*. 9a edn. Geneva: Organização Mundial de Saúde, 1975.
26. **Sahai H**, Khurshid A. *Statistics in Epidemiology. Methods, Techniques and Applications*. Boca Raton, FL: CRC Press, 1996.
27. **Kleinbaum D**, Klein M. *Survival Analysis: A Self-Learning Text*. 2nd edn. New York: Springer, 2005.