Examples of Heat Health Warning Systems: Lisbon's ÍCARO's Surveillance System, Summer of 2003

Paulo Jorge Nogueira

Abstract

During the summer of 2003 Portugal was under unusual heat stress, particularly in the period from 27th July to 15th August, when almost all Portuguese districts had weekly maximum temperatures above 32 °C.

In Portugal an operational Heat Health Warning System has existed since the summer of 1999. This system is based on meteorological data and gives three days advanced heat wave predictions. This 2003 summer had several unusual heat periods that were extremely well predicted.

This article aims at presenting the Heat Health Warning System, detailing its background, methods and its five years experience. Beyond that a particular review of the summer of 2003 is done.

The 2003 summer July – August 17 day heat wave seems to have generated about 2200 excess deaths. When age, sex and district population adjustments are made the excess mortality is evaluated at 1953 heat related deceased.

Heat related mortality affected mainly elder and female individuals.

The surveillance partners had difficulties in conveying out messages to the population, using the media, late in the heat stress period.

Our 2003 summer experience lead to the conclusion that active ways must be sought to convey information to the population, when such a silent disaster is predicted. Passive systems, such as using the media to spread messages of interest during heat stress periods, are not reliable especially in a very long heat wave.

Introduction

During the summer of 2003 Portugal was under unusual heat stress, particularly in the period from 27th July to 15th August, when almost all Portuguese districts had weekly maximum temperatures above 32 °C. In fact, 13 of 18 districts had weekly mean maximum temperatures above 35 °C during that period.

The impact was detected early by the ÍCARO surveillance system, on the 30th July high ÍCARO-index was observed and a special warning was issued. In fact, from 28th July to 14th August the predicted Index for the following 3 days was always above zero, indicating presence of heat-mortality risk. On 11 of those 17 days, the ÍCARO index was above the warning threshold 0.93 (➜ *Tab. 1)*. The higher indexes were predicted on 1st August with 2.44 and on 12th and 13th August with indexes above 3.

Tab. 1
Pre-established ÍCARO surveillance system warning levels

ÍCARO-INDEX Value	Warning Level
ÍCARO-Index = 0	No Effect – No Warning
0 <= ÍCARO-Index = 0,31	Non statistically significant effects on daily mortality
0,31<= ÍCARO-Index <0,93	Possible effect on mortality
0,93 <= ÍCARO-Index <1.55	Heat wave alert in analysis
ÍCARO-Index >=1.55	Heat wave alert – serious consequences on health and mortality expected

Note: since these warning levels are based on predicted excess mortality the Index cannot have negative values. Observed mortality when converted to ÍCARO-index can have negative values.

A posterior look at mortality data showed that predicted peaks of the ÍCARO index, which reflected also variation on daily predicted temperatures, related suitably with overall observed mortality. In 2003, the major summer heat wave was responsible for about 2000 excess deaths.

This article is divided in three sections. The first section is called Lisbon's ÍCARO Surveillance System and describes the ÍCARO surveillance system background, origin, implementation, organics and past experience up to the year 2002. The second section is called ÍCARO's summer of 2003 experience and reports last summer events from systems' perspective, describing observed summer temperatures, collected mortality data, summer predicted ÍCARO'S indexes and their interrelation; overall estimates of observed heat related excess deaths is made using both 2003 and past summer mortality data; a brief discussion of the effective system's intervention is also made. The third section is a conclusion and discussion section where several strong and weak points of the work herein are presented and discussed.

Lisbon's ÍCARO Surveillance System

1 Genesis

Ícaro is the Portuguese version of the name Icarus, the Greek mythological character that died because of the sun's heat. In 1998 when a name was sought for the study of the importance of heat on mortality, the name ÍCARO sprung naturally as an acronym for the Portuguese title "Importância do Calor e a sua Repercussão nos Óbitos" [importance of heat and its repercussion on deaths].

The "ÍCARO Project" stands for a research line within the Portuguese National Health Observatory. And the ÍCARO Surveillance System (of heat waves with probable impact on human health) stands for the Portuguese Heat Health Warning System. On a romantic note, the ÍCARO Surveillance System aims at transforming all potential Icarus' into wiser Deadalus' (Deadalus was Icarus' father, who while using the same wings did not die of the sun's heat).

The ÍCARO surveillance system of heat waves with probable impact on human health and mortality was optimised to its current version in 1998 and implemented in the summer of 1999.

Its roots are well defined in the events that occurred in the heat wave of June 1981 in Portugal. This was a notorious event, where official heat related deaths, along with deaths of animals as chicken and rabbits, lack of drinking water in several districts of the country, concerns about exhausted stocks of bottled refrigerants and beer were cited on the daily newspapers during the 10 day heat wave itself. At the time, ruptures at health services levels were felt, as well as excess of patients and lack of place to hold the deceased. Evidence of a heat wave effect on weekly mortality for the district of Lisbon was shown in Falcão et al. (1988).

In July 1991 another noteworthy heat wave occurred, with similar length, apparently not as hot, and with milder effects (Paixão & Nogueira 2002 and 2003).

By 1998, a full study on the effects of the 1981 heat wave was available, estimating an outstanding overall excess of 1906 deaths in what is called continental Portugal (Portugal minus the autonomous regions Madeira and Azores). This effect was statistically significant in 16 of 18 districts, for both sexes, and for all age groups except females below 15 years old (Garcia, Nogueira & Falcão 1999).

By then further studies were underway which showed that it was possible to model the heat-mortality relationship in a suitable simple way. Nunes e Castro (1998) used a time series approach that could be simplified when using only summer mortality and temperature data instead of full year data.

Therefore, a simple way of predicting heat waves with impact on mortality was available. Such knowledge could generate life and health gains and prevent premature avoidable deaths. The idea of a surveillance system of heat waves sprung up naturally and a partnership with the Portuguese Meteorology Institute was established allowing daily summer surveillance.

The creation of the surveillance system only within the two institutions was not ideal, since these institutions do not have an active intervening role near the health system and the population in general. In order to have a full organic surveillance system, the Portuguese National Health Directorate and the National Service of Firemen and Civil Protection, which have the mandatory ability to act within the health system and the population in general, were contacted and were manifestly interested in being part of the system.

Since the modelled heat-mortality relation is based on predicted number of deaths, and this is just an epidemiological indicator, an alternative indicator was created instead to parlay information between the surveillance system partners – the ÍCARO-Index (Nogueira et al., 1999).

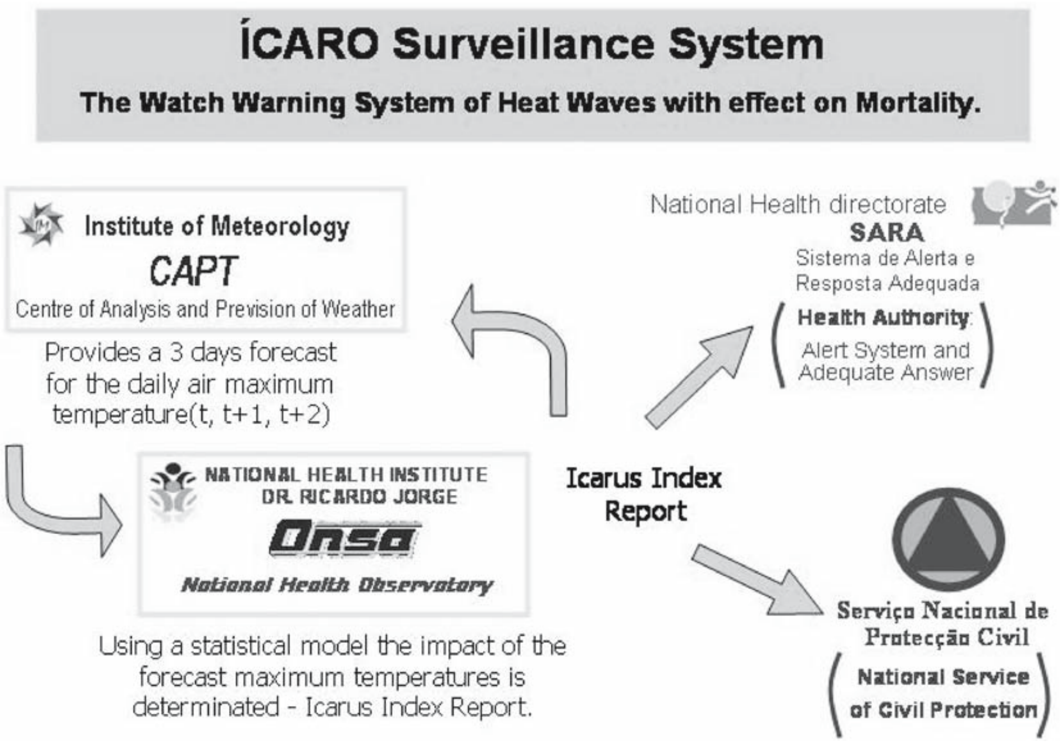
2 Organic flow

The ÍCARO surveillance system information flow starts in early May every year. The system's exchange of information starts between the Meteorology Institute (IM) and the National Health Observatory (ONSA), with the former sending forecasted weather conditions for 3 days (current day plus 2 days). Based on that information the ÍCARO-Index for the 3 days period is calculated daily at ONSA and sent back. On the 15th May this procedure is broadened to all system partners – by this date a full report can be produced (*Fig. 1*).

The system has 4 warning levels (*Tab. 1*) based on the 95 % confidence interval for Lisbon's district mortality when no abnormal weather conditions occur. Converting this mortality to ÍCARO-indexes, daily mortality varies within the values –0,31 and 0,31. The several warning levels were successively built adding this interval range (see Nogueira 1999) for technical details).

The several warning levels imply different direct interactions among the various system partners. Higher levels of risk, which imply heat wave alerts, lead to great interaction and systematic re-evaluation of observed temperatures and predicted indexes and weather conditions. When any established risk level is reached, personal messaging is made and intervening institutions issue their pre-established prevention measures.

Fig. 1



Lisbon ÍCARO Surveillance system (source: Onsa: Observatório Nacional de Saúde)

3 System scope and its past experience

The system is based on the information for the district of Lisbon and is expected to be a reasonable indicator for the rest of the country's situation. The existent information on 1981 and 1991 supports this assumption (Garcia, Nogueira & Falcão 1999 and Paixão & Nogueira 2003). Although it is a city-based system, it was mainly built on the information for its district level and is meant as a good indicator for the national level.

Since 1999 there have been several different episodes of heat waves' alerts. In 1999, the system's first year, no warning or alert was issued. The ÍCARO-Index rose up to 0.7 for one day in the beginning of July and although the observed daily mortality is not statistically different from the expected, an alteration on the randomness of the mortality process was visible (Nogueira 2001; WHO 2004). This new information gave the surveillance system an insight beyond what was previously modelled and known.

In 2000, on 15th July a first alert was issued with the 3-day predicted index with similar severity of the observed heat wave of 1991. Efforts were done by the system partners to put the information out to the health system and the population. Alert response was probably not as prompt as was required and collaboration from social media was disappointing. But oddly, two days later no such indexes were expected due to sudden changes in the weather forecast for Lisbon. Later analysis, when mortality data was available, showed that ÍCARO was absolutely correct for the district of Lisbon. But curiously, a national overall daily excess mortality was observed for the period from 15th July to 17th July just as predicted by the surveillance system on the 15th July (Nogueira 2001) and illustrated in *Figure 6*.

In 2001, a remarkable situation occurred in late May where temperatures rose from around 18 °C on the first fortnight to seven consecutive days above 30 °C. At the time awareness existed that the system was not calibrated for such occurrence.

Though heat was felt and a relative awareness of a heat wave was developing, the ÍCARO index issued only very mild warning levels. This happened because temperatures never really rose above 32 °C for more than two days, which is the departure level of the system.

A first estimation on this early heat wave was evaluated while preparing Paixão and Nogueira (2002), where an excess of 397 deaths was presented for the period of 27th May to 1st June. Future re-evaluations of this occurrence with different heat wave definitions might lead to a slightly wider estimate. In 2002 several warnings were issued but an evaluation is not yet possible because mortality data is not available yet.

ÍCARO's summer of 2003 experience

4 Temperature

This summer had several hot periods and was characterised by the following point:

- Hot temperatures occurred in late May, with temperatures equal or above 30 °C for 6 days between 21st and 31st May;
- In week 25 (*Tab. 2),* maximum air temperature raised from about twenty degrees up to 39 °C in Lisbon on the 19th June. Although it only lasted about three days it resulted in a week with excess temperature profile;
- A long hot period occurred late July – August, it lasted for about a fortnight from the 29th July up to 14th August (weeks 31 to 33). As it is shown in table 2, 16 out of the 18 continental districts of Portugal had mean temperatures above 32 °C for two full weeks, two of those had even temperatures above 40 °C. This event had no known precedent, but Lisbon's maximum air temperature from June 1981 was not reached.
- Another hot period was felt on early September (weeks 37 and 38) which was also an unexpected late summer hot period, with no presently known equivalent in the past.

In *Figure 2,* daily temperatures for Lisbon and the daily mean temperature of the 18 districts are presented. They show that the temperature of Lisbon is very closely related to the overall temperature of the mainland. Differences only arise in the relative minimum and relative maximum temperatures occurrences. The most noteworthy is the difference on 4th August where the daily maximum temperature for Lisbon goes clearly below 32 °C while the overall mean stays above 32 °C.

5 Mortality data

Mortality data presented here was only possible to assess due to the unusual occurrence of this summer heat wave. In fact, due to the awareness of this heat wave problem, the Portuguese General Health Directorate and the Portuguese National Registrar Directorate were able to optimize the regular system flow of the death certificate registration and coding. This change consisted in the registrars' offices actively sending facsimiled death certificate copies to the Mortality Coding Unit of the General Health Directorate. This resulted in years advanced data (as an example at the time this paper is being written 2002 data is still not available for Health scientific purposes).

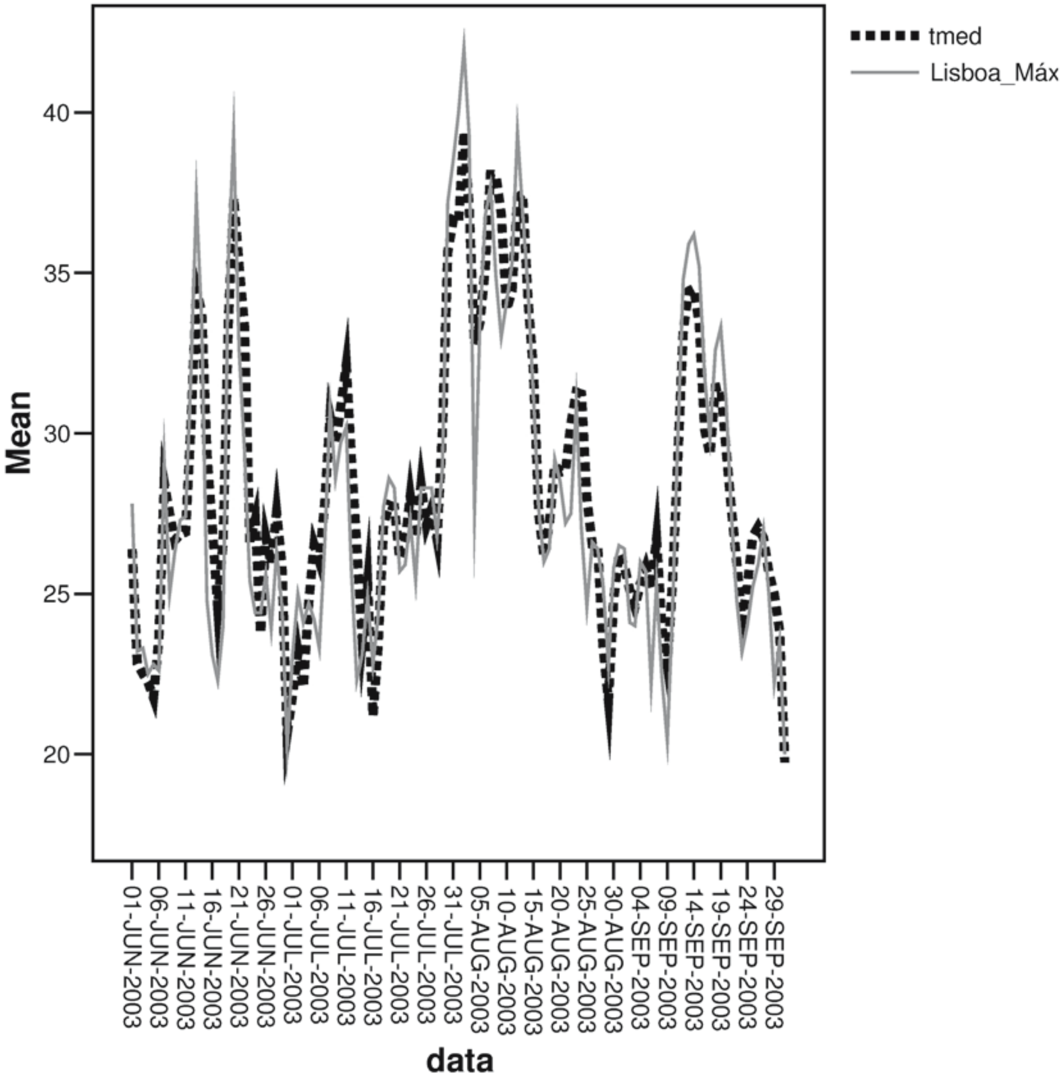
Tab. 2

Weekly mean maximum daily air temperatures for 18 districts of Portugal (districts Ordered from North to South)

Week	Viana do castelo	Porto	Braga	Vila Real	Bragança	Viseu	Aveiro	Coimbra	Guarda	Castelo Branco	Leiria	Lisboa	Santarém	Portalegre	Évora	Setúbal	Beja	Faro
18	18,6	17,5	18,6	18,4	18,4	17,5	19,2	19,7	16,1	20,7	21,4	20,3	22,6	20,0	21,7	19,4	21,7	21,0
19	21,6	18,6	22,1	21,3	21,1	20,3	18,4	21,0	15,8	23,8	20,9	21,8	23,8	22,7	24,8	23,7	24,4	22,1
20	21,7	19,7	22,3	22,5	23,4	21,9	19,5	22,8	20,2	26,5	23,1	23,7	25,4	25,9	27,9	25,9	28,1	26,5
21	25,7	23,6	26,1	24,0	24,1	23,6	22,8	26,7	20,7	27,1	27,6	28,0	**31,9**	26,8	29,7	29,4	**30,8**	27,6
22	25,1	23,0	26,4	26,1	27,2	24,9	23,7	27,0	23,3	28,1	27,2	26,7	28,0	27,0	29,4	29,0	**30,5**	25,4
23	22,7	20,4	23,5	24,4	26,4	23,1	20,9	23,8	21,8	28,7	24,3	25,1	27,5	27,7	**30,4**	27,3	**31,3**	26,8
24	27,5	25,5	28,5	29,4	**31,4**	28,3	24,7	29,4	28,2	**32,7**	28,2	28,6	**31,8**	**31,3**	**32,7**	**31,2**	**32,7**	29,5
25	**30,6**	28,4	**31,0**	**31,7**	**32,9**	30,0	27,8	**31,4**	29,1	**33,7**	**31,3**	**30,1**	**34,0**	**33,0**	**34,7**	**33,0**	**35,1**	28,7
26	21,9	20,5	22,6	22,9	26,0	21,1	20,6	23,1	25,7	27,7	24,1	24,0	26,3	26,1	29,0	26,3	29,4	26,5
27	25,1	21,9	24,0	24,1	25,6	23,4	22,7	24,8	22,6	28,6	24,9	25,5	27,9	27,4	**30,1**	28,3	**30,8**	27,0
28	25,4	21,9	26,1	**30,2**	**33,4**	28,0	22,2	24,3	29,1	**32,7**	24,9	26,4	28,5	**30,3**	**32,5**	29,7	**33,2**	28,5
29	23,1	21,7	22,6	24,1	25,3	22,5	22,9	24,9	22,1	28,2	26,1	26,2	28,1	27,2	29,8	28,4	**30,4**	29,1
30	24,0	22,6	24,6	25,9	28,6	25,0	23,2	26,0	25,1	**32,3**	27,2	27,6	**30,3**	**30,8**	**32,5**	30,0	**33,3**	**31,8**
31	**32,6**	**30,6**	**33,5**	**35,4**	**35,8**	**34,5**	28,7	**36,6**	**33,1**	**38,8**	**36,4**	**36,9**	**41,0**	**39,0**	**41,3**	**40,3**	**41,7**	**33,5**
32	**34,4**	**31,1**	**36,3**	**37,2**	**38,1**	**36,9**	27,7	**36,4**	**34,1**	**39,2**	**36,1**	**35,9**	**40,4**	**39,0**	**40,2**	**35,7**	**40,5**	**33,5**
33	28,3	25,3	28,9	**30,1**	**32,5**	29,0	24,9	28,5	29,0	**33,7**	28,9	**30,3**	**32,2**	**32,7**	**34,8**	**32,4**	**35,0**	**32,6**
34	28,1	24,4	29,4	29,9	**30,8**	29,5	23,5	28,8	28,0	**32,5**	28,8	27,5	**31,2**	**31,4**	**32,9**	29,5	**33,0**	27,8
35	23,9	22,9	23,5	22,3	22,4	21,2	24,1	25,0	19,2	25,6	26,8	25,3	28,3	24,8	28,6	26,3	29,2	25,8
36	23,8	22,4	25,3	23,5	23,7	24,1	22,7	23,7	20,4	25,3	25,5	23,7	27,3	26,1	27,6	26,9	29,1	26,8
37	**30,5**	29,9	**32,1**	**30,2**	29,5	28,3	28,8	**32,6**	26,4	**32,1**	**33,7**	**32,6**	**35,8**	**31,2**	**34,2**	**35,0**	**35,2**	29,5
38	26,3	25,7	28,3	27,9	28,3	29,3	26,6	28,9	23,3	28,3	**30,8**	28,9	**31,7**	**30,1**	**30,3**	**30,3**	**30,5**	27,0
39	23,1	22,7	25,2	25,3	25,6	25,4	23,0	24,7	23,7	25,2	26,7	24,7	29,1	27,4	29,3	28,0	28,8	25,7

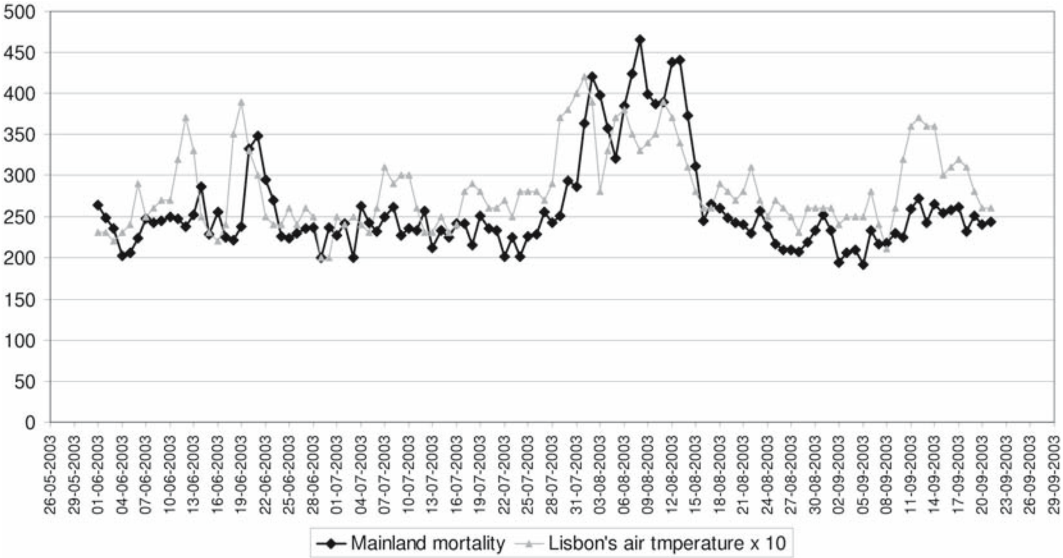
Source: Instituto de Meteorologia, Portugal

Fig. 2



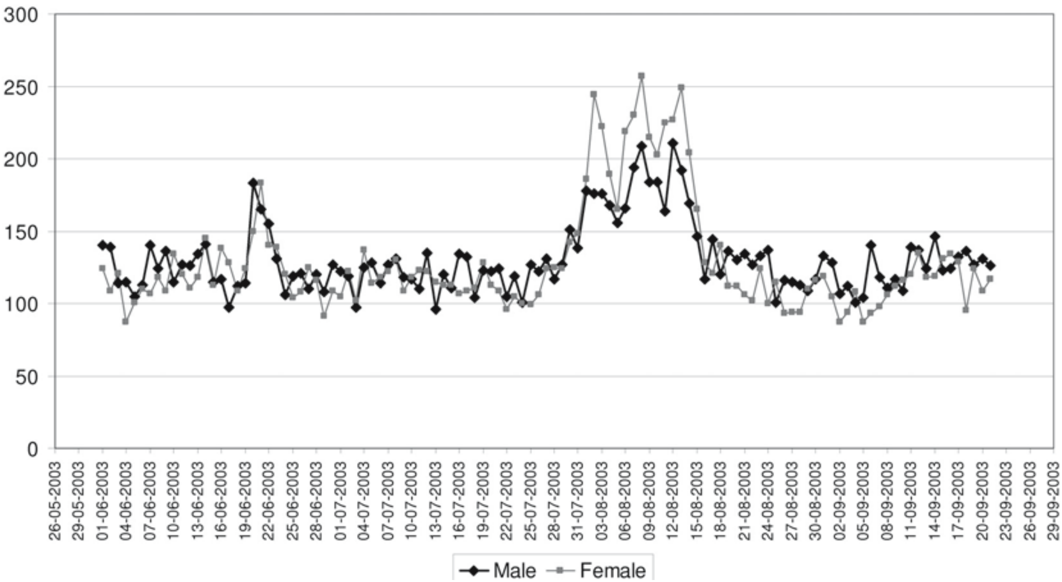
Lisbon Daily maximum temperature and Mean maximum daily temperature for the 18 districts of mainland Portugal (source: Instituto de Meteorologia, Portugal)

Fig. 3



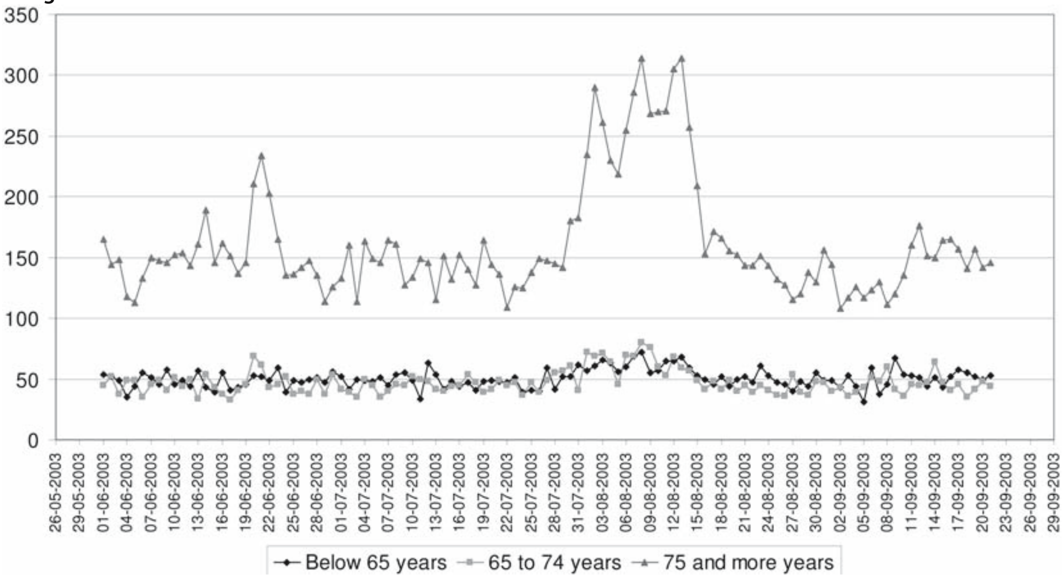
Daily Mortality and Maximum air temperature × 10 °C from 1st June to 21st September 2003 in Portugal mainland

Fig. 4



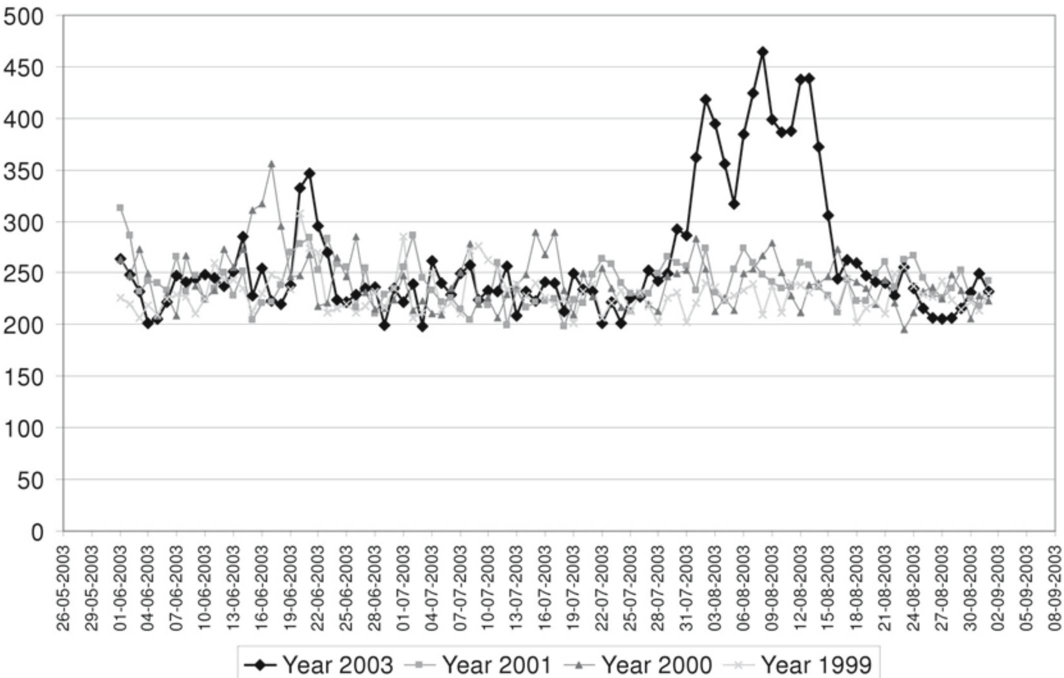
Daily Mortality by sex from 1st June to 21st September 2003 in Portugal mainland

Fig. 5



Daily Mortality by Age Group from 1st June to 21st September 2003 in Portugal mainland

Fig. 6



Daily Mortality from 1st June to 1st September in 1999 to 2001 and 2003 in Portugal mainland

Figures 3 to 6 show daily summer mortality series for some population strata. The main finding is how close mortality relates with the temperature, especially on the heat period of July – August, where the ups and downs on the mortality processes follow the ups and downs on observed temperatures.

Another important feature that has been described elsewhere (Braga AL, Zanobetti A, Schwartz J 2002, for example) concerning high temperatures' harvest effects on respiratory and cardiovascular mortality, and this had not been previously observed in Portuguese heat wave mortality data, is the apparent harvest effect at the end of August to the beginning of September.

Figure 4 compares mortality between males and females. Several features are noteworthy:

- Both mortality processes are in synchronization with the temperature evolution, same ups and downs, up to the beginning of the July – August heat wave period;
- Heat impact clearly visible around 19th June equally affects both sexes, previous to that and right afterwards mortality levels are also similar;
- On the longer and hotter extended July – August period, female mortality is higher than male mortality;
- In the subsequent time period to the July – August heat wave, female mortality shows a lower level than male, but the consequence of a harvest effect is still visible in both sexes.

Figure 5 shows evident differences between age groups. Mortality is particularly evident in the higher age group, 75 and more years old. The 65 to 74 year old age group also presents an important effect but still far from the one from that of the higher age group. The other age groups also seem to relate to the heat periods in some way but their global mortality is almost irrelevant to the total heat related mortality.

Figure 6 compares several recent years' summer mortality, delimiting clearly the 2003 heat wave mortality epidemic curve.

6 The ÍCARO Index

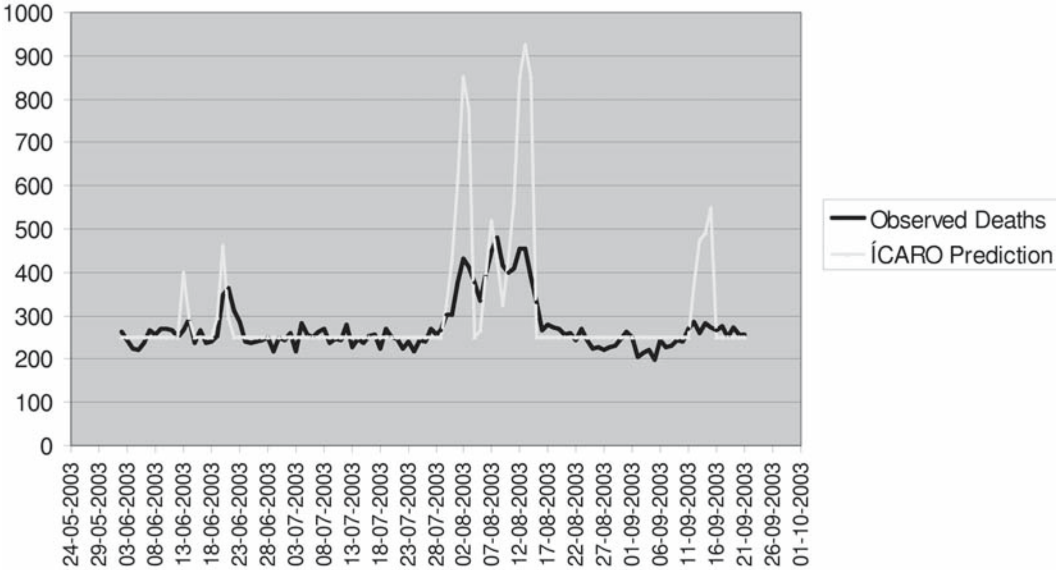
Obviously, interest always lies in knowing how well predicted heat related mortality compares with observed mortality data. Would it relate well in the summer of 2003, when so many aspects were new? New was the exceptionally full hot summer, with heat periods in May, June, July – August and September and with an early summer period; the heat wave length; as well as the late summer heat wave.

Figures 7 and 8 show the relation of the ÍCARO index and observed mortality for Portugal mainland and for the district of Lisbon respectively. Results are remarkably good.

It is not surprising that ÍCARO results seem better for Lisbon's district level, since model coefficients used were derived from past experience here. At national level, predictions were somewhat over- or under estimated, but thinking on a national heat health warning surveillance system, main excess mortality moments were particularly flagged in a practical way. On the unprecedented long July – August heat wave, ÍCARO's surveillance system correctly predicted the different upheavals (up and down mortality directions), which is also overwhelming since previous heat wave modelled data did not include such long heat waves with mortality changing in several directions. This might speak for the rationale used in the heat-mortality relation proposed on modelling.

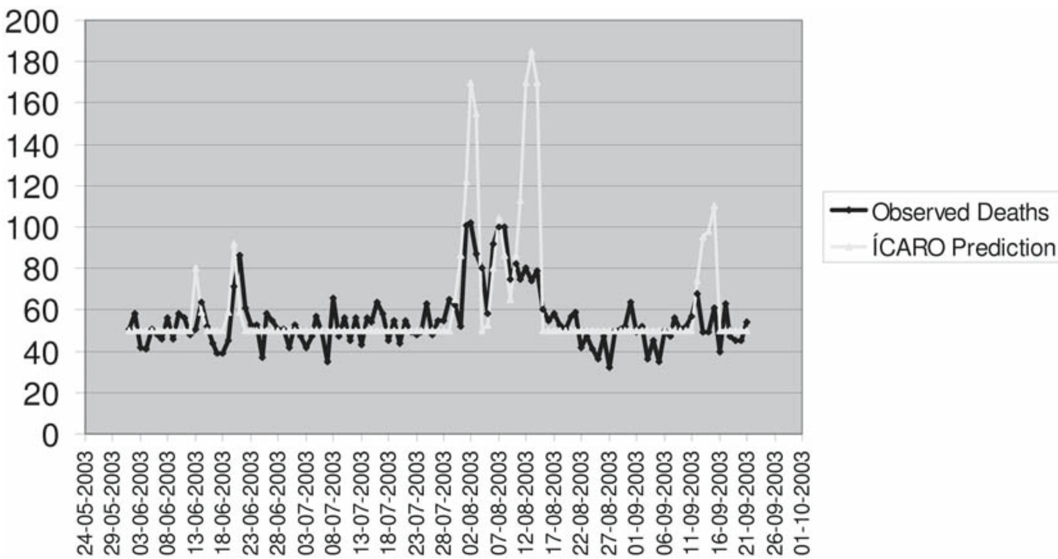
At the Lisbon District level, several aspects are also worth noting: The accuracy of 19th – 20th June and 4th August mortality predictions, particularly the latter, where mortality comes down to the non-daily statistically significant level as opposed to what happens to the national level. In fact, both two downward mortality levels in the middle of the big heat wave are particularly well predicted. Discrepancies to the

Fig. 7



Portugal Continental: Daily ÍCARO Surveillance System predicted mortality and observed daily mortality from 1st June to 21st September 2003 in Portugal mainland

Fig. 8



Districts of Lisbon 2003: Daily ÍCARO Surveillance System predicted mortality and observed daily mortality from 1st June to 21st September 2003 in Lisbon district

whole mainland level can be related to the fact that overall districts remained above their threshold risk levels, contrary to what happened in Lisbon.

At both levels, some of the predicted mortality peaks seem excessive. This is not particularly threatening as long as the risk is predicted und correctly flagged. Over the past years of experience the ÍCARO index has revealed itself as a tool that goes beyond the daily statistical level, as briefly stated before. It also flags alteration on randomness of the summer excess mortality process. This seems to hold true here, with some new features. The third mortality peak on the big heat wave behaves non-randomly at a higher mean level. This late peak, and the September one, seem to hold non-randomness and are consequences of features not previously modelled, such as its lateness in summer.

7 Early estimates of excess deaths

Very early, serious attempts were made to evaluate the impact of the long summer 2003 heat wave on Portuguese mortality. On 20th August, an estimate of 1317 heat related excess deaths up to the 12th August was presented, evaluated while the heat wave was still occurring based on the daily registered number of death data collected for a sample of Registrars' Offices (Falcão et al. 2003). Here some estimates of observed excess deaths due to this long heat wave are presented. Also presented are estimates of heat impact period.

Data and statistical Analysis

Mortality data used for 2003 are those discussed above obtained by the General Health Directorate, for all other years National Statistics Institute (INE) mortality data were used. Data on climatic conditions were kindly supplied by the Meteorology Institute.

Data analysis was done comparing several reference periods of mortality data with observed data in the summer of 2003. Exact Poisson probabilities and confidence intervals were derived (Esteve, Benhamou & Raymond 1994).

Which reference period?

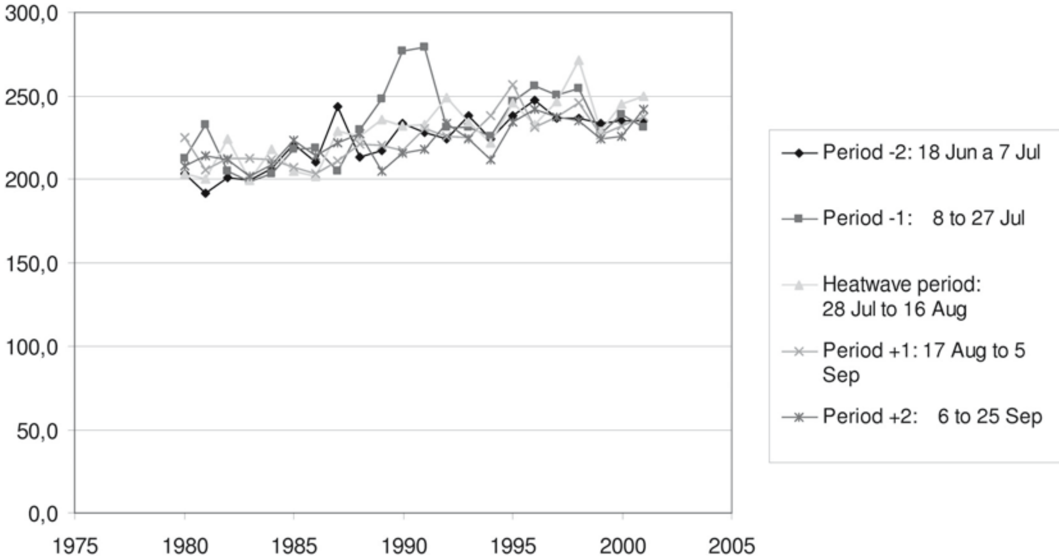
Evaluations of the 1981 and 1991 heat wave were made a posteriori where data of previous and following years were available. These allowed an estimation of the overall population state at the period of the event occurrence. During the event, or just a few months after, it is not possible to gather such knowledge. Therefore, some other approaches were required. *Figure 9* shows the reasons why the described difficulties occur, since there is a notorious increasing trend on mortality through the years.

On a first approach, the summer period of interest was divided into several periods of equal length allowing comparisons among years and between periods.

Period –2: 18 Jun to 7 Jul
Period –1: 8 to 27 Jul
Heat wave period: 28 Jul to 16 Aug
Period +1: 17 Aug to 5 Sep
Period +2: 6 to 25 Sep

The rationale behind these periods was not very theoretical though. The idea was simple: the highest temperature period begun on the 29th July up to the 14th August and the heat impact is known to last for one or two days after. Following this rationale, a rough period from 28th July to 16th August would include the heat stress period and most probably its full impact. The other periods were just equal in length.

Fig. 9



Evolution of daily mean mortality from 1980 to 2001 by different summer periods in Portugal mainland

Tab. 3

Estimates of excess mortality in 2003 by summer periods using homologues time periods in several time intervals

Year/Period		Period –2: 18 Jun a 7 Jul	Period –1: 8 to 27 Jul	Heat wave period: 28 Jul to 16 Aug	Period +1: 17 Aug to 5 Sep	Period +2: 6 to 25 Sep
2001	Daily mean	260,2	240,5	259,5	254,6	248,3
Expected in 19 days		4943	4569	4931	4838	4718
O/E ratio		1,00	1,01	1,46	0,94	1,02
	Excess deaths	-2,0	63,0	2259,0	-282,0	77,0
	IC 95 %	(-136,5 ; 137,8)	(-67,8 ; 198,4)	(2104,5 ; 2427,5)	(-411,8 ; -147,7)	(-55,8 ; 214,7)
p-value (two tailed)		0,987	0,352	0,000	0,000	0,262
1997 – 2001	Daily mean	253,5	252,9	260,0	246,3	244,6
Expected in 19 days		4816	4804,2	4939,8	4680,6	4647
O/E ratio		1,03	0,96	1,46	0,97	1,03
	Excess deaths	125,0	-172,2	2250,2	-124,6	148,0
	IC 95 %	(-9,5 ; 264,8)	(-303 ; -36,8)	(2095,7 ; 2418,7)	(-254,4 ; 9,7)	(15,2 ; 285,7)
p-value (two tailed)		0,070	0,013	0,000	0,069	0,028

Tab. 3 (Continued)

Year/Period		Period –2: 18 Jun a 7 Jul	Period –1: 8 to 27 Jul	Heat wave period: 28 Jul to 16 Aug	Period +1: 17 Aug to 5 Sep	Period +2: 6 to 25 Sep
1995 – 2001	daily mean	253,3	256,1	258,1	249,6	244,6
Expected in 19 days		4813,0	4865,3	4904,3	4743,0	4648,0
O/E ratio		1,03	0,95	1,47	0,96	1,03
	Excess deaths	128,0	-233,3	2285,7	-187,0	147,0
	IC95 %	(-6,5 ; 267,8)	(-364,1 ; -97,9)	(2131,2 ; 2454,2)	(-316,8 ; -52,7)	(14,2 ; 284,7)
p-value (two tailed)		0,063	0,001	0,000	0,006	0,029
1980 – 2001	daily mean	237,4	243,8	252,8	235,1	230,6
Expected in 19 days		4510,7	4631,6	4803,2	4466,0	4381,8
O/E ratio		1,10	1,00	1,50	1,02	1,09
	Excess deaths	430,3	0,4	2386,8	90,0	413,2
	IC95 %	(295,8 ; 570,1)	(-130,4 ; 135,8)	(2232,3 ; 2555,3)	(-39,8 ; 224,3)	(280,4 ; 550,9)
p-value (two tailed)		0,000	0,998	0,000	0,178	0,000

Source: Mortality database - Instituto Nacional de Estatística

Table 3 shows excess mortality within the several defined periods for different reference time periods in the past. The year 2001 could be thought of as a useful reference, since it provides the most recent data and relates better with current population structures. But it had its down side and did not reflect the June heat wave. In fact, recent years show mortality impacts in June (*Fig. 5*).

All other possible reference time periods have similar problems, beyond the fact that awareness exists that higher excess death estimates are obtained from wider reference periods (*Fig. 9*). But on the positive side, within heat wave period all excess deaths estimates are similar.

When did the mortality impact occur?

To assert the period of heat impact on daily mortality, data from 26th July to 21st August for 1999 to 2002 and 2003 was used, and Poisson probabilities were used to compare daily observed mortality in 2003 with period mean daily mortality for each other year and for 1999 to 2001 averages. *Table 4* illustrates that a clear pattern of 17 days, from 30 July to 15th August, arose.

Tab. 4
Estimation of the heat wave mortality impact period and estimates of excess mortality in 2003 using preceding years similar periods

	Year					Comparison with daily mean			
Date	2003	2001	2000	1999	Mean 1999 – 2001	p 2001	p 2000	p 1999	p mean 1999 – 2001
27-Jul	253	230	220	218	223	0,62	0,50	0,07	0,32
28-Jul	242	250	213	202	222	0,89	1,02	0,27	0,78
29-Jul	250	266	246	226	246	0,76	0,63	0,10	0,42
30-Jul	292	260	250	231	247	0,00	0,00	0,00	0,00
31-Jul	286	257	253	202	237	0,01	0,01	0,00	0,00
1-Aug	362	233	283	221	246	0,00	0,00	0,00	0,00
2-Aug	418	274	254	240	256	0,00	0,00	0,00	0,00
3-Aug	395	231	213	236	227	0,00	0,00	0,00	0,00
4-Aug	356	223	226	224	224	0,00	0,00	0,00	0,00
5-Aug	317	254	214	228	232	0,00	0,00	0,00	0,00
6-Aug	384	274	250	233	252	0,00	0,00	0,00	0,00
7-Aug	424	260	254	239	251	0,00	0,00	0,00	0,00
8-Aug	464	248	267	210	242	0,00	0,00	0,00	0,00
9-Aug	399	241	279	237	252	0,00	0,00	0,00	0,00
10-Aug	387	235	251	212	233	0,00	0,00	0,00	0,00
11-Aug	388	236	228	240	235	0,00	0,00	0,00	0,00
12-Aug	438	260	212	238	237	0,00	0,00	0,00	0,00
13-Aug	439	258	238	231	242	0,00	0,00	0,00	0,00
14-Aug	372	236	240	238	238	0,00	0,00	0,00	0,00
15-Aug	306	228	246	227	234	0,00	0,00	0,00	0,00
16-Aug	244	212	273	217	234	0,99	0,92	0,21	0,68
17-Aug	263	243	245	244	244	0,26	0,19	0,01	0,11
18-Aug	260	223	241	202	222	0,35	0,26	0,02	0,15
19-Aug	247	223	235	216	225	0,91	0,77	0,15	0,54
20-Aug	241	249	220	222	230	0,84	0,98	0,30	0,83
21-Aug	240	261	243	211	238	0,79	0,93	0,33	0,88
Total observed deaths	8667	6365	6294	5845	6169				
Mean	333,3	244,8	242,1	224,8	237,3				
Excess deaths in 2003		2302	2373	2822	2498				
Excess deaths in 30.7 to 15.8, 2003		2219	2269	2540	2342,7				
95 % Confidence Intervals for Excess Deaths		(2070 ; 2378,3)	(2120 ; 2428,3)	(2391; 2699,3)	(2193 ; 2501,3)				
p for overall excess		0,00	0,00	0,00	0,00				

Source: 1999 – 2001 Mortality data – Instituto Nacional de Estatística; 2003 mortality data – Direcção Geral da Saúde

How many people died?

Overall excess death numbers for the estimated 17 days of heat impact mortality (table 4) do not substantially differ from previous estimates (table 3). The estimate of 2219 excess deaths obtained for the 17 days of heat impact and for the reference year of 2001 is a reasonable figure for observed excess mortality.

The report Direcção Geral da Saúde – Direcção de Serviços de Informação e Análise & Instituto Nacional de Saúde Dr. Ricardo Jorge – Observatório Nacional de Saúde (2004), correcting for population's structure using mortality rates to calculate expected deaths, shows that the number of excess heat related deaths is 1953.

8 Intervention

The summer of 2003 accounted for an unusual amount of effective intervention and an unusual effort to convey heat wave information to the population. Very early response from intervening partners was very positive. Efforts were undertaken to assess conjoint information from both institutions able to intervene. As early as June there had been warnings on sun exposure at the beach and on how heat could affect younger and elderly people.

Later in the summer it seemed that information on the heat wave and forest fire warnings got mixed by the media. Overwhelming forest fires with very visible effects took over the media, overshadowing information on the heat wave effects on health and mortality.

The pragmatic implementation of the ÍCARO Surveillance System always relied on the institutional missions of each partner, rather than designing an exceptional plan of intervention. Otherwise the system would exceed the natural bounds of individual institutional missions. Nevertheless, this summer experience showed that in the future additional efforts must be made to inform the population of heat risks. The surveillance system must not only rely on passive informational schemes.

Conclusions and discussion

9 Conclusions

The Portuguese Heat Health Warning System – also referred as the ÍCARO Surveillance System – has been in place for five years. In the past it has issued several heat wave warnings. The 2003 summer warning was the most severe.

The 2003 summer was unusually hot, having several periods with excessive temperature. Excessive temperatures were observed in May, June, July – August (continuously for about two weeks) and September.

The ÍCARO Surveillance system (Lisbon Heat Health Warning System) gave a realistic picture about the true effects that occurred. The heat risk predicted through the ÍCARO-index showed a close relation with observed mortality. This fact supports the model rational defined by the ÍCARO methodology.

It has been shown that high heat-related mortality occurred in Portugal in the summer mainly in the July – August heat period. This article shows that this heat wave had a duration of 17 days, generating about 2200 excess deaths that, when accounting for structural population, results in an estimated number of 1953 effective heat related excess deaths. This mortality mainly affected elderly individuals, especially above 75 years old; also women; and in all Portuguese mainland districts.

The surveillance partners had difficulty on conveying messages to the population, using the media, late in the heat stress period. This was mainly due to highly visible and remarkable concomitant forest fires that occurred in most districts of the mainland country.

The ÍCARO Surveillance System experience led to the conclusion and advice that more active ways are required to convey information to the population at risk, so that substantial health and life gains can be achieved.

10 Discussion

The results presented in this article show that the summer of 2003 was an outstanding event, with generally hot temperatures and severe consequences on human health and mortality. Other studies showed that there was also an alteration on hospital and health emergency services (Paixão et al. 2003). These aspects point to the event's complexity, showing that a full report on such an occurrence might not be promptly possible.

This summer heat wave occurrences had dramatic consequences in Portugal, but past experiences and experiences elsewhere (in France for example) allowed for far worse expectations, since this major heat wave was about twice as long as previously known severe heat waves. In fact, in the 2003 summer there was no visible, known or reported health or cemetery service breakdowns.

Intervention in 2003 might not have been as extensive as wished, mainly due to other aspects that are surely also heat related. It was evidenced that reliance on passive systems to reach and inform individuals has its drawbacks; while consequences of forest fires may not have such severe health consequences as the heat wave itself, it has a visual and socially dramatic side that is appealing to the mass media, and also conveying the same information during a long heat period reduces informational interest. So system partners felt a need for and have already started a further investment on intervention planning for the near future.

The main objective of this paper was to present the ÍCARO Surveillance System as an example of a full operational heat health warning system, showing its past and current experience. Obviously, excess death estimation is one important task, since it helps the system's evaluation, but it is not the surveillance system's main concern. The excess deaths herein presented might not reflect the full population's age structure prior to the heat wave; in the winter of 2002/2003 there was not the usually recurrent influenza epidemic (Centro de Virologia – Centro Nacional da Gripe/Observatório Nacional de Saúde – Rede Médicos-Sentinela (2003) and Falcão (2003)) which might have spared some individuals at risk in the winter and may have increased their probability of dying in such a hot summer.

A full report on this 2003 July – August heat wave related mortality by the General Health Directorate and the National Health Observatory (ONSA) is available at URL [www.onsa.pt]. This report presents definitive as well as global mortality ratios and excess death estimates by gender and by age group, standardized by district level.

It is interesting to notice that for all the different time periods used for reference (table 3) the heat wave period is the one with higher expected daily mortality. In fact, if modelling daily air temperature data from 1980 to 2000 with polynomial regression, a summer maximum occurs for all the Portuguese mainland districts between the 4th and 11th August (Nogueira 2004). This suggests that heat might have an endemic nature that has not yet been referred to elsewhere. Nevertheless, comparisons with previous or later periods can lead to higher estimates and past heat wave excess death estimates can be underestimated if the August period is used as reference.

Several times in this article, the mortality process is described using the term "visible non-randomness" when there is an ÍCARO index at a non-statistically significant level. This is just an empirical comment that needs further proofing. This might be accomplished by analysing data comprising two or three days. Such proofing has not been attempted here, but awareness exits of such a necessity, and this will be done in the near future.

This article shows that the ÍCARO Surveillance System, in its current operational version, gives a correct prediction while heat waves are occurring. Such confirmation is in favour of the system existence since 1999. This summer occurrence showed the relevance of the ÍCARO Project research line, which might bring interest to other research areas and related institutions, further research efforts are needed and will allow more knowledge, further developments and more health and life gains in the future.

Acknowledgments

A special word for everyone at ONSA with special thanks to Dr. José Marinho Falcão, Dr. Baltazar Nunes and Dr. Eleonora Paixão. This article would not have been possible without the General Health Directorate's collaboration – a special thanks to Dr. Rui Calado and Dr. Jaime Botelho. And, as always in this adventure of the ÍCARO Surveillance System, a special word for the Portuguese Meteorology Institute is due – and individual thanks to Dr. Teresa Abrantes and Dr. Fátima Espírito Santo.

This work was funded by *Fundação para a Ciência e Tecnologia* (FCT-Portuguese Foundation for Science and Technology) and its *Programa Operacional "Ciência, Tecnologia e Inovação"* (POCTI), and co-funded by European Community Fund FEDER. (POCTI/ESP/39679/2001)

References

Braga AL, Zanobetti A, Schwartz J (2002) The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. Environ Health Perspect 110(9):859 – 63

Centro de Virologia – Centro Nacional da Gripe/Observatório Nacional de Saúde – Rede Médicos-Sentinela (2003) Gripe em Portugal – 2002/2003 Relatório Anual: Sistema Nacional de Vigilância da Gripe [Influenza in Portugal – 2002/2003 Annual Report: Influenza National Surveillance System] (http://www.onsa.pt/conteu/publicacoes/pub_relat_gripe-portugal-02_03_onsa.pdf, accessed 8 April 2004)

Direcção Geral da Saúde – Direcção de Serviços de Informação e Análise & Instituto Nacional de Saúde Dr. Ricardo Jorge – Observatório Nacional de Saúde (2004). Onda de calor de Agosto de 2003: os seus efeitos sobre a mortalidade da população portuguesa – Relatório. [August 2003's Heat wave: its effects on the Portuguese population's mortality – Report], Lisboa, Portugal, (http://www.onsa.pt/conteu/fontes/onda_2003_relatorio.pdf, accessed 7 September 2004)

Esteve J, Benhamu E, Raymond L (1994) Epidemiology (Statistical Methods in Cancer Ressearch, Vol. IV). IARC Scientific publications 128, pp 64

Falcão IM (2003) A pouca gripe do Inverno passado. Observações 19. [Last winter's little flu] (http://www.onsa.pt/conteu/publicacoes/pub_observacoes_019.html, accessed 8 April 2004)

Falcão JM, Castro MJ, Falcão ML (1988) Efeitos de uma onda de calor na mortalidade da população do distrito de Lisboa. Saúde em números 3:2:9 – 12

Falcão JM et al. (2003) Projecto ÍCARO. Onda de calor de Agosto de 2003: Repercussões sobre a saúde da população. Estimativas Provisorias (até 12.08.2003) [The ÍCARO Project. Effects of the heat wave in August 2003 on the health of the population. Preliminary estimates as of 12 August 2003]. Lisbon, Onsa. Observatório Nacional de Saúde, Instituto Nacional de Saúde Dr Ricardo Jorge (http://www.onsa.pt/conteu/fontes/proj_ÍCARO.html, accessed 8 April 2004)

Garcia AC, Nogueira PJ, Falcão JM (1999) Onda de calor de 1981 em Portugal: efeitos na mortalidade [Effects of the heat wave in June 1981 in Portugal on mortality]. Revista Nacional de Saúde Pública, volume temático 1:67 – 77

National Institute of Public Health Surveillance (2003) Impact sanitaire de la vague de chaleur en France survenue en août 2003. Bilan et perspectives – Octobre 2003. National Institut de Veille Sanitaire, Saint Maurice, France,

Nogueira PJ (2001) Acreditando no … ÍCARO [Believing … ÍCARO]. Observações, 12. (http://www.onsa.pt/conteu/publicacoes/pub_observacoes_012.html, accessed 8 April 2004)

Nogueira, PJ (2002) 4 x ÍCARO: um balanço [4 x ÍCARO: a balance]. Observações, 17 (http://www.onsa.pt/conteu/publicacoes/pub_observacoes_017.html, accessed 29 October 2003)

Nogueira P, Paixão E (2003) Evaluation of the Lisbon heat health warning system. cCASHh Workshop on Vulnerability to Thermal Stresses, 5 – 7 May, Freiburg, Germany

Nogueira PJ et al. (1999)Um sistema de vigilância e alerta de ondas de calor com efeitos na mortalidade: o índice Ícaro [A heat wave surveillance and warning system based on the effects on mortality: the ÍCARO index]. Revista Nacional de Saúde Pública, volume temático 1:79 – 84

Nogueira PJ (2004) Modelação do limiar superior da temperatura diária máxima durante o verão por distritos de Portugal continental – Documento Interno. [Summer maximum daily temperature upper threshold modelling by district for Portugal mainland – Internal Document]. ONSA-Lisboa.

Nunes B, Castro L (1998) Não morrer de calor! … Será uma questão de habituação? [Not dying from heat! … Is it a question of habituation?]. V Congresso Anual da Sociedade Portuguesa de Estatística 1997. in: Miranda SM, Pereira I (eds) Estatística: A diversidade na Unidade. Novas tecnologias, 7. Edições Salamandra, Lisboa, Portugal

Paixão E, Nogueira PJ (2002) Estudo da onda de calor de Julho de 1991 em Portugal: efeitos na mortalidade: relatório científico [A study of the July 1991 heat wave in Portugal: effects on mortality – scientific report]. Lisbon, Observatório Nacional de Saúde (http://www.onsa.pt/conteu/fontes/proj_ÍCARO_relat-cientifico-out02_onsa.zip, accessed 29 October 2003)

Paixão EJ, Nogueira PJ (2003) Efeitos de uma onda de calor na mortalidade. Revista Nacional de Saúde Pública 21;1:41 – 53

Paixão EJ, Nogueira PJ (2003b) Avaliação preliminar da onda de calor de Maio 2001 – Documento Interno. [Preliminary evaluation of May 2001's heat wave – internal Document] Lisboa, ONSA.

Paixão EJ, Nogueira PJ, Contreiras T, Falcão JM (2003) Onda de calor de Agosto de 2003: Estudo da Utilização de Cuidados de Urgência. Lisbon, Observatório Nacional de Saúde – Instituto Nacional de Saúde Dr. Ricardo Jorge. (http://www.onsa.pt/conteu/proj_icaro_ondacalor03_onsa.doc, accessed 15 April 2005)

WHO Regional Office for Europe (2004). Heat waves: risks and responses. WHO Regional Office for Europe (Health and Global Environmental Change Series, No. 2)