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Heat-related mortality

August 2003 Heat Wave in France: Risk Factors for Death of Elderly People Living at Home

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The August 2003 heat wave in France resulted in many thousands of excess deaths particularly of elderly people. Individual and environmental risk factors for death among the community-dwelling elderly were identified. We conducted a case–control survey and defined cases as people aged 65 years and older who lived at home and died from August 8 through August 13 from causes other than accident, suicide, or surgical complications. Controls were matched with cases for age, sex, and residential area. Interviewers used questionnaires to collect data. Satellite pictures provided profiles of the heat island characteristics around the homes. Lack of mobility was a major risk factor along with some pre-existing medical conditions. Housing characteristics associated with death were lack of thermal insulation and sleeping on the top floor, right under the roof. The temperature around the building was a major risk factor. Behaviour such as dressing lightly and use of cooling techniques and devices were protective factors. These findings suggest people with pre-existing medical conditions were likely to be vulnerable during heat waves and need information on how to adjust daily routines to heat waves. In the long term, building insulation and urban planning must be adapted to provide protection from possible heat waves.

Keywords: deaths, elderly, epidemiological survey, heat wave

In its minimum, maximum, and mean temperatures and its duration, the August 2003 heat wave was the worst in France since record-keeping began in 1873. Indeed, this heat wave struck France in early August after a warm month of June with temperatures 4–5°C above seasonal averages. It resulted in nearly 15 000 excess deaths during the period from August 1 through August 20.[1] Studies of earlier heat waves report that risk factors for death include population vulnerability[2] and environmental factors, such as living in urban areas.[3,4] The first descriptive studies of this heat wave by the French Institute of Public Health Surveillance (InVS) found that most of the heat-related deaths occurred among the community-dwelling elderly, that is, those living in their own home (alone or with others).[5] Identifying the risk factors for these deaths is an important public health priority to prevent a repetition of this toll in future heat waves.[6] A case–control study was conducted to determine individual risk factors for death in this population and thereby help define effective public health strategies for population groups at high risk.

Methods

Study design and case definition

The matched case–control study was conducted in October 2003 in four different areas: Paris, some of its suburbs (Val de Marne), and two cities south of Paris (Tours and Orleans, respectively, 235 and 130 km away). These areas were selected because of their location in the regions most severely affected by the heat wave and their architectural variety. Eligible case subjects were persons aged 65 and over who died from August 8 through August 13, lived in the selected communities, and had been at home at least 24 h before death or hospital admission. All deaths related to accident, suicide, or surgical complications were excluded. Assuming that 10% of the control subjects were exposed to any risk factor and defining the significance level at 0.05, we set the sample size at 300 cases and 300 controls to provide a statistical power of 80% to detect an odds ratio (OR) of 2.0. Eligible cases were randomly selected from the eligible death certificates, and their names and addresses obtained from their municipal vital records office. Subject's next-of-kin were contacted. Eligible controls, that is, those who had lived at home between August 8 and August 13 inclusive and matched cases for age (±5 years), sex, and residential area (we subdivided each of the areas into zones of 100 000 residents according to census records, each zone relatively homogeneous from a socioeconomic standpoint[7,8]) were randomly selected from telephone records, including unlisted numbers.

Data collection

Investigators, specially trained in interviewing persons in mourning, questioned, face-to-face where possible or otherwise by telephone, the cases' next-of-kin, or a friend or neighbor in the absence of a relative. Controls or their next-of-kin were interviewed in the same way. Information on living conditions came from direct observation. Factors related to housing conditions were grouped in three categories: related to the type of building, the particular dwelling unit, and the principal rooms, especially the bedroom. Information about medical conditions was obtained by calling the family physicians of cases and controls to know whether the patient suffered from mental disorders, cardiovascular, neurological diseases, or other chronic disease. Despite the significant effort spent on completing the questionnaires, it was not possible to collect reliable data for some items such as quantity of liquids per day, bath or shower frequency and opened windows because respondents had to have been much closer to the cases to answer such detailed questions.

Satellite pictures (acquired on 9 August 2003 at 10:17 a.m. and 10:18 a.m. UTC by Landsat 5) provided environmental data for assessing the heat-island profile of the area around the homes during the heat wave. The surface temperature in the study area

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was calculated using 120m-pixel[1] thermal infrared images. The vegetative cover, an important factor, which mitigates the heat island effect, was estimated by combining near-infrared and visible images and calculating the normalized difference vegetation index[9] by 30m-pixels.[2] After each address was geo-coded, the mean of the surface temperature within a 200 m radius area around each home was calculated using a GIS. The proportion of the 200 m radius area with an elevated normalized difference vegetation index (classes 4–10), corresponding to the proportion of the area with chorophyllous activity, was also computed. This proportion is later called, 'the vegetation index'.

Statistical analysis

Three separate analyses of deaths were performed: deaths from all causes (one control per case), heat-related deaths (one or two controls per case), and cardiovascular-related deaths (one or two controls per case), the latter because they were known to account for many of the excess deaths.[1] Heat-related deaths were defined as those whose death certificates mentioned 'dehydration', 'hyperthermia' or 'heat stroke' as the primary cause of death.

Matched data were analysed with a conditional logistical regression model to investigate the relation between each potential risk factor and mortality.[10,11] The relationships between the quantitative risk factors and mortality were initially studied non-parametrically to explore any possible nonlinear effects. Nonlinear transformation was found to be not required; these factors were introduced linearly into the multivariate model. To avoid co-linearity, the model included only one of any group of highly correlated variables representative of the same phenomenon. The multivariate analysis used conditional logistical regression and included only the potential risk factors shown to be important in the univariate analysis ($P < 0.20$) and to have relatively low rates of missing values. The final multivariate regression model contained the factors that were significant predictors of death ($P < 0.10$). Despite the matching for age, cases remained older than controls. The univariate and multivariate analyses were adjusted on age by introducing a linear term age into the model. Data analysis used SAS software.[12]

Results

Sample description

The study included 315 case and 282 control subjects. Informants were the decedents' child (48%), spouse (19%), other relative (23%), or other friend or neighbour (7%). The rate of participation was 89% among cases and 59% among controls. This rate of participation among controls was quite acceptable. About 36% among controls refused to participate (the main reasons given were lack of time, not interested or fear of receiving someone at home) and 5% of the controls could not be analysed because their interviews were incomprehensible due to confusion. The case sample analysed was similar to the population of deaths from which it was randomly drawn in terms of sex ($P = 0.40$), age ($P = 0.10$), and residential area ($P = 0.32$).

Controls were more often widowed, divorced or single than the overall French population, according to the 1999 census.

The average age was 85.1 years (SD: 8.1) in cases and 82.1 years (SD: 7.5) in controls. Most of the people lived in Paris (205 cases and 184 controls) and in Val de Marne (89 cases and 79 controls), few people lived in Tours (12 cases and 9 controls) or Orleans (9 cases and 10 controls). Cases were similar to controls in terms of sex ($P = 0.44$) with 72.7% of females in cases and 69.8% in controls.

Causes of death

Cause of death was reported for 254 (81%) of the 315 cases and most often involved either a cardiovascular cause (37%) or the heat (35%). Other causes included cancer (7.5%), respiratory (6.3%), and neurological (4.3%) diseases.

Univariate analysis of all causes of death

Health

Lack of mobility was strongly associated with death (table 1), most especially for those confined to bed (OR = 7.52). As expected, pre-existing medical conditions were also important risk factors for death (table 1). In decreasing order of odds ratios, these included mental disorders, neurological disease, cardiovascular disease, cancer, obesity, and high blood pressure.

Social factors

Lower social status was identified as a risk factor (table 2), with the risk of death three times higher among manual workers than managers. A complete absence of social activities, that is, no social, religious, cultural, or leisure activities, multiplied the risk of death by a factor of six. Surprisingly, the use of home attendants (including for paramedical care, help moving, house cleaning, or even meal delivery) was also associated with a higher risk of death.

Housing conditions

Table 3 reports the housing factors for which there were not too many missing values (as there were, for example, for building materials). For the first category (building-related), two principal risk factors were obtained: (i) construction date: buildings built before 1975 were associated with a higher risk of death than more recent ones; (ii) comfort level (the percentage of dwelling units with private toilets): buildings with higher comfort levels seemed safer. The principal risk factors related to the individual dwelling units were, in decreasing order, lack of thermal insulation (assessed by building date and questions about insulation) and living on the top floor. In addition, the number of rooms decreased the risk and the number of windows per 50 m^2 increased it. The gradient of risk according to the floor (upper floors excluded) was not statistically significant. Finally, two aspects of the bedroom's location were risk factors: its location directly under the roof and the duration of sunlight there.

Environmental factors

Of the environmental indicators that might reflect a heat-island effect around the subjects' homes, the temperature—calculated as the mean of the surface temperatures for a 200 m radius around the home—was a risk factor while the vegetation index[9]—also calculated for a 200 m radius around the home—was described as protective.

Behavioural factors

Finally, it is noteworthy that the behaviour of the case subjects during the heat wave directly influenced their likelihood of death (table 4). This includes behaviour such as visiting air-conditioned or cool places, dressing lightly, or using cooling techniques and devices (defined as any of: a mister, cool, or cold bath or shower, sponge bath, mechanical fan, or air conditioner). On the other hand, opening the windows during the afternoon (instead of opening them at any other time) was associated with an increased risk of death.

[1]A pixel correspond to a 120 meters square
[2]A pixel correspond to a 30 meters square

Table 1 Health conditions in univariate paired analysis of all causes of death[a]

	Number of pairs	Cases No.	Cases (%)	Controls No.	Controls (%)	Odds ratio	Confidence interval (95%)	
Mobility								
Hospitalization at home								
No	253	233	(90.0)	247	(95.4)	1		
Yes		20	(7.7)	6	(2.3)	3.45	1.35	8.78
Able to dress, wash and not confined to bed	259	51	(19.7)	138	(53.3)	1		
Not confined to bed but unable to dress and wash oneself		73	(28.2)	65	(25.1)	3.23	1.84	5.69
Confined to bed		135	(52.1)	56	(21.6)	7.52	4.25	13.31
Medical conditions								
Obesity								
No	258	176	(68.0)	201	(77.6)	1		
Yes		82	(31.7)	57	(22.0)	2.00	1.30	3.10
Cardiovascular disease								
No	255	102	(39.4)	163	(62.9)	1		
Yes		153	(59.1)	92	(35.5)	3.19	2.08	4.90
High blood pressure								
No	250	110	(42.5)	134	(51.7)	1		
Yes		140	(54.1)	116	(44.8)	1.46	1.02	2.08
Respiratory condition								
No	257	189	(73.0)	206	(79.5)	1		
Yes		68	(26.3)	51	(19.7)	1.48	0.96	2.26
Mental disorder								
No	259	207	(79.9)	248	(95.8)	1		
Yes		52	(20.1)	11	(4.2)	5.86	2.75	12.49
Neurological disease								
No	251	194	(74.9)	239	(92.3)	1		
Yes		57	(22.0)	12	(4.6)	4.67	2.42	8.99
Liver disease								
No	251	235	(90.7)	243	(93.8)	1		
Yes		16	(6.2)	8	(3.1)	2.01	0.80	5.04
Kidney disease								
No	251	231	(89.2)	237	(91.5)	1		
Yes		20	(7.7)	14	(5.4)	1.64	0.79	3.40
Cancer								
No	254	209	(80.7)	236	(91.1)	1		
Yes		45	(17.4)	18	(6.9)	2.79	1.53	5.08

a: For each variable, the denominator is based on the number of pairs with no missing data. All results are adjusted for age

Multivariate analysis

In the multivariate regression model, the following factors were adjusted: occupation, mobility, behavioural adjustment to the heat wave (going out, dressing, using advice for staying cool), medical conditions (cardiovascular, neurological diseases, mental disorders and high blood pressure), living conditions such as thermal insulation and having a bedroom under the roof and the thermal index (200 m radius). The multivariate analysis enabled us to identify several statistically significant risk factors (table 5). Lack of mobility (bed confinement) remained

Table 2 Social factors in univariate paired analysis of all causes of death[a]

	Number of pairs	Cases No.	Cases (%)	Controls No.	Controls (%)	Odds ratio	Confidence interval (95%)
Matrimonial status	259						
Widowed		118	(45.6)	137	(52.9)	1	
Married		77	(29.7)	64	(24.7)	1.86	1.11–3.13
Divorced		27	(10.4)	28	(10.8)	1.34	0.69–2.61
Single		37	(14.3)	30	(11.6)	1.59	0.91–2.77
Occupation	255						
Manager		48	(18.5)	72	(27.8)	1	
Artisan, farmer		40	(15.4)	38	(14.7)	1.73	0.93–3.20
Intermediate occupation		31	(12.0)	45	(17.4)	1.08	0.60–1.96
Clerical or service worker		63	(24.3)	55	(21.2)	1.65	0.97–2.81
Manual workers		73	(28.2)	45	(17.4)	2.75	1.56–4.85
Had home attendant							
No	259	55	(21.2)	120	(46.3)		
Yes		204	(78.8)	139	(53.7)	3.84	2.36–6.26
Social activity[b]							
Yes	257	161	(62.2)	232	(89.6)		
No		96	(37.1)	25	(9.7)	6.12	3.32–11.30
Lived alone							
No	259	107	(41.3)	81	(31.3)		
Yes		152	(58.7)	178	(68.7)	0.59	0.39–0.88
Had a pet							
No	256	212	(81.9)	220	(84.9)		
Yes		44	(17.0)	36	(13.9)	1.21	0.75–1.97

a: For each variable, the denominator is based on the number of pairs with no missing data. All results are adjusted for age
b: Question covered social, religious, cultural and leisure activities

a major risk factor, together with certain pre-existing medical conditions, including mental disorders, cardiovascular diseases, and neurological diseases. Of the social factors, only being a manual worker was still a significant risk factor. Housing characteristics that remained associated with death during the heat wave were thermal insulation of the unit or building and location of the bedroom under the roof. Temperature also remained a major risk factor. Finally, behaviour such as dressing lightly and using cooling devices and techniques remained protective against death.

Analysis of cardiovascular causes of death

Similar analyses were performed for 91 cases and 170 controls and adjusted for age because cases were older than controls (1.17 years). Results were similar to the analysis of all causes of death (table 5).

Analysis of heat-related causes of death

Finally, 87 cases to 164 controls were matched and adjusted for age because cases were older than controls (1.6 years). In the multivariate analysis (table 5), most of the significant factors found in the all-cause analysis were again found to be risk factors, including confinement to bed [OR = 7.12, 95% confidence interval (95% CI) 1.54–33.02] and cardiovascular diseases (OR = 4.73, 95% CI 1.23–18.24). This heat-related analysis also identified high blood pressure as a risk factor (OR = 4.05, 95% CI 1.50–10.90). Odds ratios in this analysis were estimated compared to the all-cause analysis for bedroom under the roof (OR = 5.43, 95% CI 1.33–22.21 compared with 4.06), dressing lightly (OR = 0.08, 95% CI 0.02–0.32 compared with 0.22), and using a cooling device or technique (OR = 0.19, 95% CI 0.04–0.85 compared with 0.32).

Discussion

This study showed that the elderly at greatest risk of death during this catastrophic heat wave were those confined to bed, with a cardiovascular or neurological disease or mental disorder, those living in old buildings without insulation or in the areas with the greatest heat island effects, and those with a bedroom located directly under the roof. Behaviour adapted to the heat was an important protective factor against death. The results of the three different analyses were consistent, with the strength of the relations of some factors greater in the analysis of heat-related causes of death. This result emphasizes the importance of these factors, which include a bedroom under the roof, dressing lightly, and using cooling devices and techniques.

Table 3 Housing conditions and environmental factors in univariate paired analysis of all causes of death[a]

	Number of pairs	Cases No.	Cases (%)	Controls No.	Controls (%)	Odds ratio	Confidence interval (95%)
Building	258						
Single family house		31	(12.0)	33	(12.7)	1	
Multiple dwelling unit		227	(87.6)	225	(86.9)	1.19	0.62–2.27
Construction date	259						
After 1975		37	(14.3)	62	(23.9)	1	
Before 1975		222	(85.7)	197	(76.1)	1.83	1.14–2.92
Proportion of housing with toilets	177					0.24	0.08–0.74
Dwelling unit							
Floor (story)[b]	142					1.12	1.00–1.25
Lives on the top floor							
No	207	160	(61.8)	184	(71.0)		
Yes		47	(18.1)	23	(8.9)	2.33	1.33–4.09
Thermal insulation[c]	250						
Very bad insulation		112	(43.2)	74	(28.6)	1	
Bad insulation		22	(8.5)	20	(7.7)	0.80	0.39–1.68
Average insulation		49	(18.9)	59	(22.8)	0.48	0.28–0.83
Good insulation		67	(25.9)	97	(37.5)	0.42	0.26–0.67
Number of rooms	254					0.85	0.72–0.99
Number of windows/50 m^2	203					1.19	1.03–1.37
Drafts feasible							
Yes	259	200	(77.2)	212	(81.9)	1	
No		59	(22.8)	47	(18.1)	1.25	0.80–1.93
Air conditioner in home							
No	257	253	(97.7)	249	(96.1)		
Yes		4	(1.5)	8	(3.1)	0.49	0.14–1.67
Room[d]							
Bedroom under the roof							
No	248	208	(80.3)	230	(88.8)		
Yes		40	(15.4)	18	(6.9)	2.16	1.26–3.69
Duration of sunlight in bedroom (hours)	243					1.07	1.01–1.13
Window coverings in bedroom							
Yes	203	164	(63.3)	168	(64.9)		
No		39	(15.1)	35	(13.5)	1.06	0.64–1.76
Environmental factors							
Vegetation index (200 m radius)[e]	257					0.37	0.13–1.06
Temperature index in °C (200 m radius)[f]	257					1.21	1.04–1.43

a: For each variable, the denominator is based on the number of pairs with no missing data. All results are adjusted for age. For quantitative variables, OR was calculated for an increase of one unit of the corresponding variable
b: Upper floors excluded
c: Insulation was built from three other variables: building date, work on improvement of the heat insulation for the building and for the housing
d: Results about the room were similar in the day- and night-time
e: The normalized difference vegetation index
f: The mean surface temperature in a 200 m radius (°C)

Table 4 Behavioural adjustment to heat wave in univariate paired analysis of all causes of death[a]

	Number of pairs	Cases No.	Cases (%)	Controls No.	Controls (%)	Odds ratio	Confidence interval (95%)
Going out	259						
Went out for other reasons		76	(29.3)	130	(50.2)	1	
Visited cooler places		19	(7.3)	55	(21.2)	0.54	0.29–1.01
Did not leave home		164	(63.3)	74	(28.6)	3.90	2.43–6.26
Bath or shower frequency	216						
More than one per day		17	(6.6)	85	(32.8)	1	
One per day		54	(20.8)	83	(32.0)	3.14	1.46–6.77
One per 2 days		24	(9.3)	13	(5.0)	12.09	4.20–34.76
One per week		28	(10.8)	11	(4.2)	15.61	5.02–48.53
Never		93	(35.9)	24	(9.3)	20.76	8.48–50.87
Quantity of liquids per day	215						
1 l and more		109	(42.1)	165	(63.7)	1	
0.5–1 l		82	(31.7)	48	(18.5)	2.64	1.63–4.27
<0.5 l		24	(9.3)	2	(0.8)	16.84	3.83–73.98
Dressing	239						
Dressed as usual		106	(40.9)	50	(19.3)	1	
Dressed lightly		133	(51.4)	189	(73.0)	0.35	0.23–0.53
Used cooling device or techniques[b] (no)							
No	248	68	(26.3)	46	(17.8)		
Yes		180	(69.5)	202	(78.0)	0.53	0.33–0.84
Opened windows	225						
At night		65	(25.1)	129	(49.8)	1	
Never		16	(6.2)	15	(5.8)	2.29	0.92–5.69
In the afternoon		144	(55.6)	81	(31.3)	3.27	2.08–5.15

a: For each variable, the denominator is based on the number of pairs with no missing data. All results are adjusted for age
b: For example, using a damp cloth, water spray, mister, cool or cold bath or shower, sponge bath, mechanical fan ...

The narrow case definition may have been too sensitive, but the study period covered only the peak of the heat wave, so that we can assume that we focused on subjects who died from heat. This definition probably prevented misclassification linked to information bias that might have occurred if cases had been recruited from the start of the heat wave. Moreover, a specific analysis was focused on a group of heat-related deaths. Finally, the cases included did not differ from the case pool in terms of age, sex, or residential area and were thus representatives of all the potential case-subjects. The design of the study may have introduced some bias. Thus, telephone recruitment of controls may have introduced a selection bias. Indeed, to respond to the phone, people had to be able to reach the phone and were consequently less confined to bed. To minimize this bias, we also conducted phone interviews during lunchtime to reach home attendants. This selection bias must have affected few other variables: the variable 'mental disorders'may have been affected by this bias since mentally sick elderly were not able to participate in phone interviews. However, we noted that dialogue was only incomprehensible for 5% of control. Conversely, the variables 'matrimonial status' and 'lived alone' may have been affected by a selection bias. This may be due to a residual confounding. The information brought by the variables 'living alone' and 'mobility' are not strictly independent. Indeed the people 'living alone' are most likely to be not confined to bed, able to dress and to wash themselves whereas people experiencing mobility difficulties are less susceptible to live alone. All considered, the effect of this bias was minimal as it concerned mainly this variable and did not affect other factors studied, in particular environmental factors, which are important to consider in terms of prevention. They were probably associated, however, with less information bias and fewer inaccuracies. Controls may have responded more precisely than the case informants about habits, although close relatives or friends responded precisely to detailed questions. As the nature of the study did not allow blinding of the interviewers, it might have introduced a bias that is the reason why we checked all medical information by calling the family physician of cases and controls. Recall bias was probably limited because interviews with controls were conducted immediately after those of cases. The supplemental adjustment for age should have reduced the confounding bias: age was an important risk factor even after matching.

When we take these points into account, our results are consistent with those described in previous studies. Some of the risk factors we identified have already been pointed out,

Table 5 Risk factors in multivariate paired analysis[a]

	All causes		Cardiovascular causes		Heat related causes	
	OR	95% CI	OR	95% CI	OR	95% CI
Occupation						
Manager	1		1		1	
Artisan, farmer	2.28	0.59–8.85	3.26	0.62–17.09	1.09	0.21–5.65
Intermediate occupation	1.03	0.32–3.32	0.77	0.17–3.46	0.07	0.01–0.80
Clerical and service workers	1.80	0.53–6.08	0.65	0.16–2.65	1.19	0.24–5.87
Manual workers	3.64	1.22–10.88	4.61	1.04–20.39	1.29	0.26–6.45
Social relations						
Lived alone					0.27	0.09–0.89
Behavioural adjustment to heat wave						
Going out						
Went out	1		1		1	
Visited cooler places	0.46	0.15–1.47	0.16	0.02–1.04	0.37	0.06–2.14
Did not leave home	2.00	0.79–5.04	2.49	0.74–8.37	1.99	0.63–6.33
Dressing						
Dressed as usual	1		1		1	
Dressed lightly	0.22	0.09–0.55	0.22	0.08–0.63	0.08	0.02–0.32
Used cooling device or techniques	0.32	0.12–0.82			0.19	0.04–0.85
Mobility						
Not confined to bed, able to dress and to wash oneself	1		1		1	
Not confined to bed but unable to dress and to wash oneself	4.03	1.42–11.43	3.80	0.85–17.14	7.12	1.54–33.02
Confined to bed	9.59	2.89–31.79	8.89	1.830–43.10	2.99	0.80–11.17
History of disease						
Cardiovascular disease	3.72	1.63–8.46	3.38	1.16–9.83	4.73	1.23–18.24
High blood pressure	1.86	0.86–4.06			4.05	1.50–10.90
Mental disorder	5.02	1.44–17.50	5.35	1.36–21.01		
Neurological disease	3.52	1.04–11.98				
Living conditions						
Thermal insulation						
Very bad insulation	1		1			
Bad insulation	1.27	0.24–6.70	0.43	0.08–2.23		
Average insulation	0.34	0.11–1.08	0.21	0.05–0.81		
Good insulation	0.21	0.07–0.64	0.41	0.12–1.37		
Bedroom under the roof	4.06	1.26–13.10			5.43	1.33–22.21
Environmental factors						
Temperature index (200 m radius) [b]	1.82	1.27–2.60	1.38	0.95–2.00	1.21	0.78–1.86

a: For each variable, the denominator is based on the number of pairs with no missing data (All causes: 217 pairs, Cardiovascular causes: 87 pairs or triplets, Heat related cause: 77 pairs or triplets). All results are adjusted for age.
CI denotes confidence interval
b: OR was calculated for an increase of 1°C

including lack of mobility and social isolation,[13,14] history of disease,[15–17] and lower social status.[18,19] We also identified high blood pressure as a risk factor, although it may indirectly reflect diuretic intake. This study focused on environmental factors and showed that housing conditions, such as a bedroom under the roof or the absence of any or good insulation, are risk factors for death, although it is generally difficult to estimate their weight. Other factors, such as the floor (height), the duration of sunlight in the home, the number of windows, and the ability to create drafts were significantly associated with death only in the univariate analysis, perhaps because of a lack of statistical power. Some of these factors have previously been associated with increased death rates.[14,20,21] Air conditioning is frequently described as a protective factor in North American studies,[22] but was not found to be significantly associated with death in our study, probably because its use in France remains relatively rare. Earlier studies also describe the role of environmental factors, such as heat-island effects.[23–27] Our study emphasizes the importance of the outdoor temperature near the dwelling unit and shows that levels of risk can vary for inhabitants in the same district. This is an important finding using an original use of satellite data. The vegetation index was also found to be a protective factor, as previously reported.[25] Several earlier studies document variations in the risk of death within a city, even when there is no clear relation with environmental factors.[26–28] Finally, our study showed that the subjects who were able to adapt their behaviour to the heat were protected by their actions. These behavioural factors provided the most significant protection in our analysis, and their importance for prevention is primordial.

Several types of recommendations for prevention plans can be deduced from these results. In the short term, special attention during heat waves should be paid to the elderly, those confined to bed or suffering from cardiovascular, neurological, or mental disorders, all of whom are especially vulnerable during heat waves. Secondarily, the population as a whole and especially these vulnerable groups require information on adjusting their daily routines to a heat wave. Avoiding alcoholic beverages,[21] increasing the frequency of showers and baths, dressing lightly, using cooling devices or techniques, opening windows when the outdoors temperature is cooler than indoors, and visiting cooler or airconditioned places are simple preventive measures that are widely available and could reduce excess mortality during hot weather. In the long run, improving insulation in existing buildings and urban planning are needed. Specifically, increasing urban vegetative cover and use of paving and roofing materials that are more reflective and less absorbent could reduce heat-related deaths.[29] These steps are costly and time-consuming but their implementation is necessary, given the likelihood that the frequency of heat waves will only increase in France and elsewhere.[30]

Key points

- A case–control study was conducted to determine individual risk factors for death of elderly people living at home during the heat wave in France.
- Major risk factors were chronic diseases and lack of mobility, lack of thermal insulation, sleeping on the top floor and the temperature around the building, whereas using cooling techniques were protective factors.
- Prevention message should be proposed before heat period to elderly suffering from chronic disease and lacking mobility.
- Prevention message should suggest behaviour changes: wearing light clothes, drinking more, increasing showers, opening windows at night, and avoiding housing in attic flat.
- Environmental measures should advocate for improvement of thermal insulation in old buildings and design green spaces around buildings.

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