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Death toll exceeded 70,000 in Europe during the summer of 2003

Jean-Marie Robine [a,*], Siu Lan K. Cheung [a], Sophie Le Roy [a], Herman Van Oyen [b], Clare Griffiths [c], Jean-Pierre Michel [d], François Richard Herrmann [d]

[a] *INSERM, Démographie et santé, CRLC, centre Val-d'Aurelle, parc Euromédecine, 34298 Montpellier cedex 5, France*
[b] *Unit of Epidemiology, Scientific Institute of Public Health, J. Wytsmanstraat 14, 1050 Bruxelles, Belgium*
[c] *Office of National Statistics, Mortality Statistics, 1 Drummond Gate, London SW1V 2QQ, London, UK*
[d] *Department of Rehabilitation and Geriatrics, Geneva Medical School and University Hospitals, 3, ch. Pont-Bochet, 1226 Thonex-Genève, Switzerland*

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Abstract

Daily numbers of deaths at a regional level were collected in 16 European countries. Summer mortality was analyzed for the reference period 1998–2002 and for 2003. More than 70,000 additional deaths occurred in Europe during the summer 2003. Major distortions occurred in the age distribution of the deaths, but no harvesting effect was observed in the months following August 2003. Global warming constitutes a new health threat in an aged Europe that may be difficult to detect at the country level, depending on its size. Centralizing the count of daily deaths on an operational geographical scale constitutes a priority for Public Health in Europe. ***To cite this article: J.-M. Robine et al., C. R. Biologies 331 (2008).***

Résumé

Plus de 70 000 décès en Europe au cours de l'été 2003. Nous avons collecté le nombre quotidien de décès par région dans 16 pays européens et analysé la mortalité estivale pour la période de référence (1998–2002) et pour 2003. Il s'est produit plus de 70 000 décès supplémentaires au cours de l'été 2003. On observe des distorsions importantes dans la distribution par âge des décès, mais pas d'effet de rattrapage dans les mois suivants. Le réchauffement climatique constitue une nouvelle menace pour la santé des personnes âgées, qui peut être difficile à détecter au niveau d'un pays, en fonction de la taille de ce dernier. Le décompte centralisé des décès journaliers à une échelle géographique opérationnelle constitue une priorité de santé publique en Europe. ***Pour citer cet article : J.-M. Robine et al., C. R. Biologies 331 (2008).***

Keywords: Human; Elderly; Daily mortality; Europe; Heat wave; Global warming

Mots-clés : Humain ; Personnes âgées ; Mortalité quotidienne ; Europe ; Vague de chaleur ; Réchauffement climatique

1. Background

Everyone remembers the 15,000 additional deaths caused by the heat wave of August 2003 in France [1].

* Corresponding author.
E-mail address: robine@valdorel.fnclcc.fr (J.-M. Robine).

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However, four years later, no one knows precisely the cumulative number of European victims, although more than 70 scientific reports related to this event have already been published [2]. A first assessment, made in March 2004 by the United Nations Environment Programme (UNEP), estimated the death toll on a European scale to exceed 30,000 [3]. A similar estimation was published two years later, although the available studies pertain to different periods of the summer [4]. A range between 27,000 and 40,000 excess deaths has been proposed, depending on data sources, methodology and reference period [5]. A total higher than 38,000 excess deaths during August 2003 has been declared in seven European countries [6]. These divergent figures indicate that a global assessment of excess mortality is difficult, if not impossible, because no standardized estimates across European countries have been made for the 2003 heat wave [7]. Press releases issued by statistical institutes referred to major excess mortality, potentially reaching 13,000 deaths in Spain and 20,000 deaths in Italy. This situation, in combination with current concerns about global warming [8], led the European Union to instigate a global study on the excess mortality in Europe during the summer of 2003.

2. Methods

Mortality in the summer 2003 is compared to the period 1998–2002. This five-year reference period is a compromise between the necessity of gathering enough years to get an average reference and the need of not being influenced by too far values, which may be due to higher past mortality level. Daily numbers of deaths were collected at regional level (NUTS 2 – http://en.wikipedia.org/wiki/Nomenclature_of_Territorial_Units_for_Statistics), from 1 January 1998 onwards, by gender and age, in France and nine neighbouring countries (Belgium, England, Germany, Italy, Luxemburg, the Netherlands, Portugal, Spain, and Switzerland) for which prior information on their involvement in the heat wave of August 2003 was available [9–16], as well as in six surrounding countries (Austria, Croatia, the Czech Republic, Denmark, Poland, and Slovenia), for which no information was available. The aim of this selection was to delimit better the area affected by the August heat wave. Indeed, it turns out that two countries, Croatia and Slovenia, were partially affected. The four remaining unaffected countries were kept as potential controls for the study. Altogether 19,098,574 daily mortality counts were collected for 177 NUTS belonging to these 16 European countries. Daily death frequencies were calculated by dividing, for each year, the daily number of deaths by the annual total to compare countries and regions. Assuming no seasonal variations or daily fluctuations, 0.27% ($1/365 \times 100$) of all annual deaths should be observed on any given day. Computations were performed by gender, single age, and NUTS, and then aggregated for analysis at the requested level.

Seasonality of deaths and the characteristics of the summer mortality in Europe during the reference period of 1998–2002 were analysed to set thresholds for extreme values. Robust polynomial regression models (1 to 4 degrees), weighted by the numbers of deaths in each country, were applied to the mortality profiles (summer and non-summer) to determine the proportion of variance in the daily death frequency explained by the days of the year. The multivariate models were adjusted for year and country by introducing dummy variables. Such models (in the form: $m(d,i,j) = a_0 + a_1d^1 + a_2d^2 + a_3d^3 + a_4d^4 + a_5y(i) + a_6c(j)$, where m is the daily mortality, a_n are constants, d is the day of the year at the power 1 to 4, $y(i)$ each year and $c(j)$ each country) assess the relative contribution of a specific day within two broad seasons, summer or not summer, controlling for years and countries. The variables 'year' and 'country' allow the secular trend in mortality decline as well as the geographical variation to be taken into account. The four selected polynomial degrees let the principal shapes of the potential relationship between mortality and days to be appraised within the two broad seasons. A horizontal linear fit ($a_1 = 0$, $a_2 = 0$, $a_3 = 0$, $a_4 = 0$) would mean that mortality is independent of days. A quadratic fit ($a_2 \neq 0$, $a_3 = 0$, $a_4 = 0$) would indicate a single mortality peak or hollow, whereas higher-degree polynomials would fit a more complex shape.

The first and third quartiles (Q_1 and Q_3), in combination with the inter-quartile range (IQR), allow identification of minor outliers ($Q_1 - 1.5 \times \text{IQR}$; $Q_3 + 1.5 \times \text{IQR}$) and exceptionally extreme values ($Q_1 - 3 \times \text{IQR}$; $Q_3 + 3 \times \text{IQR}$) [17].

Variations in daily mortality in combined data of all the 16 countries were examined by calculating the delta between the number of daily deaths recorded during the summer of 2003 and the average number of deaths recorded on the same day during the reference period. A positive delta means that the number of deaths in 2003 is higher than the 1998–2002 average, while a negative delta indicates a lower number. Daily death frequencies were divided by the value of the median frequency experienced during the summers of 1998–2002 to estimate the magnitude of the excess mortality. This conversion rescales all the frequencies around the unit. It is therefore immediately possible to interpret the daily mortality on any given day as a multiple of the median value.

Next, daily excess mortality in 2003 was calculated for each country. Results were grouped per month and mortality profile. Special attention was devoted to the mortality peak of August 2003. Maps at NUTS 2 level allow the geographical boundaries of this mortality crisis to be specified better. In order to identify shifts in the age of death, we estimated the ratio of 65+ as the proportion of deaths above the age of 65 years on a given day divided by the average share of the 65+ observed over the summer of 2003. A series of such ratios (by age: 65+, 75+, 85+ and 95+ and by gender) were plotted on the calendar time scale to examine the co-occurrence in the distortions in the proportion of deaths involving older people and women. More detailed information on the methods used is available on request [18].

3. Results

The distribution of daily deaths between 1998 and 2002 reveals an identical seasonality in the 16 European countries, with (*i*) a low summer mortality from June to September, where the daily mortality appears to be constant, and (*ii*) non-summer conditions from October to May, with a rise in mortality from October to December, a winter peak in January and February, followed by a drop in mortality from March to May. The regression models with a degree higher than 1 do not improve the prediction quality for the summer period. In all models, the summer days explain only between 2% and 3% of the variance, whereas the year and the country explain each between 5% and 6%. As this is negligible, the summer mortality was analysed as a single block. By contrast, outside of the summer period, the day explains around 40% of the variance of the daily death frequency in all models with a degree higher than 1.

The 9760 daily summer death frequencies (122 summer days ×16 countries ×5 years) experienced in Europe between 1998 and 2002 are distributed symmetrically around a median frequency of 0.2506 (average 0.2525). The distribution seems very concentrated compared to a normal distribution; 50% of observations are between 0.2377 (25th percentile) and 0.2655 (75th percentile). The boundaries defining the extreme values are 0.1961 and 0.3072 for the minor outliers, and 0.1544 and 0.3489 for the exceptional values. 554 days (5.68%) are outliers of which 174 days (1.78%) are exceptional outliers.

Using the delta between the numbers of daily deaths recorded during the summer of 2003 and the average number recorded on the same day during years 1998–2002, Fig. 1 represents the variations in daily mortality during the summer of 2003 for the 16 European countries together. Out of the 122 days, 27 days presented a delta lower than zero, inducing a total deficit of 5045 deaths compared to 95 days, with a delta higher than zero, creating a total excess mortality of 74,483 deaths. Both gaps do not balance each other. Excess mortality was a characteristic of the summer of 2003 affecting a major part of Europe. In particular, three main peaks exceeding 1000 additional daily deaths were observed on 13 June, between 16 and 21 July and on 12 and 13 August, days in which the mortality peak was exceptional. Excess mortality was also observed at the end of June and persisted during the month of September.

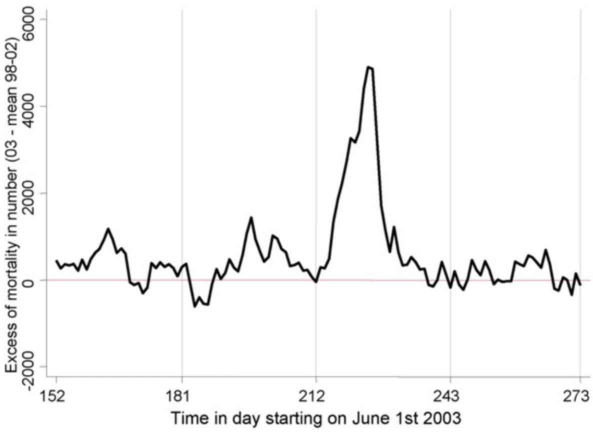

Fig. 1. Delta between the number of daily deaths recorded in the summer of 2003 and the average number of deaths recorded on the same day during the 1998–2002 reference period for the 16 European countries studied. DOY 152, the 152nd day of the year corresponds to 1 June, DOY 181 to 30 June, DOY 212 to 31 July, DOY 243 to 31 August and DOY 273 to 30 September.

In 2003, out of a total of 1952 summer days in the 16 countries, 145 days (7.5%) are outliers beyond the boundary of $[Q3 + 1.5 \times \text{IQR}]$, marking high extreme values. Fifty days (2.6%) are extreme outliers. This is more than three times the figures observed during the 1998–2002 period. The countries most affected by these exceptionally high death frequencies are Luxemburg (20 days), Portugal (eleven days), France (nine days) and Italy (four days). The first peak in mid-June is found mainly in Italy and Croatia and, to a lesser degree, in Spain. The peak seems to be delayed a few days in Portugal where it occurred on 20 June. All these days created a considerable number of excess deaths at the start of the summer, limited to southern countries. This period of excess mortality remained almost unnoticed. The second peak is centred on 16–21 July and involves the Netherlands, England and Wales, Belgium, Luxemburg, France, Germany, Switzerland and, to a lesser degree, Spain. Although excess mortality occurred simultaneously in all of these countries, it remained unnoticed, with the exception of the Netherlands [19]. The third peak, centred on 12 and 13 August is first observed in France, Italy, Portugal, and Luxemburg. It is clearly visible in Germany, England and Wales, Belgium and Switzerland. It also appears, although less sharply, in the Netherlands and in Spain.

The cumulative daily death frequencies over the summer of 2003 show a contrast between (*i*) countries such as France and Germany, which deviate abruptly from the anticipated trend during the first two weeks of August, by cumulating excess mortality, which will not be compensated later on in the summer, (*ii*) countries like Spain and Italy that move far more gradually away from the trend in several waves covering the beginning of the summer until the August peak, (*iii*) countries like Portugal, which tend towards a deficit of mortality prior to the August peak and which recover excess mortality before the end of the summer, and lastly (*iv*) countries like England and Wales, which ultimately drift away only slightly from the anticipated trend, just like the control countries not affected by the heat wave.

Table 1 presents the excess mortality, both as the absolute and the percentage difference between the observed daily number of deaths and the average number of deaths on the same day during the reference period. The absolute numbers and percentages of the excess mortality are given by country for the period before, during and after the summer of 2003 and by month for the summer period. Overall, more than 80,000 additional deaths were recorded in 2003 in the 12 countries affected by excess mortality, i.e. an excess of 2.5% compared to 1998–2002. Although about 70,000 out of these additional deaths occurred during the summer, over 3000 additional deaths occurred before and there were more than 8000 deaths in excess afterwards. The countries most affected by this excess summer mortality were Luxemburg, Spain, France, and Italy, where mortality increased by 14.3%, 13.7%, 11.8% and 11.6%, respectively. The female deaths represent 65% of the total number of the excess deaths during this period.

In August 2003 alone, nearly 45,000 additional deaths were recorded in the 12 countries, including 15,251 in France (+37%), 9713 in Italy (+21.8%), 7295 in Germany (+11%), 6461 in Spain (+22.9%) and 1987 in England and Wales (+4.9%). In less-populated countries, the numbers are lower, but excess mortality can be relatively very significant, as in Luxemburg, where 73 additional deaths increased mortality by 25%. Belgium, the Netherlands, and Switzerland each numbered about five hundred additional deaths, respectively +5.3%, +5.2%, and +9.8%. Excess mortality reached 9.9% in Slovenia, with 144 additional deaths, and 6.8% in Croatia with 269 additional deaths, while mortality dropped by more than 1% during August 2003 in the control countries.

August aside, 11,000 additional deaths were recorded in June (including 5274 in Italy and 4268 in Spain), over 10,000 in July (including 4318 in Italy and 2751 in Spain), and nearly 5000 in September. Therefore, France and Italy totalized the same excess mortality from 1 June to 30 September 2003, of 19,490 and 20,089 excess deaths, respectively, with very different cumulative profiles during the summer.

4. The mortality crisis of August 2003

The mortality crisis of August extended over the two weeks between 3 and 16 August. In the 12 countries, 15,000 additional deaths were recorded during the first week and nearly 24,000 during the second. The excess mortality ratio reached the exceptional value of 96.5% during the second week in France and very high values in Portugal (+48.9%), Italy (+45.4%), Spain (+41.2%), and Luxemburg (+40.8%). Excess mortality reached 28.9%, 26.7%, and 21.6% in Germany, Switzerland, and Belgium, respectively. It exceeded 10% in all countries, except Denmark, Poland, and the Czech Republic. Even in Austria, mortality increased by 12.6% during this week. Beyond a return to normal, no overall harvesting effect was observed in the weeks and months following the mortality crisis of August. Mortality remained high just about everywhere until the end of the summer. Only in Germany, Italy and Switzerland, slight drops in deaths after the summer were recorded (see Table 1).

The regions most affected by the mortality crisis of August lie in a southwest–northeast axis (see Fig. 2), from the Algarve in southern Portugal to Westphalia in Germany. A secondary axis starts in southern England and continues towards Latium in central Italy and Croatia. The most significant mortality focal spots are in Île-de-France and the neighbouring region of Centre, where mortality recorded between 3 and 16 August is twice what was expected. Six regions – two in southern Portugal (Algarve and Alentejo) and four in France (Pays de la Loire, Poitou-Charentes, Burgundy, and Franche-Comté) recorded a very high excess mortality during these two weeks (between 65% and 125%). Switzerland as well as some coastal regions (among others, Brittany in France and Galicia, Murcia and Valencia in Spain) seems to have been relatively spared. The southeastern limits of the mortality crisis are poorly defined due to

Table 1

Delta between the number of deaths recorded in 2003 and the average number of deaths recorded during the 1998–2002 reference period and excess mortality ratio (expressed as a percentage) for various periods in 2003 (before the summer, during the summer and after the summer) and for various countries

	Before summer		**Summer**										**After summer**		**Total of the year**	
	Nb	**Ratio**	**June**		**July**		**August**		**September**		**Total**		**Nb**	**Ratio**	**Nb**	**Ratio**
			Nb	**Ratio**	**Nb**	**Ratio**	**Nb**	**Ratio**	**Nb**	**Ratio**	**Nb**	**Ratio**				
Countries affected by the August 2003 heat wave																
Belgium	−4	−0.01	139	1.72	162	1.97	438	5.31	436	5.57	1175	3.62	1356	5.11	2528	2.41
Switzerland	92	0.34	253	5.30	187	3.89	469	9.81	130	2.75	1039	5.45	−148	−0.93	984	1.58
Germany	9290	2.55	642	0.98	1159	1.73	7295	10.97	259	0.40	9355	3.56	−5760	−2.69	12885	1.53
Spain	−1464	−0.90	4268	15.49	2751	9.64	6461	22.86	1611	6.21	15090	13.68	7249	7.95	20875	5.74
France	−3977	−1.70	1482	3.60	1706	4.06	15251	36.93	1051	2.62	19490	11.84	3415	2.53	18928	3.55
Croatia	882	3.95	193	4.85	157	3.98	269	6.83	169	4.49	788	5.04	5	0.04	1675	3.29
Italy	5575	2.24	5274	12.12	4318	9.72	9713	21.81	783	1.94	20089	11.63	−2487	−1.76	23177	4.12
Luxemburg	69	3.47	33	10.81	27	9.29	75	25.00	34	12.22	170	14.34	79	7.85	318	7.95
Netherlands	304	0.50	78	0.71	11	0.10	578	5.24	297	2.79	965	2.20	503	1.42	1771	1.26
Portugal	−2068	−4.26	220	2.83	100	1.28	2196	27.75	179	2.44	2696	8.73	2072	7.76	2699	2.54
Slovenia	351	4.30	13	0.87	62	4.21	144	9.93	70	4.86	289	4.96	74	1.55	714	3.81
England & Wales	−5695	−2.41	−1080	−2.64	−504	−1.21	1987	4.90	−103	−0.26	301	0.18	2025	1.44	−3369	−0.62
Total	3355	0.23	11516	4.50	10137	3.88	44878	17.34	4917	1.99	71449	6.99	8382	0.99	83186	2.50
Countries used as controls																
Austria	708	2.12	−42	−0.71	172	2.86	159	2.63	57	0.99	345	1.45	−645	−3.30	408	0.53
Czech Republic	2408	5.17	207	2.43	190	2.18	58	0.67	−37	−0.43	418	1.22	−335	−1.20	2491	2.29
Poland	1916	1.21	−487	−1.71	−543	−1.85	−918	−3.21	−652	−2.29	−2600	−2.26	−3436	−3.60	−4119	−1.12
Denmark	−113	−0.44	−43	−0.95	−92	−1.95	−49	−1.04	14	0.31	−170	−0.92	92	0.61	−191	−0.32
Total	4920	1.86	−365	−0.77	−273	−0.56	−750	−1.56	−618	−1.31	−2006	−1.05	−4325	−2.74	−1411	−0.23

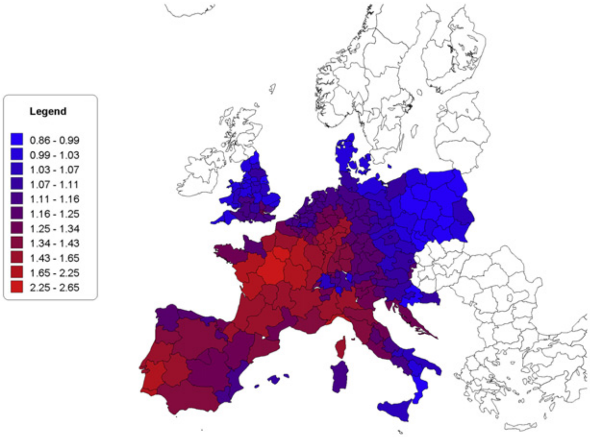

Fig. 2. Standardized daily death frequencies (1 means equal to the median death number, 2 means twice the median death number) between 3 and 16 August 2003, in 16 European countries, for 177 NUTS.

the absence of data for Bosnia-Herzegovina and Serbia. On the most lethal day – 12 August – mortality recorded in Île-de-France was over five times more than expected. It was over four times the expected mortality in the Centre region (France) and twice the expected mortality in Algarve in Portugal, in six other French regions, in three Belgian regions, in Piedmont in Italy and in the Greater London Area in England.

The August mortality crisis caused major distortions in the deaths' age and gender structure, which are illustrated in Fig. 3, using France and Italy as examples. On 12 August, the share of 65+ deaths increased by 9.5% in France, the share of 75+ deaths increased by 16.5%, the share of 85+ deaths by 26.8% and the share of 95+ deaths by 46%. These distortions in the deaths' age structure imply that excess mortality increased as age rose. The structure of deaths by gender also varied considerably during the mortality crisis. The share of female deaths increased by 21% in France on 12 August and by 14% in Italy on 13 August.

5. Interpretation

One original aspect of our work was to begin by analyzing the seasonality of mortality at the European wide scale. This study disclosed the existence of two broad mortality patterns: a constant one during the four summer months from June to September and a platykurtic pattern (flattened peak, centred on January–February) during the remaining months. Therefore, the mortality crisis of the summer 2003 was studied within this context.

More than three years after the 2003 heat wave, the total number of victims was still unknown on a European scale. The methods used for estimating the excess mortality covered various periods (from June to September or in August only) and different populations (countries, major cities), preventing comparisons among countries and therefore global appraisal [7].

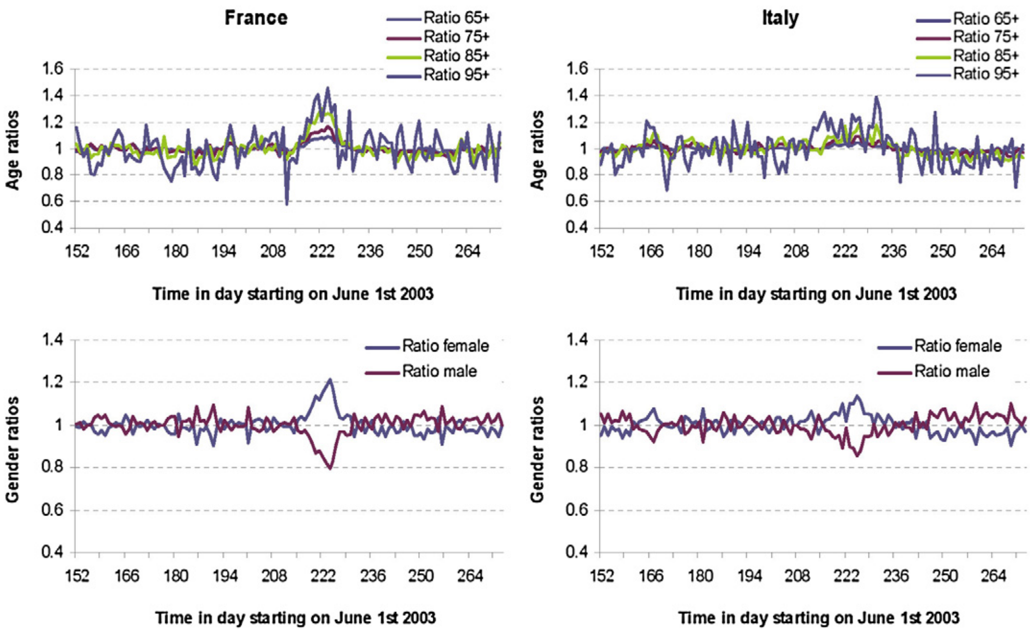

Fig. 3. Distortion of the death structure by age and gender in France and Italy during the summer of 2003. DOY 152, the 152nd day of the year corresponds to 1 June, DOY 181 to 30 June, DOY 212 to 31 July, DOY 243 to 31 August and DOY 273 to 30 September.

Gathering data from 16 European countries, our study disclosed that more than 70,000 additional deaths occurred in Europe during the summer of 2003, of which more than 20,000 before August. Excess mortality reached exceptionally high levels during the second week of the August heat wave in France. However, France and Italy totalized the same excess mortality, 19,490 and 20,089 excess deaths, respectively, with very different cumulative profiles during the summer. Obviously, this computed amount of excess mortality is sensitive to the reference period. However, a comparison with a French study of the August heat wave using a 3-year reference period [1] demonstrates a negligible impact of the duration of the reference period, ranging from 3 to 5-year, on the results.

Our study is limited to 16 European countries, basically France and its neighbouring countries, plus a group of surrounding countries kept as controls. The southeastern boundaries of the mortality crisis are poorly defined, as it was not possible to obtain the necessary data from Bosnia-Herzegovina and Serbia. These limitations probably lead to an underestimation of the real death toll in Europe due to the summer of 2003, as Bulgaria, Greece, Romania, and the south of the Balkans may have been affected by excess mortality.

Although the mortality crisis caused major distortions in the age and gender death structure, increasing the share of women and oldest ones, no overall harvesting effect was observed in the weeks and months following the mortality crisis. A French study proposed a late or postponed 'harvesting' effect that occurred in the first months of 2004 [20]. However, a subsequent study showed that the French regions with excessively low mortality in 2004 were not the most affected by the 2003 heat wave [21,22]. The most recent studies found little evidence in favour of a compensating harvesting effect [23].

Relating the number of death to person-years will provide, in the next step of our study, a better description of the populations at risk (gender, age groups...). Nevertheless, the current results, analyzed at the NUTS 2 level, strongly suggest that the excess mortality is not limited to urban areas.

Our observations showed that during the summer of 2003, a series of minor mortality crises throughout Europe, occurring almost unnoticed, led to a significant cumulative number of victims in comparison to the huge number of victims due to the August heat wave. Global warming may constitute a new threat to health in an aged Europe [8,24] that may be difficult to monitor at the level of a country or of a major city only. Centralising the count of daily deaths on a sufficiently large scale, like grouping neighbouring regions across the border and countries with small populations, should improve detecting early excess mortality due to various causes. Anticipation of excess summer mortality potentially due to global warming [25,26], through daily mortality monitoring alongside meteorological and pollution warning, may constitute a priority for Public Health in Europe.

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