ORIGINAL ARTICLE

HEAT MORTALITY IN FINLAND IN THE 2000s

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ABSTRACT

Objectives. To estimate the magnitude of heat-related mortality in Finland in the 2000s.
Study Design. Daily numbers of deaths during the period 2000–2005 in Finland were classified according to the mean daily temperature.
Methods. The temperature at which mortality was lowest was first determined from smoothed data based on the loess regression. Heat- and cold-related mortalities were estimated by subtracting deaths at this optimal temperature from actual deaths on both sides of this temperature.
Results. In 2000–2005, the fewest deaths (126 per day) occurred at a mean daily temperature of 12ºC, and they increased to 138/day (by 10%) on the warmest days (+24ºC) and to 151/day (20%) on the coldest days (-31ºC). An estimated 160 deaths per year (0.3% of all deaths) were due to higher than optimal temperatures and 2,400 /year (5%) to low temperatures. In individual years, the fraction of deaths attributable to heat varied from 0–0.5%, with little consistency with mean summer temperatures. While the relative risk of an individual dying from heat increased consistently with rising temperatures, most heat-related deaths occurred at temperatures less than +20ºC. During the warm spell in summer 2000, deaths increased by an estimated 360 cases (0.7% of annual deaths), but this decreased to 250 (0.5%) once the Midsummer Festival was excluded.
Conclusions. As heat spells may occur in the future in an unpredictable way and because heat is not recognized as a health hazard in the North, more research should be devoted to clarifying the causal mechanisms underlying heat mortality, and pre-emptive measures should be planned.
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Keywords: mortality, seasons, environmental temperature, heat, cold

INTRODUCTION

Although Finland is a cold country with mean annual temperatures of -1ºC to +5ºC and daily temperatures rarely exceeding 25ºC, significant excess mortality has been observed during warm weather spells. During the heat wave of 1972, for example, an estimated 840 excess deaths (2% of all annual deaths) occurred, mainly from cardio-respiratory causes (1), and smaller excesses have been seen during later heat waves (2). The threshold of the mean daily temperature at which mortality begins to rise in Finland is as low as +15ºC, that is, much lower than threshold temperatures of 17–32ºC reported from warmer countries (3). The excess heat mortality has declined from the 1970s to one-fourth by the 1990s (4), which was attributed to increasing prosperity rather than lifestyle and physiologic adaptation to high temperatures. Drawing on the facts that the mean annual temperatures in Finland have risen by 1ºC since the 1980s (5) and that some of the recent summers have been unusually warm, this paper estimates the excess heat mortality in Finland in the early half of the 2000s.

MATERIAL AND METHODS

The daily numbers of all deaths in Finland during the period 2000–2005 were obtained from Statistics Finland. Information on 3-hourly air temperatures in Jokioinen, south Finland (60.5º N lat., 23.3º E long.) and Oulu, north Finland (64.6º N lat., 25.2º E long.), was provided by the Finnish Meteorological Institute. Averages of mean daily temperatures in these localities were taken to provide reasonable estimates for average daily temperatures in the whole country. These temperatures were classified by 1ºC intervals, and the 2,192 days between 1 January 2000 and 31 December 2005 were assigned to them, and the mean counts of deaths were calculated in each interval. The one day that was excluded was 26 December 2004, the day of the Tsunami disaster, which left 2,191 days for study. The daily series of deaths were smoothed by the loess method (6), a locally weighted moving regression, using a smoothing span of 1/2. In each year, the temperature at which the model-predicted count was the lowest was recorded, and the numbers of deaths exceeding the lowest count were calculated on both sides of this temperature. The relative and attributable risks in relation to the lowest mortality were calculated for each temperature. The magnitude of the effect of temperature was estimated in terms of linear regressions of deaths on temperature.

Mortality during summer 2000 was subjected to a closer study, when an inspection of daily deaths suggested an obvious effect of heat. The period between 20 June and 25 July was defined as "hot," since the mean daily temperature was at least 15ºC on most days. The baseline mortality during this hot spell was estimated by first running a loess regression on a series of deaths in which the heat period was removed, then interpolating the regressed values over that period and calculating the excess mortality as the difference between the observed and regression-predicted values. This heat period included Midsummer Eve (June 23) and Midsummer Day (June 24), which necessitated a separate analysis since mortality usually increases during this holiday (3).

RESULTS

During the period studied, the mean annual temperature was +4ºC and the summer temperature +16ºC. In summer, the mean daily temperature exceeded +15ºC on 60% and +20ºC on 8% of the days (Table I). There were 291,480 deaths; 133 deaths per day on average (range 82 to 195). The method to determine the temperature of the lowest mortality is shown in Figure 1. In 2000–2005, the model-predicted number of deaths was lowest (126 per day) at the mean daily temperature of +12ºC and highest (151/day) on the coldest days (-31ºC), while on the warmest days (+24ºC) the number of deaths averaged 138/day, the relative risks for the coldest and warmest days being 1.20 and 1.10, respectively. On the warmer side of the optimal temperature, within the linear range of +16 to +24ºC, deaths increased by 1.1 percentage points by each increase of 1º in temperature.

Table I. Winter and summer temperatures in Finland, 2000–2005. Averages of temperatures recorded in Jokioinen (south) and Oulu (north).

Years	Mean temperature (°C)		Percentage of warm summer days	
	Winter[1]	Summer[2]	≥15 °C	≥20 °C
2000	-3.9	14.6	47	2
2001	-7.6	15.6	57	5
2002	-7.1	16.9	76	1
2003	-8.0	15.7	54	19
2004	-5.9	14.5	48	4
2005	-5.4	15.8	66	9
2000–2005	-6.3	15.5	60	8

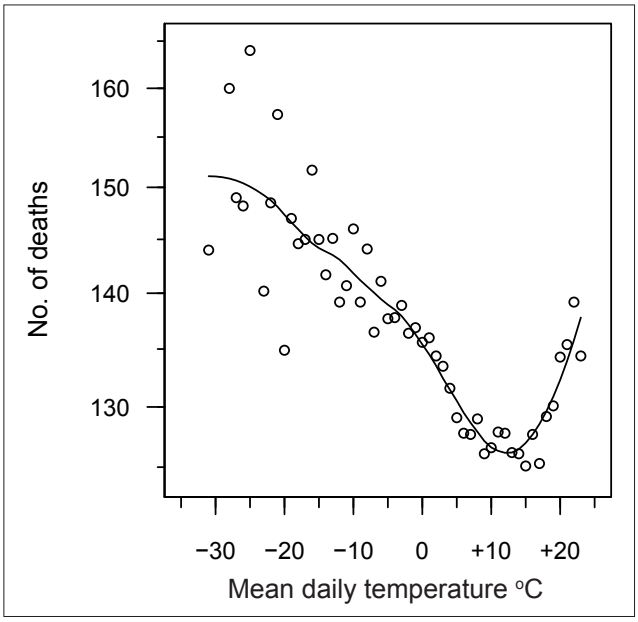

Figure 1. Daily numbers of deaths in Finland, 2000–2005, by mean daily temperature. Circles indicate mean counts of deaths in each 1°C interval; line shows regression-based smoothed values.

Table II shows the effect of heat and cold in individual years. The temperature of lowest mortality varied from +9ºC to +15ºC, the relative risk of death on the warmest days from 1.02 to 1.15, and from 1.08 to 1.29 on the coldest days. The heat-related mortality was greatest (250 cases; 0.5% of all annual deaths) in 2001 and 2003 but very low in 2002 and 2004, and cold-related deaths varied from 1,200 to 3,300 (2.4–6.8% of annual deaths). There was no consistent association between the excess mortalities and average summer temperatures.

For the most part, the excess mortality from cold was attributable to temperatures of -15ºC to

Table II. Cold- and heat-related mortality in Finland, 2000–2005.

Years	Temperature of lowest mortality (ºC)	Cold-related deaths / year		Relative risk (RR) of death on coldest days		Heat-related deaths / year		Relative risk (RR) of death on warmest days	
		No.	% of all deaths	Lowest temperature (ºC)	RR	No.	% of all deaths	Highest temperature (ºC)	RR
2000	+9	3270	6.6	-19	1.29	230	0.5	+22	1.09
2001	+13	1170	2.4	-26	1.13	250	0.5	+23	1.15
2002	+15	2640	5.4	-27	1.19	30	0.1	+23	1.03
2003	+12	3320	6.8	-31	1.21	250	0.5	+24	1.10
2004	+15	1820	3.8	-20	1.13	20	0.0	+21	1.02
2005	+12	2220	4.6	-18	1.08	140	0.3	+22	1.06
2000–2005	+12	2380	4.9	-31	1.20	160	0.3	+24	1.10

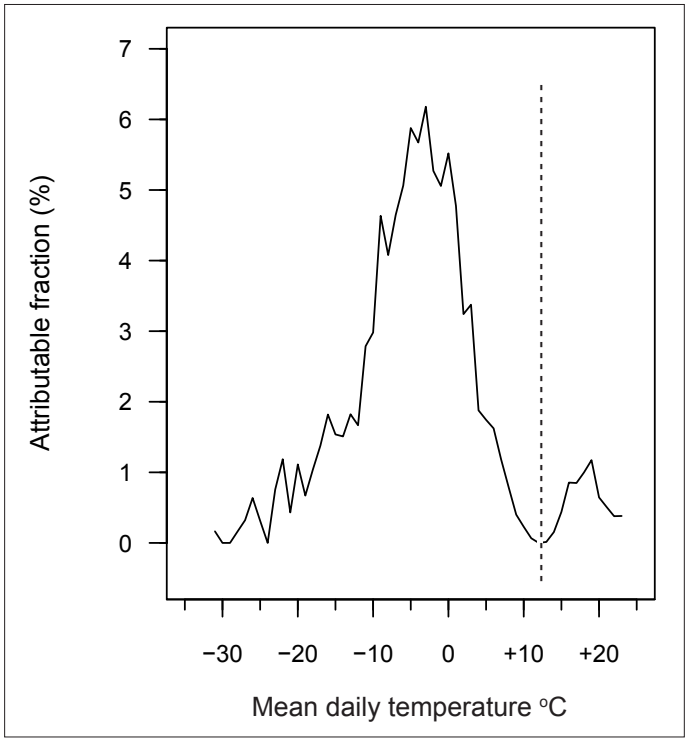

Figure 2. Fractions of excess mortality, 2000–2005, attributable to each temperature, relative to the lowest mortality. The temperature of lowest mortality (12°C) is shown by a vertical line.

+5ºC, not to the coldest temperatures (Fig. 2). On the warmer side, the greatest fraction of heat mortality came from temperatures below 20ºC and only a marginal fraction from temperatures higher than this.

Figure 3 focuses on the warm period in summer 2000. During the 5-week period from 20 June to 25 July, the mean daily temperature was at least 15ºC on most days (32 of 36) and the afternoon temperature (at 3 p.m.) at least 20ºC in 16 of 36 days. During this period, mortality increased sharply in 2 waves (peaking at Midsummer on 23–24 June, and on 30 June), both dates being preceded by hot days, 22 June and 29 June, with mean daily temperatures of +19ºC and +22ºC, respectively, and afternoon temperatures of +24ºC and +28ºC, respectively. The excess number of deaths during this 5-week period was 360 (0.7% of all annual deaths), but this reduced to 250 (0.5% of all deaths) once Midsummer Eve (Friday), Midsummer Day (Saturday) and the following Sunday were excluded.

DISCUSSION

Significant heat-related mortality existed in Finland in 2000–2005, although it was much smaller than cold-related mortality. While assessing the present estimates, some possibilities of bias should be taken into account. First,

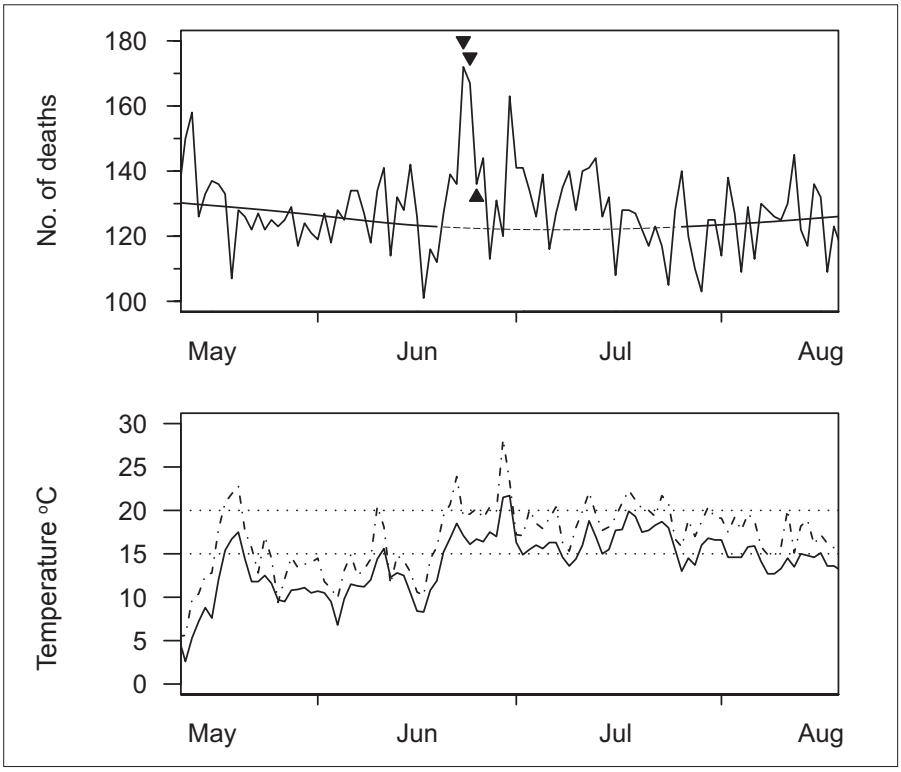

Figure 3. Daily mortality during May–August, 2000. The upper panel shows the observed numbers of deaths. The smooth line indicates the regression-based values (dotted line: values interpolated over the heat period 20 June to 25 July). The lower panel shows mean daily temperatures (continuous lines) and temperatures at 3 p.m. (dashed). The Midsummer Festival marked by black triangles.

the temperatures that were averaged over 2 localities, one in the south and the other in the north, to obtain average temperatures for the whole country may be questioned. Furthermore, in Finland the population is heavily concentrated in the south. While the mean summer temperatures were 2º to 5ºC lower in the north than in the south, and the daily temperatures some 2ºC lower, the daily variations were sufficiently uniform. A reanalysis of the temperature–mortality relationship using temperatures from the southern locality (Jokioinen) alone gave essentially similar results. Secondly, the method to determine the temperature of the lowest mortality depends on an arbitrary decision of the degree of smoothing, which directly affects the estimates of heat- and cold-related mortalities. Yet the graphed estimates pointed to a reasonable fit of the smoothed values to the actual observations, the model-based minimum mortality corresponding well to what should be expected from empirical data. Thirdly, this analysis only related the temperature on a given day to the deaths on the same day and ignored any lagged effects and effects of entire weather spells. However, evidence suggests that most heat deaths occur on the first 2 days of a hot spell (7).

The seasonality of deaths and of cold-related mortalities, in particular, have been well-known in Finland since the 1980s, as are the effects of some individual heat waves that occurred in 1961–1972 (1,2) and of high temperatures on mortality in later periods (4,8). The present paper analyses the most recent experience and shows excess heat mortality of 0–0.5% of all annual deaths, that is, estimates of the same magnitude as the previous ones (4). The period studied was too short for secular trends to be estimated for heat- and cold-related mortalities and the optimal temperature regarding mortality. No consistent association was seen between heat-related deaths and the mean temperature in each individual summer. The numbers of heat-related deaths were high in 2000 and 2001 when the summers were not the warmest (indeed, the winter 2000 was mild), but high numbers of such deaths were seen in 2003 when the number of hot summer days (≥20ºC) was by far the highest. In 2004, when the summer was relatively cool and hot summer days were few, almost no heat deaths were observed, but the same was true for the summer 2002 which was the warmest. These apparent inconsistencies are not easily explained, but a periodical selection of the population due to harvesting by extreme weather spells in the preceding summer or influenza in the preceding winter must play role. Bearing in mind the relatively short period studied and the use of temperature data from only 2 localities, the role of random factors cannot be ruled out, and the results may not be applicable to all parts of the country as such.

The optimum temperature regarding mortality is by far the lowest in Finland compared with warmer countries (3), and it is not widely accepted that the risk of death actually increases from mean daily temperatures as low as 15ºC or even lower. In fact, the numbers of deaths due to temperatures higher than this are comparable to numbers of people dying from traffic accidents. The causal mechanisms underlying heat mortality are not well known. In the older population, the excess heat mortality is mainly caused by cardiovascular and respiratory deaths, but in younger age groups, traffic accidents and drowning play a role. Deaths from hyperthermia in Finland are

rare. The excess cardiovascular deaths during heat spells have been explained in terms of the loss of water and salt by sweating and perspiration and the consequent haemoconcentration, which together with a decline in blood pressure would increase the risk of vascular thrombosis, and heat stress may lead to fatal heart failure among frail individuals (9). In Finland, alcohol consumption is concentrated on weekends and holidays, and when the Midsummer Festival coincides with a weekend and a hot spell, people's behaviours are affected, exposing them to excessive drinking, road and water traffic accidents as well as to the possibility of fatal heart attacks (3). Mortality also increases during most other holidays (1).

This analysis shows that in Finland, mean daily temperatures above the range of 9–15ºC are associated with excess mortality, although only 0–0.5% of annual deaths are attributable to heat compared with 2–7% attributable to cold – estimates that match those presented previously (4,8). Most heat-related deaths occur on days usually perceived as "normal," although it is true that an individual's risk will increase in a linear fashion with a rise in temperature by a factor of one-tenth from 16 to 24 ºC, with additional increases on days warmer than this and during longer runs of warm days. Given that heat spells may occur in unpredictable ways with the warming climate and that the hazards of heat are poorly recognized among this northern population, pre-emptive measures at individual and community levels are needed (10) as well as more research on the underlying causal mechanisms.

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