

# Seasonal variation in mortality in The Netherlands

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## Abstract

**Study objective**—The aim was to describe the pattern of seasonal variation in all cause mortality in The Netherlands, and to analyse the contribution of specific causes of death to the winter excess of all cause mortality.

**Design**—Daily numbers of deaths in The Netherlands, by cause, were obtained for the period 1979–1987. Patterns of variation were analysed using Poisson regression. The model related the observed number of deaths to (1) the number expected for that day on the basis of person-days at risk by age and sex, (2) secular trend, and (3) first and higher order cosine terms where appropriate.

**Main results**—All cause mortality has a bimodal peak in the first months of the year. After that it declines to reach a plateau in late spring. Mortality is lowest at the end of August, after which it rises steeply again. The winter excess of all cause mortality is primarily due to cardiovascular diseases (66%) and respiratory conditions (13%). Cardiovascular mortality peaks before respiratory mortality, suggesting different lag times in the effects of winter. There was an episode of exceptionally high mortality (above the normal winter excess) in early 1986, which was primarily due to cardiovascular diseases (39%) and respiratory conditions (25%). This episode was probably caused by a severe influenza epidemic, and was not followed by a compensatory lowering of mortality.

**Conclusions**—The pattern of variation of mortality within the year suggests that it is not based on a simple relationship with climatological circumstances, because the latter fluctuate according to a less complex pattern. Cause specific data suggest an instantaneous effect of “winter” on the cardiovascular system, and a delayed effect mediated by respiratory infections.

epidemics). Since 1950 the winter excess in mortality has diminished again, but it is still substantial.<sup>2</sup>

We report on an analysis of seasonal variation in mortality in The Netherlands in a recent time period (1979–1987). Using data on mortality by day and cause of death we have addressed the following questions: (1) What is the pattern of variation (functional form, timing, amplitude) of all cause mortality within the year? and (2) What is the contribution of specific causes of death to the winter excess of total mortality, and what do cause specific patterns suggest about backgrounds of the variation in all cause mortality?

We shall also pay attention to deviations from the usual pattern in this sequence of nine years, because years with exceptional patterns of variation may provide important suggestions about possible backgrounds.

The analysis to be reported here forms the first part of a larger study of seasonal variation in mortality in The Netherlands, commissioned after an episode of exceptionally high mortality rates in the first months of 1986. In later communications we will report on analyses of the association between mortality and a number of explanatory variables.

## Methods

Numbers of deaths, by day on which the death occurred (from 1 January 1979 to 31 December 1987) and by cause of death (according to the abridged mortality (AM) list of the *International classification of diseases*), were supplied by the Netherlands Central Bureau of Statistics. Table I presents some basic information about these causes of death. Some uncommon causes of death have been grouped together, as well as a number of narrowly related causes. Cardiovascular diseases are by far the largest group of causes of death in The Netherlands (44% of total mortality), followed by malignant neoplasms (27%), respiratory diseases (5%), and external causes (5%). The standard deviation of the daily number of deaths is mostly much larger than the standard deviation under the assumption of a Poisson distribution (this standard deviation is approximately equal to the square root of the observed number of deaths). This suggests that the daily variation is indeed much larger than expected on the basis of chance fluctuations alone.

Population numbers by age (in five year age groups) and sex for the first of January of each year were available from the population register. Linear interpolation provided estimates of person-days at risk, by age and sex, for each calendar day in the period considered. For the age

In countries with a “modern” mortality regime death rates are higher in the winter months than at other times of the year.<sup>1</sup> An analysis of long term trends in seasonal mortality patterns in England and Wales has shown that there has been an excess of mortality in the first quarter of the year since the start of death registration. This excess was rather small during the 19th century but rose considerably during the first half of this century (due to rapid declines in mortality from gastrointestinal infections, which used to cause summer

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group <1 year we adjusted the person-days obtained with the interpolation method for the seasonal variation in the number of births.

As daily numbers of deaths were not available by age and sex, we had to resort to a form of indirect standardisation, using person-days at risk by age and sex and average daily mortality rates by age and sex for the whole period (calculated from published data) to calculate "expected" numbers of deaths for each calendar day.

In order to summarise the patterns of variation in mortality we performed a Poisson regression analysis.<sup>3</sup> We started with a simple model in which the observed numbers of deaths ( $y$ ) were related to the expected numbers of deaths (see above) and a linear function of time to allow for secular trends. We then proceeded by adding a simple periodic function to describe the pattern of variation within the year.<sup>4</sup> The regression equation for this model is:

$$\log \hat{y}_d = \log e_d + \beta_1 (t - \bar{t}) + \gamma_1 \cos [(2\pi / 365 \cdot 25)(t - \tau_1)]$$

in which:  $\hat{y}_d$  = estimated number of deaths on day  $d$ ;  $e_d$  = expected number of deaths on day  $d$ , calculated on the basis of average daily mortality rates by age and sex over the whole period (offset parameter);  $t$  = time ( $t = 1$  for 1.1.1979,  $t = 3287$  for 31.12.1987);  $\bar{t}$  = central point of the time-axis (2.7.1983); and  $\beta_1$ ,  $\gamma_1$ , and  $\tau_1$  are the parameters to be estimated:  $\beta_1$  describes linear changes of mortality over time;  $\gamma_1$  and  $\tau_1$  are the amplitude and acrophase (location in time of the peak) of a simple cosine function with frequency  $2\pi/365 \cdot 25$  (one complete cycle per period of 365.25 days).

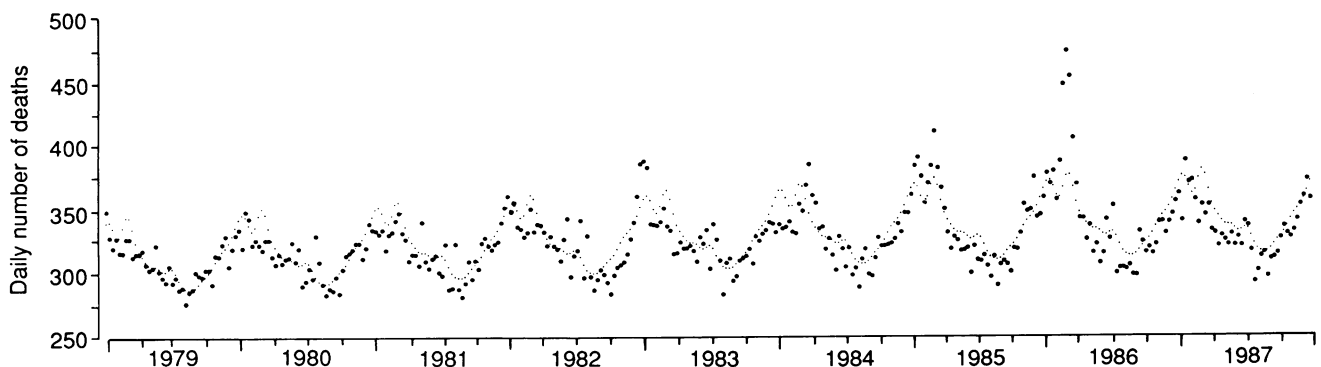
When the cosine term was statistically significant at the 5% level, we proceeded by subsequently adding cosine terms of the form  $\gamma_k \cos [(k2\pi/365 \cdot 25)(t - \tau_k)]$ , in which  $k = 2, k = 3$ , etc.<sup>4</sup> If the term with  $k = 2$  was statistically significant, we also tried a term with  $k = 3$ , and so on until a further refinement did not prove to be significant at the 5% level. These higher order cosine terms or trigonometric polynomials allow for the presence of additional mortality fluctuations of frequency  $4\pi/365 \cdot 25$  (two complete cycles per year),  $6\pi/365 \cdot 25$  (three complete cycles per year), etc. Trigonometric polynomials can describe quite complicated patterns of variation, such as bimodal distributions, differences in slope before and after the mortality peak, etc. With  $k > 1$ ,  $\gamma_k$  and  $\tau_k$  cannot directly be interpreted as amplitude and acrophase but can be used to calculate a maximum and minimum of the curve.

A period of nine years is of course rather short to establish "usual patterns of variation". In order to test the stability of the estimates based on the nine year period, we repeated the analysis by subsequently omitting each of the nine years. The results of this informal "jack knife" method indicate whether the estimates may be biased by the presence of one "exceptional" year.

The computations were performed with the GLIM computer package,<sup>5</sup> which calculates maximum likelihood estimates for the regression parameters by using an iteratively reweighted least squares procedure. Differences in scaled deviance between models were used to test the statistical significance of added terms.

Table 1 Causes of death included in the analysis. The Netherlands, 1979-1987

Causes of death	Code number (ICD-AM)	Average number of deaths per day	Standard deviation
Intestinal infections	01	0.12	0.35
Tuberculosis	02,03	0.45	0.66
Meningitis	24	0.18	0.42
Septicaemia	07	0.57	0.77
Other infectious diseases	04-06,08-11	0.59	0.76
Stomach cancer	12	6.84	2.67
Colorectal cancer	13,14	10.48	3.28
Lung cancer	15	21.92	4.93
Breast cancer	16	7.98	2.87
Other cancers	17-19	41.46	7.16
Diabetes mellitus	20	5.38	3.41
Ischaemic heart disease	28,29	68.27	11.14
Cerebrovascular disease	30	32.70	6.47
Other cardiovascular diseases	25-27,31,32	42.57	8.55
Pneumonia	33	8.17	3.70
Influenza	34	0.47	1.40
Chronic non-specific lung disease (CNSLD)	35	7.67	3.11
Nephritis, etc	39	3.22	1.91
Congenital anomalies	43	2.15	1.48
Perinatal conditions	44,45	1.60	1.32
Symptoms and ill defined conditions	46	11.66	5.43
All other natural causes	21-23,36-38, 40-42,47	34.15	7.47
Motor vehicle accidents	48,49	4.58	2.49
Accidental falls	50	4.38	2.22
Suicide	51	4.33	2.19
Other external causes	52,53	2.86	1.84
Total mortality	all	324.7	32.86



Seasonal variation in all cause mortality in The Netherlands, 1979-1987: daily numbers of deaths averaged over nine day periods. ...Observed; .... Fitted using a ninth order trigonometric polynomial model (see text)

## Results

The figure summarises the variation over time of all cause mortality. For this illustration, observed numbers of deaths have been averaged over periods of arbitrary length (nine days) to reduce random error. A slightly rising tendency can be noted; this is due to shifts in the age distribution of the population. Mortality peaks in the first quarter of the year. There is a clear suggestion of bimodality within the winter period in at least some of the years considered (1981, 1983, 1984, 1985). The height of the peaks differs substantially between the years, with record heights being attained in early 1986. The trough is located in the third quarter of the year, with little variation in depth. The decline from winter peak to summer trough is frequently interrupted by minor peaks around the middle of the year.

Table II presents the results of a regression analysis allowing for changes in age and sex distribution of the population, secular trend, and an appropriate periodic function. For total mortality, a ninth order model is selected, including cosine terms with  $k=1$ ,  $k=2$ , etc, up to  $k=9$ . Despite the use of higher order

trigonometric polynomials, the pattern is not particularly complicated. The figure contains the fitted values (averaged over nine day periods) using this selected model, in the form of small dots. After its late summer trough mortality risk rises steeply to a first peak in early January. Shortly after this first peak a second, slightly higher, peak follows in early March. The decline which follows is interrupted by a plateau in May and June. The ratio of the peak and trough values, a transformation of the amplitude of the wave function which enables us to make comparisons between causes of death, is 1.22 for total mortality.

According to the results presented in table II, the stability of the peak day estimate for this nine year period is unsatisfactory for total mortality. If one of the years (1986) is omitted, the peak day estimate changes from March 3 to January 8. Apparently, the second peak loses its predominance and the first one becomes largest.

For a small number of causes of death (stomach cancer, colorectal cancer, breast cancer, perinatal conditions) there appears to be no seasonal variation of sufficient magnitude for a simple cosine term to reach statistical significance. For the other causes there is, and sometimes of surprising magnitude: mortality due to influenza on average is more than 70 times higher at its late winter peak than in summer.

Fifteen causes of death peak in either January, February, or March. Important exceptions are intestinal infections (August), other cancers (November), symptoms and ill defined conditions (May), motor vehicle accidents (November), and other external causes (May). For some causes of death the peak estimate is unstable. In two cases (other cardiovascular diseases, chronic non-specific lung disease) the problem is the same as with total mortality: the "exceptional" situation in 1986 has shifted the maximum from a first, "normal" peak to a second peak. In the other cases the pattern of variation is more complicated than a bimodal pattern, and the location of the maximum varies between the years.

Of the causes having their peak in January, February, or March, some peak earlier than others. The clearest contrast is between cardiovascular diseases, which normally peak in January, and pneumonia and influenza which peak in March. This suggests the possibility of a difference in lag time of the effects of "winter".

The main contributors to the winter excess of mortality are cardiovascular and respiratory diseases (table III). We used the results of the regression analysis of total mortality to pinpoint the beginning and end of the period of a winter excess in total mortality. This was defined as the period during which the fitted values calculated with the ninth order model were higher than those calculated with a model without a periodic function. This period starts at November 11, and ends at April 14.

The average excess number of deaths is 2964 per winter period (approximately 2.5% of the yearly number of deaths in The Netherlands). Sixty six percent of these are due to cardiovascular diseases, and 13% to respiratory conditions. The contribution of these causes to the winter excess of mortality is much higher than their contribution

Table II Results of Poisson regression of the daily number of deaths on periodic functions of time, controlling for changes in the age and sex distribution of the population and for secular trend

Causes of death	Order of selected model <sup>a</sup>	Estimates according to selected model			
		Peak day	Trough day	Ratio of peak and trough value	Stability of peak day estimate <sup>b</sup>
Intestinal infections	2	Aug 10	Nov 29	2.37	OK
Tuberculosis	2	Jan 14	Sep 24	1.59	OK
Meningitis	1	Mar 2	Aug 31	1.49	OK
Septicaemia	1	Apr 27	Oct 26	1.21	OK
Other infectious diseases	2	Feb 15	Oct 28	1.33	OK
Stomach cancer	0	-	-	-	na
Colorectal cancer	0	-	-	-	na
Lung cancer	1	Jan 24	Jul 25	1.06	OK
Breast cancer	0	-	-	-	na
Other cancers	3	Nov 29	May 17	1.07	excl 1987: Feb 22
Diabetes mellitus	1	Feb 7	Aug 8	1.28	OK
Ischaemic heart disease	7	Jan 5	Aug 14	1.34	OK
Cerebrovascular disease	2	Jan 23	Sep 1	1.25	OK
Other cardiovascular diseases	4	Feb 7	Aug 27	1.33	excl 1986: Jan 16
Pneumonia	6	Mar 6	Sep 1	1.88	OK
Influenza	8	Mar 6	Sep 8	73.10	OK
Chronic non-specific lung disease	6	Mar 6	Aug 29	1.50	excl 1986: Jan 5
Nephritis, etc	1	Feb 18	Aug 19	1.30	OK
Congenital anomalies	4	Dec 8	Jul 31	1.23	excl 1987: Mar 10
Perinatal conditions	0	-	-	-	na
Symptoms and ill-defined conditions	8	May 23	Apr 20	1.62	excl 1986: Oct 17
All other natural causes	4	Feb 24	Sep 23	1.20	OK
Motor vehicle accidents	5	Nov 27	Feb 26	1.39	excl 1986: May 26
Accidental falls	2	Jan 21	Sep 12	1.28	OK
Suicide	4	Mar 15	Jan 12	1.17	OK
Other external causes	2	May 30	Apr 21	1.45	excl 1982: Aug 4
Total mortality	9	Mar 3	Aug 24	1.22	excl 1986: Jan 8

<sup>a</sup>The model was selected using a forward stepping procedure, in which cosine terms with  $k=1$ ,  $k=2$  etc. were subsequently added. A zero order model does not include a cosine term because even a term with  $k=1$  was not statistically significant at 5% level. A ninth order model, the highest order occurring in this table, includes cosine terms with  $k=1$ ,  $k=2$  etc. up to  $k=9$ .

<sup>b</sup>The stability of the peak day estimate was tested by performing nine additional analyses, in each of which one of the nine years was omitted. If none of these analyses resulted in a peak day estimate > 20 days before or after the estimate presented in this table, we considered the stability of the latter estimate "OK". If the stability was not satisfactory according to this measure, we mention the results of the analysis which produced the largest difference. "na" = not applicable.

to year round mortality (44% and 5% respectively). Malignant neoplasms, although accounting for 27% of year round mortality, do not contribute substantially to the winter excess in all cause mortality. Neither do external causes.

The most important deviation from the usual pattern in this nine year period is an episode of exceptionally high mortality in early 1986 (figure). If it is defined as a period of consecutive days on each of which the number of deaths exceeds the number expected on the basis of the

selected (ninth order) model, this episode lasted from February 10 to March 25. It is perhaps to be interpreted as a larger than usual second peak in the normal winter excess.

The total number of deaths in this period was 24% (or 3700 in absolute terms) higher than the numbers expected. Table IV shows the contribution of specific causes of death to this increase in all cause mortality. The main contributors are cardiovascular diseases (39%) and respiratory conditions (25%). A comparison with table III shows that the contribution of respiratory conditions, especially that of pneumonia and influenza, is much larger than what one would expect if this episode simply represented the normal winter excess on a larger scale.

The high mortality rates in the first quarter of 1986 were not followed by lower than normal mortality rates later in the same year (table V). The numbers of deaths in the second, third, and fourth quarters of 1986 were not lower than expected on the basis of the numbers observed in other years. Also, the total number of deaths in 1986 is clearly higher than expected. To a lesser extent this also applies to (the first quarter of) 1985. The absence of a compensatory lowering of mortality suggests that the extra deaths in February and March 1986 did not only, or even primarily, occur among those who were going to die soon anyway.

## Discussion

Our results show that variation of mortality within the year is not negligible in The Netherlands. At its winter peak, mortality is on average 22% higher than at its summer trough, and the average winter excess accounts for 2.5% of year round mortality. For some specific causes of death, for example cardiovascular diseases and respiratory conditions, these figures are considerably higher. Although this underlines the potential gains in public health after a (further) elimination of seasonal variation in mortality, it is important to note that the variation in The Netherlands is small by international standards. In a comparison of 18 European countries The Netherlands, Western Germany, and the Scandinavian countries were shown to have a much smaller winter excess of mortality than the United Kingdom, Ireland, Belgium, and a number of Mediterranean countries.<sup>6</sup>

The variation of mortality within the year in The Netherlands represents an interesting pattern, with a steep rise from the end of August to the beginning of January, a second peak in early March, and a decrease starting in March which is interrupted by a plateau in late spring. To our knowledge, no equally detailed descriptions of the situation in other countries have been made, with the exception of Finland.<sup>7</sup> The pattern which we observe contains an important clue to the explanation of seasonal variation in mortality because temperature, which has often been shown to be associated with mortality<sup>8-10</sup> has a much more simple pattern of variation in The Netherlands. Maximum daily temperature peaks around the first of August, declines regularly to reach its lowest value six months later around the first of February, and then rises regularly again.

Table III The contribution of selected causes of death to the winter excess in all cause mortality

Cause of death	Extra deaths during winter period <sup>a</sup>	
	Absolute number	Percentage share in the winter excess of all cause mortality
Stomach cancer	8	0
Colorectal cancer	1	0
Lung cancer	59	2
Breast cancer	41	1
Other cancers	101	3
Ischaemic heart disease	929	31
Cerebrovascular disease	403	14
Other cardiovascular diseases	634	21
Pneumonia	191	6
Influenza	70	2
Chronic non-specific lung disease	156	5
All other natural causes	366	12
Motor vehicle accidents	-37	-1
Accidental falls	59	2
Suicide	-3	-0
Other external causes	-14	-0
Total mortality	2964	100

<sup>a</sup>Deaths in excess of number expected on the basis of yearly average. Average over a period of nine years (1979-1987). Winter period = November 11-April 14 (see text for explanation).

Table IV The contribution of selected causes of death to the episode of exceptionally high mortality in early 1986

Cause of death	Extra deaths during this episode (Feb 10-Mar 25) <sup>a</sup>	
	Absolute number	Percentage share in the extra deaths for all cause mortality
Stomach cancer	-27	-1
Colorectal cancer	14	0
Lung cancer	98	3
Breast cancer	19	0
Other cancers	206	6
Ischaemic heart disease	584	16
Cerebrovascular disease	181	5
Other cardiovascular diseases	680	18
Pneumonia	423	11
Influenza	300	8
Chronic non-specific lung disease	234	6
All other natural causes	945	26
Motor vehicle accidents	-12	-0
Accidental falls	31	1
Suicide	16	0
Other external causes	8	0
Total mortality	3700	100

<sup>a</sup>Deaths in excess of number expected on the basis of average during this time of the year

Table V Quarterly number of deaths, 1979-1987

Year	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total
1979	29 373	27 875	26 473	28 847	112 568
1980	30 061	28 042	26 919	29 302	114 324
1981	30 145	28 221	27 077	30 118	115 561
1982	30 750	29 073	27 608	29 876	117 305
1983	31 056	28 956	27 964	29 873	117 849
1984	31 812	29 724	27 735	30 463	119 734
1985	34 314	28 979	27 671	31 677	122 641
1986	36 469	29 769	28 228	30 808	125 274
1987	32 384	29 699	28 280	31 724	122 087

(An instantaneous effect of) temperature thus cannot be the only factor.

The fact that the first winter peak is followed by a second one is not what one would expect on the basis of the general improvement of climatological circumstances during the first months of the year. This suggests that the effect of "winter" may consist of a more or less instantaneous effect and a more delayed effect. Several hypotheses could be formulated on the nature of such a delayed effect. Thus many effects of winter on behaviour (eg, hours spent indoors) or food intake (eg, fruit) probably peak after the lowest temperature values; and the same may be true for the effects on physiological or psychological (eg, depressiveness) condition.

Most causes of death also display a winter excess. Mortality due to cardiovascular diseases, which forms the largest contributor to the winter excess of total mortality, peaks at about the same moment as maximum temperature reaches its trough. Variation in mortality from these causes of death has frequently been found to be related to variation in temperature.<sup>8-10</sup> Possible mechanisms accounting for this association include the effects of thermoregulatory responses on arterial pressure and the risk of thrombosis (through increased blood platelets, red cell counts, and blood viscosity).<sup>11 12</sup>

Mortality due to pneumonia and influenza peaks in early March. This reflects the responsiveness of these causes of death to influenza epidemics (and maybe to other respiratory infections), which happen to occur mostly in February or March in The Netherlands. This is of course not by chance alone: conditions for the spread of these epidemics are obviously more favourable in these months than at other times of the year. The delayed effects of winter mentioned above (eg, hours spent indoors, fruit intake, general physiological condition) may be involved here. At the same time, influenza epidemics also contribute to increased rates of cardiovascular mortality in late winter.

Mortality due to malignant neoplasms does not show a marked seasonal variation. This is remarkable because it shows that the increased mortality in winter is not a generalised phenomenon striking all those whose health is compromised. It appears to be caused by more specific mechanisms.

The importance of influenza is also apparent from its contribution to an episode of exceptionally high mortality in February/March 1986. The influenza surveillance system of The Netherlands registered a very high incidence of

influenza in this period.<sup>13</sup> Although mortality due to influenza (as a registered underlying cause of death) forms only 8% of this mortality increase, it is well known that influenza also contributes to the death of people with other underlying conditions, especially chronic cardiovascular and respiratory diseases.

Analyses from the United Kingdom have shown that each influenza death was associated with 3.6 excess deaths (due to all causes including influenza) in 1949-1985.<sup>14</sup> There appears to have been a rise in the total number of excess deaths per influenza death over this period, and during a recent epidemic in the winter of 1989/1990 a ratio of 10:1 was found.<sup>15</sup> On the basis of table IV we would calculate a ratio of 12:1 (3700:300) for the 1986 epidemic in The Netherlands.

The high mortality rates during this epidemic were not followed by a compensatory lowering of mortality later in the same year. It is clearly not those who were already terminally ill who were killed by this epidemic. This again stresses the importance of improving vaccination strategies in The Netherlands, which are rather inadequate at this moment.<sup>16</sup>

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