Soc. Sci. Med. Vol. 47, No. 4, pp. 429–443, 1998

Printed in Great Britain
0277-9536/98 $19.00 + 0.00

MORTALITY DECLINE IN THE NETHERLANDS IN THE PERIOD 1850–1992: A TURNING POINT ANALYSIS

JUDITH H. WOLLESWINKEL-VAN DEN BOSCH,[1]*
FRANS W. A. VAN POPPEL,[2] EWA TABEAU[2] and JOHAN P. MACKENBACH[1]

[1]Department of Public Health, Faculty of Medicine and Health Sciences, Erasmus University Rotterdam, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands and [2]Netherlands Interdisciplinary Demographic Institute, P.O. Box 11650, 2502 AR The Hague, The Netherlands

Abstract—The aim of this paper is to give a detailed and fairly objective description of rapid mortality decline in The Netherlands between 1850 and 1992 with respect to the start, end, and phases of the decline. Turning points were estimated for the standardized mortality trend, and for age and sex-specific trends between 1850–1992. The technique used was derived from spline functions. The turning points divided the trends into phases with different paces of decline. Standardized mortality started to decline rapidly in The Netherlands around 1880. Four phases in the period of decline could be distinguished: 1880–1917 (1.2% annually), 1917–1955 (1.6%), 1955–1970 (0.4%), 1970–1992 (1.1%). For nearly all age groups, the most rapid decline occurred in a period comparable to 1917–1955. Causes of death which might have shaped the standardized mortality trend are, among others, respiratory tuberculosis (1917), heart disease (except ischemic) (1955), and ischemic heart disease (1970). Causes of death that shaped the mortality trend are related to trends of determinants of mortality decline. The technique used in this paper can also be applied to other trends e.g. fertility decline. © 1998 Elsevier Science Ltd. All rights reserved

Key words—mortality decline, turning point analysis, Netherlands

INTRODUCTION

Over the last two centuries, most Western countries have seen enormous demographic and epidemiologic changes: mortality declined enormously, as did fertility, the population grew and disease patterns shifted. These major changes led to the formulation of two important theories, *viz*. the demographic transition theory and the epidemiologic transition theory. The demographic transition theory explains the population growth in terms of a process in which there is a transition from a stage with high mortality and fertility rates to a stage with low mortality and fertility rates (Beaver, 1975; Caldwell, 1976; Chesnais, 1992).

In the early 1970s, Omran introduced the epidemiological transition theory. This theory can be regarded as a more detailed description of mortality decline in the demographic transition theory. Omran distinguished three stages in the epidemiologic transition. The first stage is the "age of pestilence and famine" in which mortality is high and fluctuating. The second stage is the "age of receding pandemics" in which mortality declines progressively. The rate of decline accelerates as epidemic peaks become less frequent and eventually disappear. The third stage is the "age of degenerative and man-made diseases" in which mortality first continues to decline and eventually approaches stability at a relatively low level. The dominating causes of death of this stage are cardiovascular diseases, cancer and external causes of death (Omran, 1971; Omran, 1983). The demographic and epidemiologic transitions have been observed in many countries albeit with differences in start, development and duration of the transitions.

Figure 1 shows the demographic transition as observed in The Netherlands (Hofstee, 1981). It suggests that crude mortality rates had been declining slowly since the beginning of the 19th century and started to decline rapidly around 1875.

The aim of this paper is to give a detailed description of the period of rapid mortality decline in The Netherlands, or more specifically, to describe the start of rapid mortality decline, the phases in the decline in terms of changes in the pace of decline and the end of rapid mortality decline. A description of sex and age-specific mortality changes as well as cause-specific mortality changes is given to elucidate possible sex-specified, age-specific and cause-specific developments in mortality that might have shaped the total mortality trend.

The turning points in the mortality trend described in this paper are not based on a simple visual inspection of the trend, but on a more formal statistical method. A so-called turning point analysis was used to determine phases with different paces of mortality decline. The Netherlands provide

*Author for correspondence.

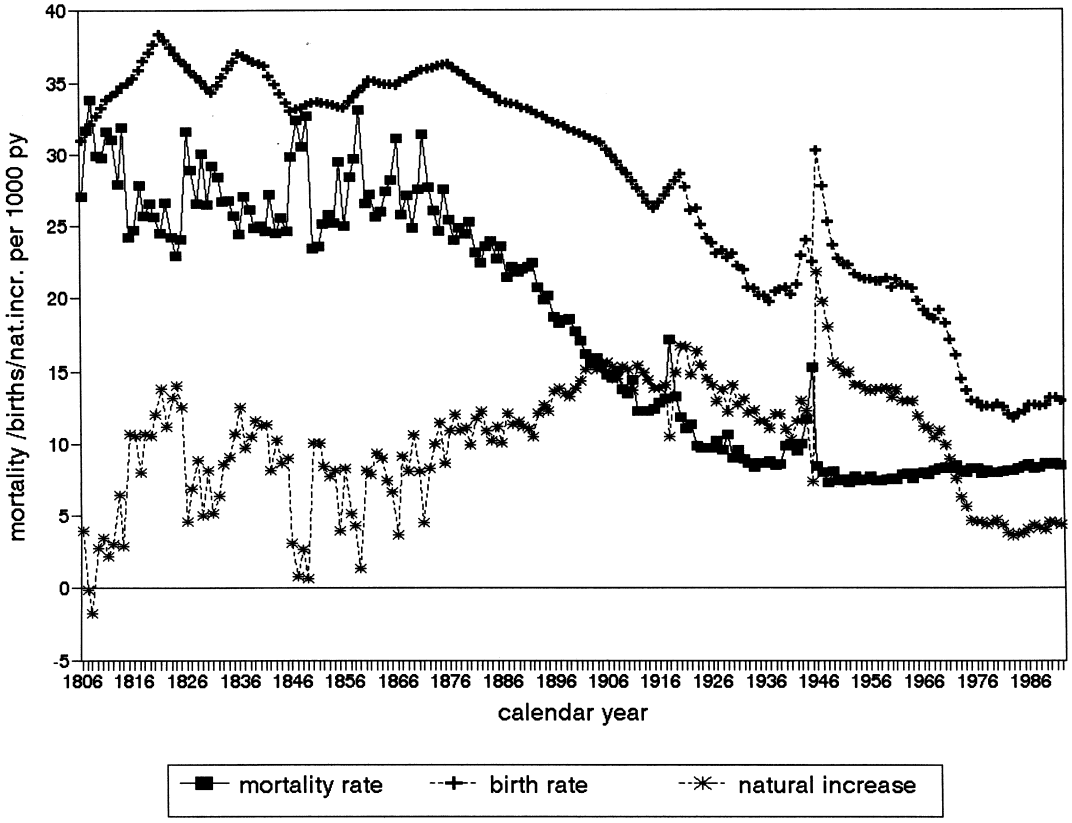

Fig. 1. The demographic transition in The Netherlands, 1806–1992. The birth rates are 5-year averages until 1924 (Hofstee, 1981), and yearly figures derived from the Central Bureau of Statistics after 1924. Crude mortality figures are obtained from the Netherlands Interdisciplinary Demographic Institute.

a good opportunity for such an analysis because the quality of historical mortality and population data in The Netherlands can be considered as good in comparison to many other Western countries. Ever since 1865 medical doctors have been legally required to issue a medical certificate stating the cause of death, which was then given to the Registrar (van Poppel, 1997).

The advantage of a formal statistical method and reliable data is that these will generate more objective results, and thus provide a sound basis to relate changes in mortality to changes in determinants of mortality.

DATA AND METHOD

Data

Mortality data for the period 1850–1875 were derived from a mortality database constructed by the Netherlands Interdisciplinary Demographic Institute (NIDI) (Tabeau *et al.*, 1994). Annual publications of mortality figures by Statistics Netherlands (CBS) were used for the period 1875–1992. Population data for the period 1850–1949 were also provided by the NIDI, and population data for the period 1950–1992 were again obtained from the CBS. The data were used to calculate age- and sex-standardized mortality rates to correct for the effect of changing age and sex distributions on mortality. Direct standardization was carried out by using the total population from 1901–1992 as the reference population. Eight age groups were used in the standardization procedure, which was the greatest common denominator of all age subdivisions used in the study period (1850–1992). The age groups were 0, 1–4, 5–14, 15–19, 20–49, 50–64, 65–79 and 80 years and over.

The influence of 27 causes of death on the turning points in the total standardized mortality trend is presented in this study. The 27 cause of death categories are the result of an extensive reclassification procedure of all cause-of-death classifications in the period 1875–1992, i.e. nine revisions of the International Classification of Diseases, Injuries and Causes of Death (ICD) and one pre-ICD classification. This reclassification procedure has been described elsewhere (Wolleswinkel-van den Bosch *et al.*, 1996). Table 1 contains the 27 cause-of-death groups together with the corresponding codes of the ninth ICD revision.

Table 1. Description of the 27 cause-of-death groups as well as the corresponding codes of the ninth revision of the International Classification of Diseases, Injuries and Causes of Death

27 causes 1875–1992	ICD-9 codes
1. Congenital anomalies	740–759
2. *Debility.Including: Several types of tuberculosis. Scrofula. Rachitis. Diseases of skin. Abscess. Ulcer. Gangrene. Pyemia. Hemorrhage. Continuous fever. Senility. Dementia. Perinatal causes of death. Septicemia. Pyemia. Other infectious diseases. Other non infectious diseases.	003, 015–018, 020–027, 030–031, 035, 037–044, 051–054, 056–057, 060–061, 065–066, 070–075, 077–083, 085–088, 100–104, 110–118, 120–137, 139, 201, 204–208, 210–217, 222–239, 251, 253–266, 268–274, 275–290, 292–302, 306–319, 471, 680–686, 690–698, 700–739, 760–779, 797
3. Cancer	142, 150–165, 170–175, 179–185, 200, 202–203
4. Scurvy	267
5. Typhus. Typhoid fever.	002
6. Malaria	084
7. Smallpox	050
8. Scarlet fever	034
9. Measles	055
10. Cerebrovascular disease	430–438
11. Diseases of the nervous system.Including: Insanity. Syphilis. Convulsions. Encephalitis. Meningitis. Tuberculosis of the meninges and central nervous system. Diseases of the ear (otitis media).	013, 036, 045–049, 062–064, 076, 090–097, 138, 240–246, 252, 291, 303, 320–326, 330–337, 340–389
12. Respiratory tuberculosis	010–012
13. Diabetes	250
14. Diphtheria. Group	032
15. Whooping cough	033
16. Acute respiratory diseases Including: Acute bronchitis. Influenza. Pneumonia. Pleurisy	466, 487 480–486 510–511
17. Chronic respiratory diseases Including: Diseases of larynx, pharynx, nasal cavity. Chronic bronchitis. Asthma. Other diseases of the respiratory system.	415, 460–465, 470, 472–478, 490–496, 500–508, 512–529
18. Diseases of circulatory system. Including: Rheumatic fever. Chronic rheumatic heart disease. Ischemic heart disease. Other heart diseases. Diseases of arteries and veins.	390–398, 401–405, 410–414, 416–417, 420–429, 445, 451–456, 458–459
19. Acute diseases of digestive system.Including: Diarrhoeal disease. Dysentery. Peritonitis. Appendicitis	004, 006–009, 532, 540–543, 555–558, 562, 567
20. Asiatic cholera. Cholera nostras	001
21. Chronic diseases of digestive system Including: Tuberculosis of intestines, peritoneum and mesenteric glands. Stomach ulcer. Diseases of the oesophagus. Other digestive diseases.	014, 530–531, 533–537, 550–553, 560, 564–566, 568–579
22. Diseases of the genito-urinary system Including: Venereal diseases (exc. syphilis). Acute nephritis. Chronic nephritis. Diseases of the urinary tract. Diseases of the male and female genital organs.	098–099, 218–221, 580–599, 600–608, 610–611, 614–629
23. Puerperal diseases (exc. puerperal fever)	630–639, 640–648, 650–669, 671–676
24. Puerperal fever	670
25. External causes Including: Homicide. Traffic accidents. Other external causes of death	005, 304–305, E800–807, E810–838, E840–848, E850–876, E878–888, E890–903, E905–949, E960–978, E980–999
26. Suicide	E950–959
27. Unspecified, ill-defined or unknown causes of death. Sudden death	780–796, 798–799, E904

*This category consists of several causes of death from the 19th century classification. Debility consists predominantly of senility and perinatal causes of death. Only types of tuberculosis other than mentioned elsewhere in this table are included. Hemorrhage related to pregnancy or respiratory tuberculosis is not included in this category.

Turning point analysis: Total mortality and age and sex-specific mortality

In order to identify turning points in the mortality trend that mark periods with a different rate of mortality decline we used a derivation of a spline function. Spline functions are used to describe global movements by estimating turning points that characterize significant changes in that movement. Spline functions may be regarded as a sequence of polynomials each fitted to another part of the study period, which pair-wise have the same values in each knot (Kendall, 1973; McNeill *et al.*, 1977; Suits *et al.*, 1978). The function used in this study is given below (De Beer, 1986).

$$\ln Y_t = \alpha_0 + \alpha_1 t + \sum_{i=2}^{j} \alpha_i (t - t_i) D(t - t_i) + \epsilon_t$$

Y_t is the standardized mortality in year t; $t_2\ t_3\ \ldots\ t_i$ are the turning points; α_0, $\alpha_1\ \ldots\ \alpha_i$ are the intercept and slopes; ϵ_t is an error term and $D(t - t_i)$ is a step function,

$$D(t - t_i) = 0 \quad \text{if } t \leq t_i$$

$$D(t - t_i) = 1 \quad \text{if } t > t_i$$

i = turning point In the model $D(t - t_i)$ is defined as

$$D(t - t_i) = (1 + \sqrt{(t - t_i)^2}/(t - t_i))/2$$

The TSP program was used to solve this non-linear least squares regression problem. The number of turning points and initial values for the turning points and coefficients have to be set to run the model. The optimum solutions for the parameters

α_0, α_1 ... α_i and t_i are estimated by minimizing the sum of squares of the residuals, which is an iterating process. At every iteration step the values of the parameters are slightly changed, and it is determined whether the sum of squared residuals has decreased. If it has, the changes are adopted and a new iteration step begins. The process continues until the proposed changes are very small in comparison to the parameters themselves (Hall *et al.*, 1990). Residual analysis may show that the model is not adequate. A model with a smaller number of turning points was estimated if a significant difference between the slopes before and after the turning point was not found. A model with a larger number of turning points was estimated if there was serious autocorrelation of the residuals (Durbin–Watson statistic) and the sum of squared residuals was relatively high.The rates of change in the different periods can be calculated as follows:

$$100\{\exp(\sum_{i=1}^{j} \alpha_i) - 1\}\%$$

The years 1940–1946 (Second World War) as well as the influenza epidemic of 1918 were excluded from the analyses because these events caused extraordinarily high peaks in the mortality trend, which hampered a good estimation of turning points in most cases.

Contribution of causes of death

Causes of death which greatly contributed to the level of total mortality in the "turning point years", and which showed a considerable change in the pace of mortality in the period after the turning point compared to the period before the turning point, have probably played a role in the occurrence of the turning points in the total mortality trend. Therefore rates of change of 27 causes of death, which could be studied for the period 1875–1992, were calculated for only those phases in mortality decline for which reliable cause-specific data were available. A simple linear regression analysis with the natural logarithm of mortality as the dependent variable and calendar year as the independent variable was used to calculate the rates of change. In these analyses the years 1918 (influenza epidemic) and 1940–46 were excluded as was the case in the turning point analyses on total mortality. During the Second World War high peaks in mortality due to diphtheria, tuberculosis, acute digestive diseases and violent death were seen in The Netherlands (Lumey and van Poppel, 1994).

RESULTS

The onset of rapid mortality decline

Table 2 represents the turning points and rates of change for the distinguished periods in the total mortality trend and in sex and age-specific mortality trends for the period 1850–1992. The results indicate that mortality started to decline in 1855, because then a change occurred from a period of increase to a period of decrease in mortality rates. The sex and age-specific results show that mortality started to decline around 1855 for both sexes and for all age groups, except for the age group 0–1. In this age group mortality started to decline about 15 years later.

Phases in the period of rapid mortality decline

Total mortality. The results of the turning point analysis show five phases with different paces of mortality decline in the period 1855–1992 (Table 2, Fig. 2). A first acceleration in the decline started in 1880. The most rapid decline (1.6% annually) occurred in the period 1917–1955. This period was followed by a phase (1955–1970) of very slow mortality decline (0.4% annually). Then mortality started to decline rapidly again (1.1%).

Sex-specific mortality. Male and female mortality trends differ with respect to turning points in the pace of mortality decline (Table 2). Female mortality started to decline in 1858 at a rate which was not reached by males until 1881. A turning point near the year 1880 was not found for the female mortality trend. Male mortality increased in the period 1952–1972 while female mortality continued to decline. Contrary to males, female mortality has been declining continuously since 1858 at a fairly high rate.

Age-specific mortality. The turning point in 1880, in the total mortality trend, could only be found in age group 20–49. Other age groups with turning points near the turning point in 1880 are age group 0–1 (1871) age group 1–4 (1888) and 5–14 (1890) (Table 2).

Turning points near 1917 and 1955 (total mortality decline) were found for most age groups (1–4, 15–19, 20–49, 50–64 and 65–79) (Table 2). The period between those turning points shows the most rapid decline in the whole period of mortality decline for these age groups.

Total mortality decline decelerated in the period 1955–1970. An increase in mortality was found in age groups 15–19, 50–64 and 65–79 in a period equivalent to 1955–1970 (Table 2).

The rates of change were generally higher for age groups 0–1 to 15–19 compared to the rates of change of older age groups both in the late 19th and early 20th centuries, and also during the remainder of the 20th century.

It was hard to give a reliable estimation of the turning points for the age group 80 + , because of the highly fluctuating trend for this age group until the Second World War.

Cause-specific mortality. Table 3 shows the importance of the 27 causes of death in terms of contribution to the level of total mortality in the

Table 2. Turning points and growth rates for the total mortality trend and sex and age-specific mortality trends in The Netherlands, 1850–1992

	Turning	Period	Annual growth rate (%)
Total		1850–1855	4.8
	1855	1855–1880	–0.8
	1880	1880–1917	–1.2
	1917	1917–1955	–1.6
	1955	1955–1970	–0.4
	1970	1970–1992	–1.1
Males		1850–1855	4.6
	1855	1855–1881	–0.7
	1881	1881–1917	–1.2
	1917	1917–1952	–1.6
	1952	1952–1972	0.3
	1972	1972–1992	–0.8
Females		1850–1858	2.8
	1858	1858–1919	–1.1
	1919	1919–1960	–1.8
	1960	1960–1992	–1.3
Age 0		1850–1871	0.6
	1871	1871–1905	–1.2
	1905	1905–1924	–4.3
	1924	1924–1948	–3.1
	1948	1948–1957	–5.1
	1957	1957–1992	–3.0
Age 1–4		1850–1859	2.6
	1859	1859–1888	–1.7
	1888	1888–1919	–3.0
	1919	1919–1947	–5.8
	1947	1947–1992	–3.6
Age 5–14		1850–1859	4.6
	1859	1859–1890	–2.4
	1890	1890–1910	–3.4
	1910	1910–1928	–2.0
	1928	1928–1951	–4.4
	1951	1951–1970	–1.7
	1970	1970–1992	–3.8
Age 15–19		1850–1859	3.1
	1859	1859–1919	–1.3
	1919	1919–1957	–4.7
	1957	1957–1972	2.3
	1972	1972–1992	–3.3
Age 20–49		1850–1858	2.3
	1858	1858–1881	–1.3
	1881	1881–1920	–1.9
	1920	1920–1955	–2.8
	1955	1955–1992	–1.1
Age 50–64		1850–1855	5.1
	1855	1855–1917	–0.9
	1917	1917–1957	–1.4
	1957	1957–1970	0.7
	1970	1970–1992	–1.3
Age 65–79		1850–1854	4.3
	1854	1854–1922	–0.4
	1922	1922–1961	–0.9
	1961	1961–1970	0.1
	1970	1970–1992	–1.0
Age 80 + *		1850–1855	3.5
	1855	1855–1927	–0.04
	1927	1927–1992	–0.7

*The results of this age-group are not very reliable, because of the highly fluctuating trend.

turning point years, and in terms of the rates of change in the phases of the total mortality trend for which cause-specific mortality data were available, i.e. 1880–1917, 1917–1955, 1955–1970 and 1970–1992. A change in the rate of decline of important causes of death might indicate that those causes of death played a role in the changes in the total mortality trend.

Causes of death which contributed largely to the level of mortality in 1880 were ''debility'' (mainly consisting of diseases of the newly born, and ''old age'') (25.0%), respiratory tuberculosis (9.7%), acute respiratory diseases (9.7%), diseases of the nervous systems (mainly meningitis and tuberculosis of the meninges) (8.3%), chronic respiratory diseases (8.3%), unknown and ill-defined causes of death (6.6%), and diarrhoeal diseases (6.4%). The pace of decline was relatively rapid for ''debility'', diseases of the nervous systems and chronic respiratory diseases in the period 1880–1917 in comparison to the other important causes of death. However, because of a lack of data for the period 1855–1880 we cannot draw firm conclusions as to

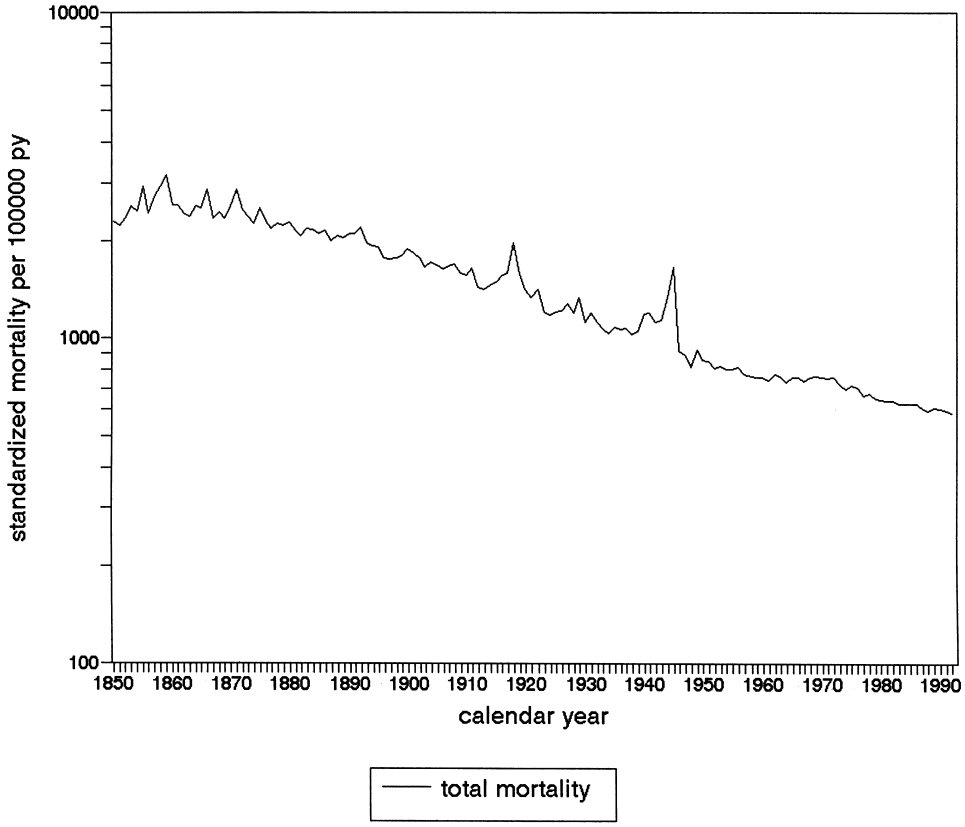

Fig. 2. Total mortality decline in The Netherlands 1850–1992.

which causes of death might be responsible for the acceleration of mortality decline after 1880.

The causes of death mentioned above were still important in 1917, although the percentage of contribution to total mortality had declined. But other causes, *viz*. cerebrovascular disease (6.7%), heart disease (12.4%) and cancer (9.4%) also became prominent. The most rapid acceleration in mortality decline can be seen for respiratory tuberculosis (from 2.0% to 6.6%), acute respiratory diseases (from 0.8% to 4.9%) and diarrhoeal diseases (from 1.6% to 3.5%).

Important causes of death in 1955 were heart disease (30.5%), cancer (19.6%), cerebrovascular disease (13.8%), debility (7.8%), violence (4.5%) and acute respiratory diseases (4.1%). The pace of decline of the, previously rapidly declining, causes of death debility and acute respiratory diseases slightly decelerated in the period 1955–1970 compared to the period 1917–1955. More important, however, are the trends of heart diseases and cancer. The mortality of heart disease reached stability in the period 1955–1970 (0.02% annual change). The stability of this trend was caused by two complementary trends, *viz*. the increasing trend of ischemic heart disease and the decreasing trend of other heart diseases. The pace of increase of cancer mortality was not high in the period 1955–1970, but accelerated in this period (0.9%) compared to the period 1917–1955 (0.2%).

Heart diseases and cancer were the most important causes of death in 1970 (32.9% and 22.9% respectively). The trend of both causes of death changed from an increasing to a decreasing trend after 1970. The same change in trend, but more obvious, was apparent for a less important cause of death i.e. external causes of death (6.3%), and more specifically traffic accidents (3.2%).

The end of rapid mortality decline

A deceleration of mortality decline occurred in the period 1955–1970, which might be regarded as the end of a period of rapid mortality decline. However, mortality started to decline rather rapidly again after 1970 (1.1% annually) (Table 2).

There was even an increase in mortality in the period 1955–1970 for males, but then mortality started to decline again although less progressively than total mortality decline (0.8%). There was no deceleration in female mortality decline that could be labelled as the end of rapid mortality decline (Table 2).

Periods of increasing mortality could only be found for the age groups 15–19, 50–64 and 65–79 all of which were followed by a period of renewed, relatively rapid, decline (Table 2).

Table 3. The contribution of several causes of death to total mortality in turning point years and the rate of change in the periods 1880–1917, 1917–1955, 1955–1970 and 1970–1992

	1880 (% total mortality)	1880–1917 (% annual change)	1917 (% total mortality)	1917–1955 (% annual change)	1955 (% total mortality)	1955–1970 (% annual change)	1970 (% total mortality)	1970–1992 (% annual change)
Debility*	24.96	−2.26	17.74	−2.96	7.75	−2.73	5.03	−0.77
Respiratory tb	9.68	−1.96	8.71	−6.56	0.70	−13.21	0.09	−10.45
Acute respiratory disease	9.74	−0.83	11.72	−4.91	4.10	−4.04	3.70	−2.71
Measles	0.97	−1.17	0.49	−9.46	0.04	−7.80	0.02	eradicated
Diphtheria	1.16	−5.78	0.42	−2.61	0.05	eradicated	0.00	eradicated
Whooping cough	1.08	−2.19	0.70	−7.37	0.03	eradicated	0.00	eradicated
Scarlet fever	0.42	−4.07	0.20	−7.05	0.02	−20.64	0.00	eradicated
Diseases of the nervous system	8.33	−2.38	5.82	−3.53	2.68	−1.52	2.14	0.09
Acute digestive diseases	6.44	−1.63	4.90	−3.46	1.49	−1.02	1.23	−1.02
Cholera	0.13	−7.07	0.02	eradicated	0.00	eradicated	0.00	eradicated
Typhoid fever	0.93	−4.43	0.29	−9.13	0.01	eradicated	0.00	eradicated
Malaria	0.49	−12.06	0.01	−5.20	0.00	eradicated	0.00	eradicated
Smallpox	0.19	−13.50	0.00	eradicated	0.00	eradicated	0.00	eradicated
Scurvy	0.06	−0.24	0.04	−9.77	0.00	eradicated	0.00	eradicated
Puerperal fever	0.08	−1.84	0.13	−8.16	0.01	−4.81	0.00	eradicated
Other diseases of pregnancy	0.61	−2.72	0.29	−2.97	0.16	−10.29	0.03	−4.77
Chronic digestive diseases	3.64	−2.94	2.08	−1.49	2.02	−0.59	1.96	−0.67
Chronic respiratory diseases	8.33	−3.78	3.58	−2.46	2.72	1.86	3.73	0.58
Genito-urinary diseases	2.16	0.44	4.31	−2.05	2.83	−2.05	2.13	−2.31
Cerebrovascular diseases	3.96	−0.08	6.73	−0.13	13.82	−1.77	11.27	−2.44
Diabetes	0.05	6.85	1.05	−1.48	1.69	−0.05	1.42	2.17
Heart disease (total)	4.05	1.99	12.41	0.56	30.46	0.02	32.85	−1.68
IHD	n.a.	n.a.	0.30	8.31	10.80	3.72	21.41	−2.34
Other heart dis.	n.a.	n.a.	12.11	−0.08	19.66	−4.03	11.44	−0.46
Cancer	3.38	1.80	9.39	0.15	19.62	0.90	22.94	−0.07
Arrested development	0.54	−3.08	0.40	2.31	1.67	−1.78	1.38	−1.88
External causes (total)	1.83	−0.75	2.15	1.38	4.49	2.24	6.29	−4.35
Traffic accidents	n.a.	n.a.	0.26	2.91	1.96	3.25	3.23	−5.49
Suicide	0.27	0.63	0.46	−0.45	0.77	0.54	1.02	0.66
Unknown/ill-defined	6.60	−1.20	5.93	−2.57	2.87	−0.45	2.76	−1.04
All causes	100.00	−1.24	100.00	−1.51	100.00	−0.35	100.00	−1.16

*This cause of death category consists predominantly of old age/dementia and diseases of the newly born. More detailed information on all cause of death groups is given in Table 1.

DISCUSSION

Mortality decline in The Netherlands in the period 1850–1992 can be divided into five phases with different paces of decline, *viz*. 1855–1880 (0.8% annually), 1880–1917 (1.2%), 1917–1955 (1.6%), 1955–1970 (0.4%), and 1970–1992 (1.1%). Male mortality figures showed roughly the same phases in mortality decline as total mortality, with the exception of an increase in mortality in the period 1952–1972. Female mortality could only be divided into three periods with different paces of decline *viz*. 1858–1919 (1.1% decline), 1919–1960 (1.8%), and 1960–1992 (1.3%). The most rapid decline was found in nearly all age groups in the period 1917–1955. Causes of death which played a role in the location of the turning points in the total mortality trend are "debility", chronic respiratory diseases, respiratory tuberculosis, diseases of the nervous systems (turning point 1880), acute respiratory diseases, respiratory tuberculosis, diarrhoeal diseases (1917), heart diseases (1955), ischemic heart diseases, cancer (1970).

Before we will discuss these results and the relationship with possible determinants of mortality decline, it is necessary to comment briefly on the data and method that were used in this study.

Evaluation of data and methods

Cause-specific mortality. The reliability of the (cause-specific) mortality data was already briefly mentioned in the introduction. An important characteristic of the Dutch cause-of-death registration is that is has been a medical registration since 1865. Although medical knowledge was not as extensive in the late nineteenth century as it is today, the fact that medical doctors were involved in the certification of causes of death in The Netherlands instead of laymen or clergymen, which was the case in many other European countries (Johansen, 1993; Kintner, 1993; Rogers, 1993), improved the reliability of the Dutch cause-of-death statistics. It took, however, some time before cause of death statistics were considered reliable for medical–statistical research. Although doctors were required to issue a medical certificate of cause of death to the registrar (Medical Practitioners Act 1865), the registrar himself was not obliged to request one. After the Burial Act of 1869, in which a medical certificate with the cause of death stated was required in order to bury someone, the quality of the cause of death statistics improved. Since 1875/79, quinquennial mortality statistics were published by age, sex and cause of death, with identical nomenclature until 1895/99. Those statistics were considered extremely useful to anyone involved in medical–statistical research (van Poppel, 1997). Therefore, cause of death statistics from 1875/79 onwards are used in this study.

The causes of death used in this study are the result of an extensive reclassification procedure. This reclassification was undertaken to create nosologically continuous categories of causes of death, and to reduce the influence of changes in cause-of-death classification on cause-specific mortality trends to a minimum (Wolleswinkel-van den Bosch *et al*., 1996). However, the nosological content of the cause of death categories is also influenced by the accuracy of the diagnosis made by the medical doctors. In particular the difficulties in distinguishing between respiratory tuberculosis and other respiratory diseases has been reported. In the 19th century, respiratory tuberculosis was also known as "phthisis" or "consumption". Phthisis could, however, also occur from other causes than tuberculosis. The accuracy of diagnosing tuberculosis might also have been affected by the stigma attached to tuberculosis in the 19th and early 20th century. Tuberculosis was thought to be hereditary, and families of tuberculosis patients could face problems with their insurance (Hardy, 1988, Bryder, 1996). Bryder points out that there were still diagnostic problems of respiratory tuberculosis in the 20th century despite of bacteriological tests and X-ray facilities (Bryder, 1996).

It is difficult to assess the impact of diagnostic uncertainties on the cause specific mortality results presented in this study. The possibility of exchanges between "respiratory tuberculosis" and "chronic respiratory diseases" or "acute respiratory diseases"(including pneumonia) was mentioned by some Dutch 19th century authors, but considered as a minor problem by others (Evers, 1882; van Vollenhoven, 1889; Saltet, 1909). There are some reports that cases of acute respiratory and digestive diseases in the late nineteenth century might have wrongly been notified as cases of chronic respiratory and digestive diseases, and vice versa (Evers, 1882). The trend of mortality from unknown and ill-defined causes of death might be an indication of development in accuracy of diagnosis. Table 3 shows an acceleration in mortality decline of unknown and ill-defined causes of death in the period 1917–1955 compared to 1880–1917. This suggests an improvement in diagnosis in the period 1917–1955. The rates of change for the causes of death that played a role in the turning point in 1917, i.e. respiratory tuberculosis, acute respiratory diseases, and acute digestive diseases, are much more rapid in the period 1917–1955 than the rate of change of unknown and ill-defined causes of death (cf. Table 3). This suggests that improvements of diagnosis can not explain all of the changes in the trends of those causes of death.

A final remark with respect to cause-of-death categories has to be made on the broad cause-of-death groups present among the 27 causes used in this study. Some of these groups consist of a combination of infectious and non-infectious diseases e.g.

"debility", diseases of the nervous system. It should be kept in mind that the distribution of deaths within these broad groups will change over time from predominantly infectious to non-infectious diseases. The category "diseases of the nervous system" consisted predominantly of (tuberculous) meningitis and convulsions in the late 19th and early 20th centuries, but over time non-communicable diseases such as Parkinson's disease became more important. With respect to "debility" this category consists of a variety of causes (cf. Table 1) including causes related to the "newly born" and causes related to "old age". It is likely that those causes also included infectious diseases. Over time the cause "diseases of the newly born" will more specifically refer to, for example, perinatal mortality and "diseases of old age" to, for example, dementia.

Turning point analysis. In this study turning points in mortality trends from 1850 to 1992 were estimated. In particular during the nineteenth century, mortality was highly fluctuating. Such fluctuations can mask the "real" mortality trend and hamper the estimation of turning points (Suits *et al*., 1978; Perrenoud, 1989). Extremely high mortality peaks due to epidemics or other extraneous events such as war can induce turning points that are solely related to such events. For that reason, the years of the influenza epidemic and the second world war were excluded from the analyses.

The results showed an early turning point around 1855 for most of the analyzed trends, which marked the end of a period of increasing mortality (1850–1855) followed by a period of decreasing mortality (1855–1917). However, it is conceivable that the early years of the 1850s were years with relatively low mortality as a reaction to the high mortality rates during the cholera epidemic in 1848/49. The increase in the period 1850–1855 would then be artificial. We checked this by carrying out an additional analysis for total crude mortality, starting in the year 1804. The data for this analysis were derived from a publication of the Dutch Statistical Bureau (Oomens, 1989), and are only available for total mortality, and not for age and sex-specific mortality. Therefore the analyses presented in this study were based on the period 1850–1992. The years 1847–1849, 1866 and 1871 were excluded from this analysis, because of epidemics in those years *viz*. cholera (1847–1849), smallpox (1866), and cholera again (1871) (cf. Figure 1). The result of the additional analysis for crude mortality shows turning points around 1836, 1870, 1917, 1955, and 1970. Mortality declined with 0.4% annually in the period 1804–1836, with 0.1% annually in the period 1836–1870, and with 1.1% annually in the period 1870–1917. The decline in the other periods is similar to the results of the analysis for the period 1850–1992 (cf. Table 2). This analysis shows that the turning points around 1855 in the total standardized mortality trend and sex, and age-specific mortality trends are likely to be artifacts caused by the preceding cholera epidemic. Therefore, we consider the rapid total standardized mortality decline to have started around 1880 (cf. Table 2).

Big fluctuations also hampered a good estimation of turning points in the trend of age group 80 + . Mortality for this age group was enormously fluctuating from one year to the next until the Second World War. Smoothing the trend by calculating 5-year moving averages did not improve the estimation of the turning points.

Recent changes in the pace of mortality decline, for example changes in the late 1980's, might not have been detected in this type of analysis. The period until 1992 might be to short to detect a turning point. Besides, the rates of change for the most recent period detected in a turning point analysis should not be extended to future years.

The onset and phases of rapid mortality decline: The relationship with determinants of mortality decline

A brief review of the literature on trend and determinants of mortality decline. Secular mortality decline is considered to have started in the mid 18th and early 19th centuries for several European countries e.g. France, England and Wales, Sweden (Wrigley and Schofield, 1981; Perrenoud, 1984; Fridlizius, 1984). Economic changes in the pre-industrial agricultural sector, climatic changes, a changing relationship between host and infective agent (e.g. improved nutritional status of the host) and changing attitudes towards child care have been put forward as determinants of pre-industrial mortality decline. Mortality decline in the late nineteenth century was more rapid and has mostly been related to industrialization (Bengtsson *et al*., 1984), or modernization (Omran, 1971) as the cause of mortality decline.

Many determinants of mortality decline, which started in the late nineteenth century, have been described in the literature. In this paper, we will distinguish four sets of determinants *viz*. socio-economic factors, socio-cultural factors, public health measures and medical factors. *Socio-economic determinants* are regarded as important factors in mortality decline. Industrialization was already mentioned as a determinant of the onset of mortality decline. The early phases of industrialization and urbanization could, however, negatively affect health (e.g. the dusty and damp factories and bad urban sanitary conditions). For Britain, it has been described that living standards did not increase during the early stages of industrialization (Armstrong, 1981; Huck, 1995), and that bad urban sanitary conditions had negative effects on infant health (Woods *et al*., 1988, 1989). For The Netherlands, however, such strong negative health effects have not been reported (de Jonge, 1977). The beneficial effect of industrialization is the improve-

ment of the economic wealth of a country and consequently the improvement in the standard of living of its inhabitants. Aspects of the standard of living that influence mortality are, for example, availability of food, housing and working conditions.

Thomas McKeown considered improved nutritional status as the most important factor of nineteenth century and early twentieth centuries mortality decline (McKeown, 1976a; McKeown, 1976b). Causes of death that are related to nutritional status are, for example, respiratory tuberculosis and acute respiratory diseases (pneumonia). Housing conditions also influence the occurrence of respiratory diseases, but ''diseases of the nervous system'' which consist mainly of meningitis (related to crowding and bad hygiene) might have been influenced by housing conditions too. Working conditions might also have had an effect on respiratory diseases, and probably predominantly on males aged 20–49 and 50–64.

Socio-cultural determinants, have also been brought up as a factor in mortality decline. The Dutch demographer Hofstee came up with a hypothesis in which mortality decline was related to the extent to which new ideas, especially with respect to hygiene, could diffuse in a society. New ideas would be more easily accepted in modern dynamic societies compared to traditional societies (Hofstee, 1979; Hofstee, 1981). The acceptance of certain health ideas would lead to a change in behavior of the population e.g. changing breastfeeding practices and changes in child care in the late 19th and early 20th centuries, or changes in smoking habits in the late 20th century. The effects of changes in breastfeeding practices and child care are expected to be seen in age groups 0, and 1–4, and probably mostly in the cause-of-death category of acute digestive diseases.

Fertility is a determinant of mortality decline which is (partially) determined by cultural factors. There is an interaction between levels of fertility and mortality. Mortality decline can induce fertility decline because more children will survive to adult ages and thus reduce the need for the replacement of children that died. Fertility decline on the other hand can also induce mortality decline. Birth spacing, for example, is negatively associated with child and maternal mortality (Forste, 1994; LeGrand and Philips, 1996).

Another set of determinants of mortality are *public health measures*. One of the main criticizers of McKeowns ''nutrition-thesis'', Szreter, argued that the public health movement working through local governments, and resulting in the implementation of preventive measures of municipal sanitation and regulation of the urban environment, was the true force behind the decline in mortality in the period 1850–1914 (Szreter, 1988). Public health measures such as the construction of sewage and water supply systems predominantly affected mortality from acute digestive diseases, typhoid fever and cholera. The construction of sewage and water supply systems started in The Netherlands in the late 19th century, but a coverage of more than half of the population was not reached until after the turn of the century (Vogelzang, 1956; van Zon, 1986). Economic wealth and the public health movement both played a role in the introduction of these public health measures.

The last set of determinants, *medical care and technology*, became particularly important after the introduction of antibiotics after 1945, but medical determinants might also have played a role before, although it was less important than, for example, economic determinants. Two examples of early effects of medical care are smallpox vaccination and the anti-diphtheria serum. The introduction of smallpox vaccination in the late 18th, early 19th centuries coincided with a considerable decline in smallpox mortality. In the 1870s a resurgence of the epidemic led to an enforcement of vaccination laws in many European countries (Mercer, 1985). In The Netherlands, the Law on Communicable Diseases of 1872 stated that a written confirmation of vaccination against smallpox was required from teachers and children to enter the school. Although mortality rates declined, the effects were not as large compared to countries with compulsory smallpox vaccination (Burgmeijer and Bolscher, 1995). The introduction of anti-diphtheria serum in The Netherlands in 1896 might have influenced the decline of mortality from diphtheria in the late 19th and early 20th century (Saltet, 1909). However, the possibility that a diminishing of bacterial virulence played a role in diphtheria mortality decline has also been suggested (Hardy, 1993).

The First World War had an impact on medicine *viz*. the development of health education induced by the need for fit human resources (Rosen, 1993). In The Netherlands, tuberculosis control was intensified after the First World War. Special tuberculosis clinics were set up. An important role of these clinics was to investigate the social setting of the patient and to give recommendations on the amount and nature of social aid. Besides, the clinic played an important role in health education (Querido, 1968; Sickenga, 1980). It is not likely that the introduction of BCG immunization in 1921 greatly affected mortality due to tuberculosis. In The Netherlands, BCG vaccination has never been applied to the general population. The administration of the BCG vaccine has always been restricted to high risk groups (Burgmeijer and Bolscher, 1995). After the Second World War a new or accelerated mortality decline was found, among other causes of death, for scarlet fever, rheumatic fever, influenza, tuberculosis, bacillary dysentery, which was probably related to the introduction of antibiotics (Mackenbach and Looman, 1988).

In the remainder of this paper we will discuss which determinants of mortality decline are most likely to have played a role in the subsequent changes in the pace of mortality decline in The Netherlands, thereby using the results of the sex, age, and cause-specific analyses.

The onset and first phase of rapid mortality decline in The Netherlands: 1880–1917. The pattern of mortality decline in The Netherlands, i.e. slowly declining mortality in the first half of the 19th century and a progressive decline afterwards (cf. Figure 1), is in accordance with other literature on the start of secular mortality decline in other European countries. The result that rates of change in female mortality were higher during most periods of mortality decline in comparison to males, and that rates of change for younger age groups were generally higher than for adult age groups, are in accordance with Omran's propositions that females were favored over males and children over adults (Omran, 1971, 1983).

Possible Determinants of Decline

Socio-economic determinants. Industrialization was mentioned as an important factor in the onset of mortality decline. In The Netherlands, we find similarities in the timing of mortality decline and industrialization. The first symptoms of industrialization occurred around 1870, and it really started around 1890 (de Jonge, 1977). In the first phase of progressive mortality decline (1880–1917) we then expect to see the effects of industrialization such as the rise in living standards. Real wages increased in The Netherlands from 1870 onwards until 1930. There was an acceleration in the increase in the period 1901–30 compared to the former years (van der Spek, 1976).

Data on nutrition, e.g. calorie-intake, hardly exist in The Netherlands for the late nineteenth and early twentieth centuries. There are, however, some data about the availability of certain foodstuffs per capita such as wheat, rice, potatoes, sugar, and beef which all increased from 1850 until 1882–1886 and stabilized afterwards until 1916 (CBS, 1895; CBS, 1920).

Data on housing and working conditions were also hardly available. Measures to improve housing conditions were taken around 1900 (Querido, 1968). Data on the average number of persons per room show that there were 1.65 persons/room in 1899, 1.43 in 1909, 0.95 in 1930, and 0.80 in 1956 (CBS, 1994). This reduction of the number of persons per room was seen in urbanized as well as rural areas.

Other data that reflect the standard of living are height data of twenty-year-old males that were examined for military service in The Netherlands. Data for the period 1863 to 1941 show a decrease in the percentage of males under 1 m 55 until 1905, a stabilization until 1922 and a renewed decrease after 1922 (CBS, 1900–1940). Bearing in mind that height at age twenty reflects living standards at young ages, a time lag of about 10 to 20 years should be considered to interpret the data on height as a measure of living standards. The height trend might reflect an increase in living standards until 1885/95, a stabilization in the period 1885/95 to 1900/10, and a renewed increase in living standards after 1900/10.

Socio-cultural determinants. Another factor that probably influenced mortality decline in the period 1880–1917 is fertility. Figure 1 shows that birth rates started to decline around 1880. Coale determined the onset of marital fertility decline in The Netherlands in 1897 (Coale and Cott Watkins, 1986), which is included in the period 1880–1917. Fertility rates declined rapidly until 1930, and a renewed decline set in after the Second World War (CBS, 1994).

In the early twentieth century, the percentage of people without religious affiliation sharply increased (CBS, 1994). Secularization is a measure of the culture changes in the modernization process such as rationalization, openness to new ideas.

Public health measures. The effects of public health measures are expected to emerge in the first phase of rapid mortality decline. As mentioned before, the introduction of sewage and water supply systems in many towns started in the late nineteenth century. Other research showed a cluster of causes of death, of which typhoid fever, convulsions and acute digestive diseases declined most rapidly in the late nineteenth and early twentieth centuries (Wolleswinkel-van den Bosch *et al*., 1997).

In this period no large effects of medical factors on mortality decline were expected. Improvements in living standards (probably mainly housing), socio-cultural change (e.g. fertility declines) and public health improvements can all have contributed to mortality decline in the period 1880–1917.

Cause and Age-specific Mortality Decline

Causes of death that greatly contributed to mortality in 1880 are "debility", respiratory tuberculosis, acute respiratory diseases, diseases of the nervous system, chronic respiratory diseases and acute digestive diseases. Among these causes of death "debility", diseases of the nervous system, chronic respiratory diseases and respiratory tuberculosis showed relatively rapid declines in the period 1880–1917 (cf. Table 3), which could indicate that these causes of death were important in the first phase of rapid mortality decline in The Netherlands.

The decline of respiratory tuberculosis, chronic respiratory diseases and diseases of the nervous systems (31% meningitis) might all be related to improvements in housing. Diseases of the nervous systems also covers "convulsions" (42%). Convulsions can be a symptom of various infectious

diseases, but several studies reported a relationship between convulsions and diarrhoeal diseases/dysentery (Kintner, 1986; Wolleswinkel-van den Bosch *et al.*, 1997). Therefore, the decline in mortality from diseases of the nervous system might also be (partially) related to sanitary improvements (public health measures).

The rapid decline in chronic respiratory diseases as well as the turning point in 1880 for age group 20–49 suggest that improved working conditions played a role in mortality decline in the period 1880–1917. However, measures by the central government to improve working conditions were taken as late as 1889. The measures include the Labor Act to reduce working hours, and in 1895, the Factory Safety Act to reduce accidents.

Another cause of death, which showed a rapid decline in the period 1880–1917 was "debility" (predominantly deaths under 5 years of age and "old age"). The mortality trend for age group 1–4 showed a turning point in 1888. According to Evers (1882), the majority of deaths in the category "debility" under the age of 5 was due to poor nutrition. However, cultural changes, for example new ideas on child care, might also have played a role.

We found a turning point around 1875 in the mortality trend for females aged 20–49 (results not shown), and an acceleration of infant mortality decline in 1905. These age-specific mortality declines might be related to the onset of marital fertility decline around 1897 (cf. Table 2).

The period 1917–1955: Acceleration of the decline. After 1917 a period of rapid mortality decline started and lasted nearly four decades (excluding the Second World War). The decline was apparent in male and female mortality and in a young age group (1–4), but was most apparent in adult age groups (15–19, 20–49, 50–64 and 65–79) (cf. Table 2).

Possible Determinants of Decline

Socio-economic determinant. Incomes increased from 1917 until about 1930, but after that period economic recession set in (CBS, 1994). Indicators of living standard more directly related to mortality decline, e.g. housing and nutrition, showed the same pattern as income per head. The number of persons per room continued to decrease until 1930 and stabilized afterwards (CBS, 1994). As far as nutrition is concerned there are only data on the availability of specific foodstuffs and not on calorie-intake. The availability of sugar, cheese, margarine and fresh subtropical fruits increased until about 1930 and stabilized thereafter (CBS, 1994). In the early 1950s new improvements of the socio-economic factors were visible.

Socio-cultural determinants. The percentage people with no religious affiliation strongly increased in this period. Fertility rates further declined until the mid 1930s, and increased thereafter (CBS, 1994).

Medical care and technology. In this period, tuberculosis control became an important issue. After the First World War, tuberculosis clinics were set up. The introduction of antibiotics, after 1945, took place in the last decade of this period. Bearing in mind that the introduction of antibiotics was at the end of the period 1917–1955, the influence of this determinant was probably of minor importance in comparison to other factors in the period 1917–1955.

As far as public health measures are concerned, no important changes occurred in this period.

Cause and Age-specific Mortality Decline

In 1917, the most important causes of death were "debility", acute respiratory diseases, respiratory tuberculosis and heart diseases. Respiratory tuberculosis and acute respiratory diseases (predominantly pneumonia) showed the strongest acceleration of mortality decline in the period 1917–1955 compared to 1880–1917, which indicates that those causes might have played an important role in the acceleration of total mortality decline after 1917.

The decline of respiratory tuberculosis is in accordance with the fact that total mortality decline was predominantly apparent in adult ages, the improvements in socio-economic determinants at the onset of this period, and with the more intensified tuberculosis control. The introduction of antibiotics probably played a role too (Mackenbach and Looman, 1988). Improvements in housing, nutrition and the introduction of antibiotics are all determinants that might also have affected acute respiratory mortality decline. The role of housing conditions in tuberculosis mortality has been clearly shown by McFarlane in his article "Tuberculosis mortality in Glasgow in the period 1911–51". Bad housing acted as a brake on the downward trend of tuberculosis mortality in Glasgow (McFarlane, 1989).

The fact that mortality declines for infants in the period most comparable to the period 1917–1955 (i.e. 1924–1948 cf. Table 2) were a deceleration in mortality decline, and that accelerations in mortality declines occurred predominantly in adult age groups, might indicate that the socio-cultural factors, and public health factors were of minor importance for total mortality decline in the period 1917–1955.

The end and a renewal of mortality decline

The end of rapid mortality decline was reached by 1955. After this year total mortality virtually stabilized until 1970. In literature this period has been marked as the end of the demographic and epidemiologic transition. Chesnais (1992), for example, defined the end of the demographic tran-

sition as a lasting return (at least five years) to an average rate of natural increase which equals or is less than that of the period preceding the starting point. Also, life expectancy has to be at least 73 years for females. A female life expectancy of 73 years was reached in The Netherlands in 1952. The natural increase was on average 10 per 100,000 (ranging from 9.5 to 10.3) in the period 1860/70, and was at about the same level in 1970 (9.9 per 100,000). It has been below that level since 1970. According to Omran's epidemiologic transition theory, mortality eventually approaches stability in the last stage of the epidemiologic transition, which is the case in The Netherlands in the period 1955–1970 (Omran, 1971; Omran, 1983).

However, after 1970 a renewed decline set in, but this decline differed considerably from former periods of decline from an epidemiological point of view. Causes of death which showed an increasing trend before 1970, started to decline from 1970 onwards e.g. ischemic heart disease, some cancers and traffic accidents. These new epidemiological changes have been regarded by some researchers as a fourth stage in the epidemiological transition (Olshansky and Ault, 1986; Rogers and Hackenberg, 1987).

Stabilization of mortality and renewed decline: Cause-specific mortality and determinants. Mortality decline decelerated in the period 1955–1970. Mortality from heart diseases, an important cause of death in 1955, shows a stabilization of the trend in the period 1955–1970 in comparison to the period 1917–1955 (cf. Table 3). This stabilization was caused by two complementary trends: an increase in ischemic heart disease and a decline in other heart diseases. We did find increasing trends in male mortality as well as in age groups 15–19, 50–64, 65–79 in periods similar to 1955–1970. The increase in male and adult mortality corresponds with the increase in ischemic heart disease.

The increase in age group 15–19 might be related to an increase in mortality from violence, which was a less important but relatively rapidly increasing cause of death in the period 1955–1970 in comparison to 1917–1955 (cf. Table 3). Van Poppel regarded smoking as the most important determinant related to the increase in male mortality in the period 1955–1970. The number of cigarettes smoked per year per person aged 10 years and older increased from 1926 onwards until 1979. He found that trends in food consumption and in composition of nutrients were not compatible with trends in mortality from ischemic heart diseases (van Poppel, 1985).

With respect to the renewed decline after 1970, the decline in ischemic heart disease mortality was important. Changes in life-style such as smoking habits, which could be classified under the heading of socio-cultural factors, and medical factors, diagnostic as well as therapeutic measures, all played a role in reducing the death rate due to ischemic heart diseases (Walker, 1977; Kleinmann *et al*., 1979; Crimmins, 1981; van Poppel, 1985). An example of a medical factor that might have contributed to the decline of heart diseases (excluding ischemic heart disease) is the introduction of antibiotics after the Second World War. Heart diseases included rheumatic fever and chronic rheumatic heart diseases which are bacterial infections in origin, and therefore could be influenced by the introduction of antibiotics (Mackenbach and Looman, 1988).

Another aspect of mortality decline after 1970, that is important in the ongoing decline of female mortality, is the shift of mortality to older age groups. This shift is, among others, due to improvements in medical technology and medical care (Olshansky and Ault, 1986).

To conclude

Mortality started to decline rapidly around 1880 in The Netherlands and this lasted until 1955–1970. A new period of mortality decline started around 1970. The turning point analysis resulted in a more objective and more sharply defined onset, phases and end of the epidemiologic transition in The Netherlands compared to mere visual inspection of the trend. Turning point analysis is a statistical device to determine periods with different paces of change in long term processes. As such it is applicable to all types of trend studies e.g. fertility trends.

We were able to point out which causes of death were likely to have influenced the changes in the pace of total mortality decline in The Netherlands. However, to link the changes in cause-of-death mortality to determinants of mortality decline turned out to be a more difficult task. A lower aggregation level than the national level as used in this study would enhance the discriminative power of many determinants. Multivariate regression analyses of e.g. regional data on mortality decline and determinants would be a good statistical method to tie social, economic and medical variables to mortality decline. This paper is part of a larger project on epidemiologic transition in The Netherlands in which results of above mentioned regression analyses are forthcoming.

REFERENCES

Armstrong, W.A. (1981) The trend of mortality in Carlisle between 1780 and the 1840s: a demographic contribution to the standard of living debate. *Economic History Review, 2nd Series* **34,** 94–114.

Beaver, S. E. (1975) *Demographic transition theory reinterpreted*. Lexington Books, Lexington, MA.

De Beer, J. A. A. (1986) Omslagpunten in demografische trends. *Maandstatistiek van de Bevolking* **3,** 29–33.

Bengtsson, T., Fridlizius, G., Ohlsson, R. (1984) *Pre-Industrial Population Change*. Almquist and Wiksell International, Stockholm.

Bryder, L. (1996) Not always one and the same thing: The registration of tuberculosis death in Britain, 1900–1950. *Social History of Medicine* **9,** 253–265.

Burgmeijer, R., Bolscher, N. (Eds.) (1995) Vaccinaties bij kinderen. Uitvoering en achtergronden van het rijksvaccinatieprogramma en andere vaccinaties bij kinderen. Van Gorcum, Assen.

Caldwell, J. C. (1976) Towards a restatement of demographic transition theory. *Population Development Review* **23,** 321–366.

CBS (1895) Bijdragen tot de Statistiek van Nederland. *Onderzoek naar het gebruik van sommige voedings- en genotmiddelen*. Van Weelden en Mingelen, The Hague.

CBS (1920) Maandschrift van het Centraal Bureau voor de Statistiek. *Onderzoek naar het verbruik van sommige voedings- en genotmiddelen 1892–1918*. N.V. Drukkerij Trio, The Hague.

CBS (1900–1940) Jaarcijfers voor het Koninkrijk der Nederlanden. Belinfante/SDU uitgeverij, The Hague.

CBS (1994) *Vijfennegentig jaren statistiek in tijdreeksen*. SDU uitgeverij, The Hague.

Chesnais, J. C. (1992) *The Demographic Transition. Stages, Patterns and Economic Implications*. Oxford University Press, New York.

Coale, A. J., Cott Watkins, S. (Eds.) (1986) *The decline of fertility in Europe*, p. 38. Princeton University Press, Princeton, NJ.

Crimmins, E. M. (1981) The changing pattern of American Mortality Decline, 1940–1977, and its implications for the future. *Population and Development Review* **2,** 229–254.

Evers, J. C. G. (1882) *Bijdrage tot de bevolkingsleer van Nederland*. Belinfante, The Hague.

Forste, R. (1994) The effects of breastfeeding and birth spacing on infant and child mortality in Bolivia. *Population Studies* **48,** 497–511.

Fridlizius, G. (1984) The mortality decline in the first phase of the demographic transition: Swedish experiences. in *Pre-Industrial Population Change*, ed. T. Bengtsson, G. Fridlizius and R. Ohlsson. Almquist and Wiksell International, Stockholm.

Hall, R. E., Johnston, J., Lilien, D. M. (1990) Micro TSP User's Manual. Quantitative Micro Software, Irvine, CA.

Hardy, A. (1988) Diagnosis, death and diet: the case of London, 1750–1909. *Journal of Interdisciplinary History* **19,** 387–401.

Hardy, A. (1993) The epidemic streets. *Infectious disease and the rise of preventive medicine, 1856–1900*. Clarendon Press, Oxford.

Hofstee, E. W. (1979) *De demografische ontwikkeling van Nederland in de eerste helft van de negentiende eeuw*. Van Loghum Slaterus, Deventer.

Hofstee, E. W. (1981) *Korte demografische geschiedenis van Nederland van 1800 tot heden*. Fibula Van Dishoeck, Haarlem.

Huck, P. (1995) Infant mortality and living standards of English workers during the industrial revolution. *Journal of Economic History* **55,** 528–550.

Johansen, H. C. (1993) The Development of Reporting Systems for Causes of Death in Denmark, paper presented at the Conference on the History of Registration of Causes of Death. November 11–14. Bloomington, IN.

de Jonge, J. A. (1977) The role of the outer provinces in the process of Dutch economic growth in the nineteenth century. in *Britain and The Netherlands*, ed. J. S. Bromley, E. H. Kossmann, Vol. IV, Metropolis, Dominion and Province. Martinus Nijhoff, The Hague.

Kendall, M. G. (1973) *Time-Series*. Griffin, London.

Kintner, H. J. (1986) Classifying causes of death during the late nineteenth and early twentieth centuries: the case of German infant mortality. *Historical Methods* **19,** 45–54.

Kintner, H. J. (1993) Recording the Epidemiologic Transition in Germany, 1816 to 1934, paper presented at the Conference on the History of Registration of Causes of Death. November 11–14. Bloomington, IN.

Kleinmann, J. C., Feldman, J. J. and Monk, M. A. (1979) The effects of changes in smoking habits on coronary heart disease mortality. *American Journal of Public Health* **69,** 795–802.

LeGrand, T. K. and Philips, J. F. (1996) The effect of fertility reductions on infant and child mortality: evidence from Matlab in Rural Bangladesh. *Population Studies* **50,** 51–68.

Lumey, L. H. and van Poppel, F. W. A. (1994) The Dutch Famine of 1944–1945: mortality and morbidity in past and present generations. *Social History of Medicine* **7,** 229–246.

Mackenbach, J. P. and Looman, C. W. N. (1988) Secular trends in infectious disease mortality in The Netherlands: quantitative estimates of changes coinciding with the introduction of antibiotics. *International Journal of Epidemiology* **17,** 618–624.

McFarlane, N. (1989) Hospitals, housing, and tuberculosis in Glasgow, 1911–1951. *Social History of Medicine* **2,** 59–85.

McKeown, Th. F. (1976) *The modern rise of population*. Edward Arnold, London.

McKeown, Th. F. (1976) *The role of medicine-dream, mirage or nemesis?*. Nuffield Provincial Hospital Trust, London.

McNeill, D. R., Trussell, T. J. and Turner, J. C. (1977) Spline interpolation of demographic data. *Demography* **14,** 245–252.

Mercer, A. J. (1985) Smallpox and epidemiological-demographic change in Europe: the role of vaccination. *Population Studies* **39,** 287–307.

Omran, A. R. (1971) The epidemiologic transition. A theory of the Epidemiology of Population Change, *The Millbank Memorial Fund Quarterly*, 49, part 1.

Omran, A. R. (1983) The epidemiologic transition theory; a preliminary update. *Journal of Tropical Pediatrics* **29,** 305–316.

Olshansky, S. J. and Ault, A. B. (1986) The fourth stage of the epidemiologic transition: The age of delayed degenerative diseases. *Millbank Memorial Fund Quarterly* **64,** 355–391.

Oomens, C. A. (1989). *De loop der bevolking van Nederland in de negentiende eeuw, CBS statistische onderzoekingen M35*. SDU, The Hague.

Perrenoud, A. (1984). The Mortality Decline in long-term Perspective. in *Pre-Industrial Population Change*. ed. T. Bengtsson, G. Fridlizius, R. Ohlsson. Almquist and Wiksell International, Stockholm.

Perrenoud, A. (1989). Atténuation des Crises et Déclin de la Mortalité, *Annales de Démographie Historique*.

van Poppel, F.W.A. (1985) Reversal of declining mortality-the case of The Netherlands in the period 1950–80. *Maandbericht Gezondheid (Statistics Netherlands)* **November,** 5–19.

van Poppel, F. W. A. (1997) The development of cause-of-death registration in The Netherlands: 1865–1955, *Continuity and Change*, in press.

Querido, M. D. (1968) *The Development of Socio-Medical Care in The Netherlands*. Routledge and Kegan Paul, London.

Rogers, R. G. and Hackenberg, R. (1987) Extending epidemiologic transition theory: A new stage. *Social Biology* **34,** 234–243.

Rogers, J. (1993) Reporting Causes of Death in Sweden 1750–1930: the relationship between the development of

a classification system and its practical implementation. paper presented at the Conference on the History of Registration of Causes of Death. November 11–14. Bloomington, IN.

Rosen, G. (1993) *A History of Public Health*. John Hopkins University Press, Baltimore/London.

Saltet, R. H. (1909) De sterfte aan besmettelijke ziekten in Nederland en in Amsterdam van 1866–1905. *Nederlands Tijdschrift voor Geneeskunde*, 83–92.

Sickenga, F. N. (1980) Korte geschiedenis van de tuberculosebestrijding in Nederland 1900–1960. Koninklijke Nederlandse Centrale Vereniging tot Bestrijding der Tuberculose, The Hague.

van der Spek, J. (1976) Lonen en prijzen vanaf 1870. *Economisch-Statistische Berichten* **November,** 1144–1147.

Suits, D. B., Mason, A. and Chan, L. (1978) Spline functions fitted by standard regression methods. *Review of Economics and Statistics* **60,** 132–139.

Szreter, S. (1988) The importance of social intervention in Britain's mortality decline c. 1850–1914. *Journal of Social History of Medicine* **1,** 1–37.

Tabeau, E., van Poppel, F. W. A. and Willekens, F. (1994) Mortality in The Netherlands: the data base. NIDI report no. 36. Netherlands Interdisciplinary Demographic Institute, The Hague.

Vogelzang, I. (1956) De drinkwatervoorziening van Nederland voor de aanleg van de drinkwaterleidingen. Dutch Thesis, Utrecht.

van Vollenhoven, H. (1889) Twee vijfjarige overzichten. Vergelijkende beschouwingen van sterfte in Nederland 1875–1885. *Nederlands Tijdschrift voor Geneeskunde* **25,** 597–616.

Walker, W. J. (1977) Changing United States life-style and declining vascular mortality: cause or coincidence? *New England Journal of Medicine* **297,** 163–165.

Wolleswinkel-van den Bosch, J. H., van Poppel, F. W. A. and Mackenbach, J. P. (1996) Reclassifying causes of death to study the epidemiological transition in The Netherlands, 1875–1992. *European Journal of Population* **12,** 327–361.

Wolleswinkel-van den Bosch, J. H., Looman, C. W. N., van Poppel, F. W. A. and Mackenbach, J. P. (1997) Cause-specific mortality decline in The Netherlands, 1875–1992: a formal analysis of the epidemiologic transition. *International Journal of Epidemiology* **26,** 772–781.

Woods, R., Watterson, P. and Woodward, J. (1988) The causes of rapid infant mortality decline in England and Wales, 1861–1921, Part I. *Population Studies* **42,** 343–366.

Woods, R., Watterson, P. and Woodward, J. (1989) The causes of rapid infant mortality decline in England and Wales, 1861–1921, Part II. *Population Studies* **43,** 113–132.

Wrigley, E. A. and Schofield, R. S. (1981) *The population History of England, 1541–1871: A Reconstruction*. Edward Arnold, London.

van Zon, H. (1986) Een zeer onfrisse geschiedenis. Studies over niet-industriële vervuiling in Nederland 1850–1920. Dutch thesis, Groningen.