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Stagnation in Mortality Decline Among Elders in The Netherlands

Fanny Janssen, MSc,[1] Wilma J. Nusselder, PhD,[1] Caspar W. N. Looman, MSc,[1] Johan P. Mackenbach, MD, PhD,[1] and Anton E. Kunst, PhD,[1] for NEDCOM[2]

Purpose: This study assesses whether the stagnation of old-age (80+) mortality decline observed in The Netherlands in the 1980s continued in the 1990s and determines which factors contributed to this stagnation. Emphasis is on the role of smoking. - ***Design and Methods:*** Poisson regression analysis with linear splines was applied to total and cause-specific mortality data by age, year of death (1950–1999), and sex. An age–period–cohort analysis was carried out to determine whether the trends followed period or cohort patterns. ICD revisions were bridged by use of a concordance table. ***Results:*** A sudden reversal in old-age mortality decline occurred around 1980, leading to a stagnation of the decline and even increases in mortality thereafter. Smoking-related cancers, chronic obstructive pulmonary disease, and diseases specifically related to old age contributed to this stagnation. Trends in smoking-related cancers and chronic obstructive pulmonary disease showed a cohort pattern—especially for men. When these smoking-related diseases were excluded, the trends in old-age mortality in The Netherlands showed an increasing stagnation for both sexes. ***Implications:*** Smoking behavior can only partly explain the stagnation of mortality. Other factors such as increased frailty and changes in medical and social services for elderly people probably played a more decisive role in the recent stagnation.

Key Words: Trends, Causes of death, Age–period–cohort analysis, Smoking, Frailty

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Address correspondence to Fanny Janssen, Department of Public Health, Erasmus MC, University Medical Center Rotterdam, PO Box 1738, 3000 DR Rotterdam, The Netherlands. E-mail: f.janssen@erasmusmc.nl

[1]Department of Public Health, Erasmus MC, The Netherlands.

[2]The Netherlands Epidemiology and Demography Compression of Morbidity research group, which also includes J. Barendregt,[1] L. Bonneux,[1] C. de Laet,[1] A. Peeters,[1] A. Al Mamun,[3] and F. Willekens.[3]

[3]Population Research Centre, University of Groningen, The Netherlands.

In almost all low-mortality countries, mortality among the elderly population has shown a decrease since 1950, with an accelerated improvement from 1970 onward (Kannisto, 1994; Kannisto, Lauritsen, Thatcher, & Vaupel, 1994; Myers, 1996; Thatcher, 1992). This trend has contributed to the current increase in both the proportion and the mean age of elderly people in these populations. Furthermore, the ongoing reduction in old-age mortality raises interesting questions concerning the extent to which today's populations are approaching a limit to human life expectancy (Fries, 1980; Manton, Stallard, & Tolley, 1991; Oeppen & Vaupel, 2002; Olshansky, Carnes, & Cassel, 1990; Olshansky, Carnes, & Desesquelles, 2001; Vaupel et al., 1998; Wilmoth, 1998).

However, the general pattern of sustained mortality decline among the elderly population since 1970 was not observed in all low-mortality countries. In The Netherlands and Norway, old-age mortality even showed signs of an increase (Kannisto et al., 1994; Nusselder & Mackenbach, 2000; van der Wilk, Achterberg, & Kramers, 2001). This raises the question of whether The Netherlands and Norway can be regarded as precursors of trends in old-age mortality, implying that the same stagnation will happen in other low-mortality countries in the future, or that the stagnation as observed in The Netherlands and Norway is unique and is not likely to occur elsewhere. This led us to study the determinants underlying the stagnation of mortality decline. More specifically, are these unfavorable mortality trends the result of determinants specifically operating in The Netherlands and Norway, or are they the result of factors that may be expected to influence trends in other countries as well?

Here we focus on trends in old-age mortality in The Netherlands. A stagnation of the decrease in mortality in The Netherlands in the 1980s was described by Nusselder and Mackenbach (2000). They found that life expectancy at the age of 85 had decreased for men and had stagnated for women. One of the possible reasons suggested

relates to smoking histories. In The Netherlands, smoking rates among men were exceptionally high during the 20th century (Barendregt, Looman, & Brønnum-Hansen, 2002). In particular, men born between 1897 to 1917 had a high lifetime exposure to smoking (Gunning-Schepers, 1988), and these are the men who reached old age at the end of the 20th century.

Here we describe in more detail the mortality trends among Dutch elderly people in the second half of the 20th century. We will (a) determine whether the stagnation of old-age mortality has persisted in more recent years and (b) explore possible explanations for recent trends in old-age mortality. The contribution of smoking will be emphasized. Because smoking behavior in The Netherlands has been shown to vary markedly between birth cohorts, we assess whether mortality trends are dominated by cohort patterns.

In this analysis we go one step farther than most prior analyses of old-age mortality by analyzing both period and cohort patterns in total mortality as well as in an extensive range of causes of death. We cover trends in the period 1950–1999. Furthermore, in our analysis we made an effort to carefully bridge the different International Classification of Diseases (ICD) revisions.

Methods

Data

In this study, total mortality and population data by single year of age (up to 112), sex, and year of death (1950–1999) have been included for the total Dutch population. In addition, for the causes of death, data were available by three digit codes, 5-year age groups (up to 85+ for 1950–1969; thereafter up to 95+), sex, and year of death (1950–1999). All data were originally obtained from Statistics Netherlands (1996, 1998; Tabeau, van Poppel, & Willekens, 1994). The deaths per cause in the older age groups (85+ or 95+) were redistributed over 5-year age groups up to 100+ on the basis of the distribution of total mortality among these age groups.

We distinguished 26 (groups of) specific and homogeneous causes of death, which were selected predominantly on the basis of their relative importance in old-age mortality. In addition we selected (a) cancers that are strongly (population attributable risk [PAR] larger than 0.50) or moderately (PAR between 0.25 and 0.50) related to smoking, using PARs from the American Cancer Study (Wald & Hackshaw, 1996), and (b) causes that could indicate changes in coding practices. Table 1 lists the causes of death, their accompanying ICD10 codes, and their relative share in all-cause mortality among those aged 80 and older in 1950 and 1999.

Statistical Analysis

We analyzed the data by means of a (log-linear) Poisson regression model. The dependent variable was the number of deaths, with the person-years at risk as offset. As independent variables, we used age (5-year age groups) and year (year of death in the period analysis or birth year in the cohort analysis).

The use of 5-year age groups in all of our analyses—except the one on which Figure 1 is based—was due to the restriction that data on the causes of death were available by 5-year age groups instead of single years of age. To evaluate to what extent a possible change over time in the distribution of deaths within a 5-year age group could affect our results, we compared the results for total mortality by using data by 5 years of age with the results from data by single years of age. Because this comparison generated virtually the same results, we expect that, although age patterns can differ for the specific causes of death, the bias when the data by 5-year age groups are used will be minimal.

For the period analysis, linear splines were used in the regression model to describe mortality trends by year of death. Spline functions accommodate piecewise fits connected with one another at the transition from one segment to the next (McNeil, Trussell, & Turner, 1977). For the period analysis, we used five segments, each covering a period of 10 years (1950–1959, 1960–1969, 1970–1979, 1980–1989, and 1990–1999). The analysis including splines yielded estimates of annual changes in mortality within each 10-year period. Comparison of these five decade-specific rates of change enabled us to detect and quantify changes in the secular trend in mortality, such as a stagnation of the decrease in mortality.

For the cohort analysis, the year of birth was used as independent variable. For this purpose we determined the mean birth year for every combination of a single calendar year and a 5-year age group, taking into account the distribution of the population within this age group. To obtain equal degrees of freedom compared with the age–period model, we divided the range of birth years into five segments as well (1848–1879, 1880–1889, 1890–1899, 1900–1909, and 1910–1936). These five cohort segments were chosen in such a way that approximately the same number of deaths (for those aged 80 and over) occurred in each segment.

In a last step, we fitted a regression model including age, year of death, and birth year, that is, a full age–period–cohort (APC) model. This model was based on the same period and cohort splines as just described. By comparing the scaled deviances (a measure of unexplained variance) of the different models (age, age–period, age–cohort, age–period–cohort), we evaluated the extent to which the secular trends followed a cohort or period pattern. It should be noted that our analysis differs from traditional

Table 1. Causes of Death, Accompanying ICD10 Codes, and Their Relative Share in All-Cause Mortality, by Sex

Cause of Death	ICD10 (1996–1999)	80+ in 1950 (%)		80+ in 1999 (%)	
		Men	Women	Men	Women
Strongly Smoking-Related Cancers					
Esophagus	C15	0.68	0.40	0.55	0.27
Upper resp./digest. system	C00–C14, C30–C32	0.46	0.10	0.34	0.13
Lung	C33–34	0.45	0.15	5.18	0.73
Moderately Smoking-Related Cancers					
Pancreas	C25	0.12	0.09	0.60	0.81
Bladder	C67	0.28	0.23	1.25	0.44
Kidney	C64–C66, C68	0.05	0.05	0.53	0.27
Other cancers[a]	Rest (C00–D48)	1.63	2.83	3.08	3.75
Other Specific Cancers					
Stomach	C16	4.40	3.44	1.11	0.73
Colorectum	C18–C21	1.86	2.00	2.39	2.28
Breast	C50	0.01	1.00	0.05	2.31
Prostate	C61	2.15	0.00	4.75	0.00
Unspecified	C76–C80; C97; D37–D48	0.57	0.59	2.09	2.14
Cardiovascular Diseases					
IHD	I20–I25	11.29	9.71	13.45	10.98
Other heart diseases	I00–I13, I15, I27, I30–I52	18.68	20.77	11.53	14.33
Cerebrovascular diseases	I60–I69	14.40	16.91	9.51	12.55
Other circulatory diseases	Rest (I00–I99)	6.04	5.45	3.56	2.63
Other Causes of Death					
Infectious diseases	A00–B99	0.64	0.74	1.01	1.05
Pneumonia/influenza	J10–J18	5.71	6.11	7.70	7.97
COPD	J40–47	2.79	2.26	8.39	3.23
Accidental fall	W00–W19, X59	1.24	1.67	1.40	2.27
Other external causes	Rest (V01–Y98)	0.96	0.42	0.63	0.30
Diseases Highly Sensitive to Coding Practices					
Diabetes mellitus	E10–E14	0.70	1.47	1.63	2.81
Dementia and Alzheimer's	F00, F01, F03, G30	3.37	3.67	3.97	8.35
Senility	R54	9.55	11.81	1.87	3.48
Other symptoms & ill-defined cond.	Rest (R00–R99)	1.99	1.78	2.83	2.84
Other Diseases	Rest (A00–R99)	9.96	6.34	10.59	13.33
All Causes 80+ (*n*)		7,532	8,665	22,791	40,214

Notes: All-cause mortality is for 1950 and 1999 for people aged 80 and older. ICD = International Classification of Diseases; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease.
[a]This excludes all the cancers listed in this table.

APC analyses, because we evaluate the effects of year of birth by means of splines instead of a nominal variable for 5- or 10-year periods.

The use of splines helped us to overcome the identification problem or drift in APC analysis. Drift has been described as a common linear trend that cannot be ascribed to either period or cohort influences (Clayton & Schifflers, 1987). Because the splines enabled us to identify nonlinear trends, we avoided the identification problem, especially for causes of death showing these nonlinear trends.

We focused in most of these analyses on deaths among people aged 80 and older. We made an exception when identifying underlying cohort patterns (in APC analyses) and analyzing these cohort patterns (in cohort analyses). Because it would not be possible to separate period and cohort effects in an analysis of those 80 years and older, we decided to use the data on deaths among people aged 60 and over.

Concordance

In analyzing the trends for the selected causes of death, we had to bridge four different ICD revisions: ICD6/7 (1950–1968), ICD8 (1969–1978), ICD9 (1979–1995), and ICD10 (1996–1999). To do this, we built on the work of Wolleswinkel-van den Bosch to construct a concordance table in which the different codes for a specific cause of death in successive ICD revisions are linked (Wolleswinkel-van den Bosch, van Poppel, & Mackenbach, 1996). Available information from the World Health Organization, for example, the ICD9 to ICD10 translator (WHO,

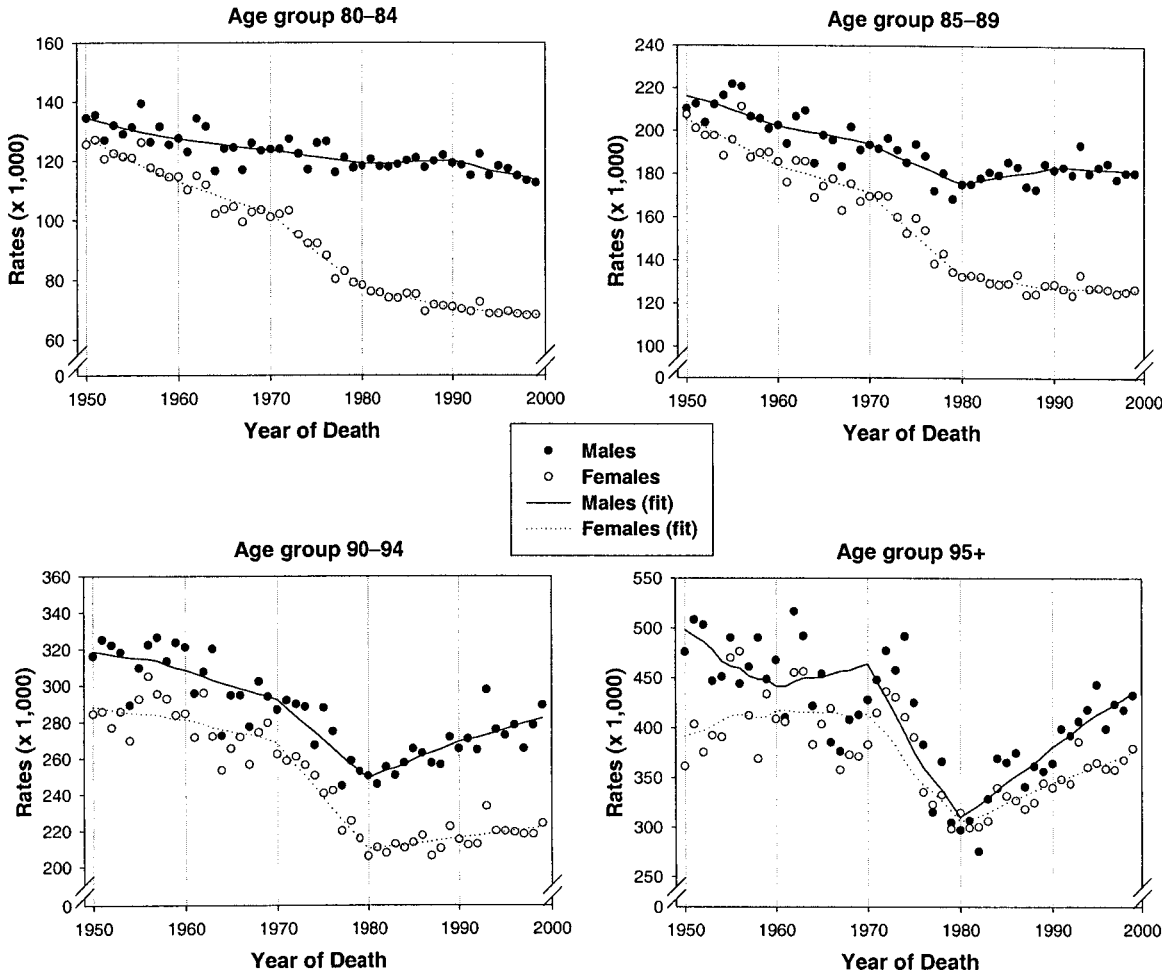

Figure 1. Observed and fitted all-cause mortality rates, for people aged 80 and older, 1950–1999, by sex and 5-year age groups.

1957, 1967, 1977/78, 1993, 1997), and Statistics Netherlands (1997) was used, among others, to extend the existing concordance tables to ICD10. The basic rule applied was that continuity of the medical content of the causes of death should be safeguarded.

Using a prefinal version of the resulting concordance table, we looked at the trends in mortality to check whether sudden changes in mortality at ICD transitions still occurred. Whenever irregularities were found, we checked whether the concordance table could be improved. The final concordance table is presented in the appendix. We made special efforts to accurately bridge the change from ICD6/7 to ICD8 for ischemic heart disease (IHD) by using published data on the four-digit code for IHD under ICD6/7 (Mackenbach, Kunst, Looman, Habbema, & van der Maas, 1988).

After application of the final concordance table, irregularities in the trends caused by ICD transitions persisted for a number of causes of death. We judged these irregularities in our regression model (age–period) by adding variables indicating the three ICD transitions, that is, ICD6/7 to 8, ICD8 to 9, or ICD9 to 10. For nine causes of death, these variables had to be included in the model for one or two transitions. We selected these cases on the basis of the following criteria: (a) the parameter estimate corresponding to this variable had to be statistically significant; (b) the significant effect could not be attributed to nonlinear trends or to a single outlier, for instance an influenza epidemic; and (c) the observed effect could be explained, for example, by a four-digit code not included in the concordance table or an effect on one cause of death mirrored by an opposite effect on a complementary cause of death.

Another problem in analyzing trends by cause of death related to changes within ICD revisions, such as changes in the reporting of causes of death by physicians or in coding rules applied at Statistics Netherlands. This again might have caused irregularities in mortality trends (Meslé & Vallin, 1996). For diabetes mellitus, we had information on the presence of incidental changes in coding rules that had a demonstrable effect on trends in mortality from this cause in the 1980s (Mackenbach, Snels, & Friden-Kill, 1991). To control for it, we included an extra variable in the regression model for this specific cause of death.

For three causes of death, one single year exhibited exceptional mortality levels. For example, in 1953, ''external causes'' showed an enormous increase in mortality because of a flood disaster. In 1980, a strike of medical specialists resulted in high mortality rates for ''other symptoms and ill-defined conditions'' (Mackenbach, 1992). Another outlier occurred in 1971 for diabetes mellitus. These outliers were excluded from the cause-specific analyses.

Results

Total mortality rates for those aged 80 and over (Figure 1) showed a general tendency of a moderate decline in the period 1950–1969 (except for the highest age group) and a steep decline between 1970 and 1979. Around 1980, a sudden reversal of the trend led to stagnation of the decline and even increases in mortality, especially among the highest age groups and for men in the 1980s.

In the first row of Tables 2a and 2b, the pace of mortality decline within each of the five decades is quantified by means of annual rates of change. Male old-age mortality decreased from 1950 to 1979 by annual percentage changes of −0.57, −0.31, and −0.89 for the successive decades. In the 1980s, however, mortality increased by 0.37% per year. The annual percentage change of −0.18 for 1990–1999 suggests a modest reemergence of the decrease in old-age mortality. The confidence intervals for successive decades do not overlap (except for 1950–1959 to 1960–1969), implying that the changes in the pace of mortality decline are statistically significant.

Among women, mortality showed generally the same secular trends, but with important differences. The annual percentage changes indicate a pronounced decrease in the 1970s (−2.67), followed by a leveling off of the mortality decline between 1980 and 1989 (−0.42) and stagnation in the 1990s (+0.06).

Table 2 moreover shows widely different trends for the different causes of death for both sexes. A number of causes of death exhibited unfavorable trends. First, some causes of death underwent a stagnation of an initial mortality decline. For men (Table 2a), this applies for cancer of the esophagus, ''other heart diseases,'' infectious diseases, pneumonia, dementia, and senility. Second, some causes of death underwent a sustained increase in mortality until the 1980s or even the 1990s, such as lung cancer, all the moderately smoking-related cancers, prostate cancer, unspecified cancers, chronic obstructive pulmonary disease (COPD), and ''other symptoms and ill-defined conditions.'' As a result of their long-term increase, these causes gradually had an increased share in total mortality (see also Table 1) and thus their trends had increasingly more effect on the trends observed for all-cause mortality.

For women (Table 2b), the causes of death with an unfavorable trend were almost the same as those for men. However, cancer of the bladder and ''other cancers'' did not show unfavorable trends, and accidental fall exhibited a stagnation of the decrease. Mortality from unspecified cancers and COPD showed a recent increase, instead of the long-term increase observed for men.

To assess whether the trends in both total and cause-specific mortality among those aged 60 and older followed predominantly a period or a cohort pattern, we conducted an APC analysis. In Table 3, the scaled deviances—a measure of the unexplained variance—are given for the age–period (AP) model, the age–cohort (AC) model, and the APC model. They are expressed as percentages of the scaled deviance of the model using age only. The lower the scaled deviance of a model, the better the model is able to describe the trends observed.

For total male mortality, the scaled deviance of the AC model (32%) was much lower than the scaled deviance of the AP model (52%), indicating that the trends predominantly followed a cohort pattern. For women, the scaled deviance of the AC model (11%) was higher than the scaled deviance of the AP model (6%); here, therefore, period patterns contributed more to the trends observed.

For most causes of death, the scaled deviance for the AP model was much lower than the scaled deviance for the AC model, indicating that the secular trends followed a period rather than a cohort pattern. Moreover, the little difference between the scaled deviance for the AP model and that for the APC model suggests that cohort effects, if any, were small. However, for some causes of death, the scaled deviances indicate that secular trends can be explained largely by cohort patterns. This applies to all smoking-related cancers (except for pancreatic cancer among men), prostate cancer, ''other circulatory diseases'' (men only), COPD (men only), and ''other diseases.''

Figure 2 shows the fitted mortality rates by birth year for all-cause mortality and a selection of causes of death, for men aged 80–84. The fitted mortality rates are based on the cohort analysis for those aged 60 and older as a whole. This analysis generated equal parameter estimates for each age group. Figure 2 therefore illustrates the overall cohort pattern for those aged 60 and older.

Total male mortality showed a reversal between birth cohorts 1880–1890 and 1890–1899, with annual percentage changes of −0.49 and 0.78, respectively. An annual percentage change of 0.78 indicates that mortality among those aged 60 and older increased by 0.78% per birth year between 1890 and 1899. Among the cohorts born between 1900 and 1909, mortality stagnated (−0.01); among the youngest birth cohorts, the mortality decline reemerged (−1.31).

Although the trends for the selected causes of death tended to vary, some general tendencies can be distinguished. ''Other diseases'' exhibited an increasing rate of decline in the youngest birth cohorts.

Table 2a. Annual Changes (%) by Period for Total and Cause-Specific Mortality: Men

	1950–1959		1960–1969		1970–1979		1980–1989		1990–1999	
Cause of Death	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Total Mortality	−0.57	(−0.72; −0.41)	−0.31	(−0.42; −0.19)	−0.89	(−0.99; −0.79)	0.37	(0.28; 0.47)	−0.18	(−0.30; −0.06)
Strongly Smoking-Related Cancers										
Esophagus	−4.28	(−6.32; −2.19)	−1.15	(−2.86; 0.59)	−1.70	(−3.29; −0.09)	1.37	(−0.18; 2.94)	2.43	(0.60; 4.29)
Upper resp./digest. system	−1.97	(−4.42; 0.54)	0.99	(−0.87; 2.89)	−0.94	(−2.54; 0.69)	−0.75	(−2.32; 0.84)	−1.70	(−3.74; 0.38)
Lung	6.96	(5.11; 8.86)	8.19	(7.21; 9.18)	7.55	(6.95; 8.16)	1.85	(1.42; 2.29)	−1.97	(−2.47; −1.47)
Moderately Smoking-Related Cancers										
Pancreas	10.05	(6.44; 13.79)	4.84	(3.04; 6.67)	2.40	(1.12; 3.69)	0.05	(−1.06; 1.16)	−2.05	(−3.44; −0.64)
Bladder	4.94	(2.63; 7.29)	2.75	(1.38; 4.14)	1.66	(0.61; 2.71)	1.78	(0.87; 2.69)	−1.73	(−2.82; −0.63)
Kidney	10.93	(4.50; 17.75)	3.41	(0.29; 6.64)	5.70	(3.46; 7.98)	3.94	(2.27; 5.63)	1.01	(−0.78; 2.82)
Other cancers[a]	1.51	(0.27; 2.76)	1.77	(0.48; 3.08)	2.36	(1.59; 3.13)	1.71	(1.10; 2.32)	0.24	(−0.47; 0.95)
Other Specific Cancers										
Stomach	−1.63	(−2.42; −0.83)	−1.98	(−2.60; −1.35)	−3.36	(−3.97; −2.75)	−2.68	(−3.35; −2.01)	−5.71	(−6.69; −4.73)
Colorectum	0.95	(−0.18; 2.08)	0.81	(0.04; 1.59)	0.78	(0.14; 1.44)	−0.54	(−1.13; 0.07)	−0.90	(−1.67; −0.13)
Prostate	3.22	(2.19; 4.25)	1.57	(0.92; 2.22)	0.14	(−0.39; 0.67)	2.16	(1.68; 2.64)	0.78	(0.23; 1.34)
Unspecified	8.75	(6.37; 11.20)	1.81	(−0.17; 3.83)	−2.36	(−3.23; −1.48)	2.35	(1.56; 3.15)	2.78	(1.88; 3.69)
Cardiovascular Diseases										
IHD	3.85	(3.41; 4.29)	1.32	(1.03; 1.60)	−0.32	(−0.68; 0.05)	−1.41	(−1.65; −1.16)	−2.41	(−2.71; −2.10)
Other heart diseases	−1.57	(−1.96; −1.19)	−3.46	(−3.77; −3.15)	−0.63	(−1.09; −0.16)	−2.17	(−2.46; −1.88)	0.68	(0.32; 1.04)
Cerebrovascular diseases	0.81	(0.41; 1.21)	−1.86	(−2.14; −1.57)	−2.78	(−3.06; −2.51)	−0.99	(−1.27; −0.70)	−1.76	(−2.13; −1.38)
Other circulatory diseases	−1.12	(−1.76; −0.47)	−3.98	(−4.73; −3.22)	−5.78	(−6.54; −5.01)	2.96	(2.39; 3.52)	−2.83	(−3.44; −2.21)
Other Causes of Death										
Infectious diseases	−5.34	(−7.57; −3.05)	−2.33	(−5.28; 0.73)	−2.92	(−4.45; −1.36)	2.97	(1.57; 4.39)	6.32	(4.80; 7.87)
Pneumonia	−2.77	(−3.43; −2.11)	−5.41	(−6.23; −4.59)	−3.27	(−3.72; −2.82)	0.07	(−0.35; 0.49)	5.28	(4.77; 5.79)
COPD	0.03	(−0.94; 1.00)	4.11	(3.45; 4.77)	2.40	(1.92; 2.88)	4.86	(4.47; 5.26)	−0.69	(−1.11; −0.27)
Accidental fall	4.19	(2.85; 5.55)	2.85	(2.03; 3.68)	−4.77	(−5.43; −4.11)	−1.17	(−1.88; −0.44)	−2.04	(−3.00; −1.06)
Other external causes	3.40	(1.75; 5.08)	−0.78	(−1.82; 0.27)	−2.27	(−3.22; −1.32)	−1.19	(−2.17; −0.20)	−3.60	(−4.92; −2.25)
Diseases Strongly Sensitive to Coding Practices										
Diabetes	4.62	(2.94; 6.33)	−0.18	(−1.79; 1.45)	−0.99	(−2.78; 0.83)	0.21	(−2.09; 2.56)	−2.38	(−3.34; −1.41)
Dementia	−10.77	(−11.89; −9.63)	4.59	(3.46; 5.74)	−14.48	(−15.47; −13.47)	14.14	(12.90; 15.40)	15.63	(14.67; 16.59)
Senility	−8.97	(−9.56; −8.38)	−7.72	(−8.33; −7.11)	−4.21	(−4.91; −3.51)	−0.35	(−1.10; 0.40)	2.64	(1.69; 3.59)
Other symptoms & ill-defined cond.	−2.84	(−3.95; −1.72)	2.25	(1.37; 3.13)	4.86	(3.80; 5.93)	2.71	(1.81; 3.62)	4.03	(3.19; 4.89)
Other Diseases	−0.60	(−1.11; −0.08)	−1.22	(−1.59; −0.84)	0.51	(0.18; 0.85)	1.79	(1.49; 2.10)	−1.92	(−2.29; −1.55)

Notes: Mortalities are for people aged 80 and older. CI = confidence interval; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease.
[a]This refers to the cause of death "other cancers" as listed in Table 1.

Table 2b. Annual Changes (%) by Period for Total and Cause-Specific Mortality: Women

Cause of Death	1950–1959		1960–1969		1970–1979		1980–1989		1990–1999	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Total Mortality	−1.08	(−1.23; −0.94)	−0.81	(−0.92; −0.70)	−2.67	(−2.76; −2.58)	−0.42	(−0.50; −0.33)	0.06	(−0.04; 0.15)
Strongly Smoking-Related Cancers										
Esophagus	−6.50	(−8.95; −3.98)	−1.44	(−3.57; 0.73)	−0.81	(−2.62; 1.04)	1.75	(0.21; 3.31)	−0.40	(−2.09; 1.32)
Upper resp./digest. system	0.17	(−3.84; 4.35)	−2.46	(−5.29; 0.46)	0.76	(−1.67; 3.26)	−2.03	(−4.07; 0.05)	−0.44	(−2.95; 2.13)
Lung	5.39	(1.92; 8.98)	−0.47	(−2.48; 1.58)	4.92	(3.38; 6.49)	0.87	(−0.22; 1.96)	2.63	(1.45; 3.83)
Moderately Smoking-Related Cancers										
Pancreas	10.88	(7.15; 14.75)	4.47	(2.70; 6.27)	1.64	(0.48; 2.81)	0.94	(0.04; 1.85)	−1.25	(−2.27; −0.22)
Bladder	2.05	(−0.81; 4.99)	0.61	(−1.25; 2.50)	−1.10	(−2.55; 0.36)	1.23	(−0.01; 2.48)	−2.16	(−3.56; −0.73)
Kidney	6.00	(−0.09; 12.46)	4.69	(1.34; 8.15)	4.32	(2.15; 6.53)	1.63	(0.10; 3.19)	−0.96	(−2.65; 0.75)
Other cancers[a]	0.36	(−0.55; 1.27)	0.52	(−0.46; 1.50)	0.47	(−0.07; 1.01)	0.60	(0.19; 1.01)	−0.63	(−1.10; −0.17)
Other Specific Cancers										
Stomach	−2.80	(−3.62; −1.97)	−2.44	(−3.09; −1.79)	−6.03	(−6.64; −5.42)	−3.48	(−4.14; −2.82)	−5.36	(−6.27; −4.44)
Colorectum	0.09	(−0.94; 1.14)	0.85	(0.14; 1.56)	−1.02	(−1.57; −0.46)	−1.01	(−1.49; −0.52)	−1.93	(−2.51; −1.34)
Breast	3.71	(2.31; 5.12)	1.24	(0.39; 2.09)	−0.46	(−1.10; 0.18)	0.57	(0.04; 1.11)	−0.35	(−0.96; 0.26)
Unspecified	7.53	(5.66; 9.43)	1.95	(0.38; 3.56)	−5.15	(−5.81; −4.48)	−0.01	(−0.61; 0.59)	2.23	(1.55; 2.92)
Cardiovascular Diseases										
IHD	3.19	(2.76; 3.62)	0.32	(0.04; 0.60)	−0.95	(−1.29; −0.61)	−2.18	(−2.39; −1.96)	−3.02	(−3.28; −2.77)
Other heart diseases	−1.63	(−1.96; −1.29)	−3.57	(−3.83; −3.30)	−1.80	(−2.17; −1.43)	−2.04	(−2.25; −1.82)	−0.41	(−0.66; −0.17)
Cerebrovascular diseases	0.53	(0.18; 0.88)	−2.35	(−2.59; −2.10)	−3.62	(−3.84; −3.41)	−0.90	(−1.11; −0.70)	−1.70	(−1.95; −1.45)
Other circulatory diseases	−0.21	(−0.84; 0.42)	−4.25	(−4.95; −3.55)	−8.37	(−9.01; −7.72)	0.18	(−0.28; 0.65)	−4.56	(−5.07; −4.04)
Other Causes of Death										
Infectious diseases	−7.45	(−9.72; −5.12)	−3.34	(−6.51; −0.08)	−7.12	(−8.35; −5.88)	4.81	(3.68; 5.96)	5.31	(4.22; 6.41)
Pneumonia	−4.23	(−4.85; −3.61)	−4.85	(−5.63; −4.05)	−3.91	(−4.31; −3.50)	−0.89	(−1.23; −0.54)	4.69	(4.30; 5.08)
COPD	−2.43	(−3.56; −1.28)	0.18	(−0.67; 1.04)	−2.21	(−2.89; −1.54)	4.61	(4.04; 5.18)	1.38	(0.82; 1.95)
Accidental fall	5.01	(4.00; 6.02)	4.35	(3.77; 4.93)	−7.01	(−7.43; −6.58)	−4.74	(−5.18; −4.29)	−1.62	(−2.24; −1.01)
Other external causes	0.91	(−1.56; 3.44)	−0.60	(−2.23; 1.06)	−2.90	(−4.24; −1.53)	2.41	(1.17; 3.66)	−5.12	(−6.52; −3.69)
Diseases Strongly Sensitive to Coding Practices										
Diabetes	2.32	(1.22; 3.43)	−0.65	(−1.77; 0.47)	−2.87	(−4.09; −1.64)	−1.39	(−2.77; 0.00)	−2.79	(−3.36; −2.21)
Dementia	−10.08	(−11.04; −9.12)	5.07	(4.16; 6.00)	−14.70	(−15.39; −14.00)	15.69	(14.90; 16.49)	15.24	(14.72; 15.75)
Senility	−8.97	(−9.48; −8.46)	−7.60	(−8.11; −7.09)	−4.87	(−5.41; −4.33)	−0.97	(−1.48; −0.45)	4.54	(3.96; 5.12)
Other symptoms & ill-defined cond.	−3.31	(−4.50; −2.11)	2.62	(1.70; 3.55)	5.48	(4.45; 6.51)	1.04	(0.30; 1.77)	4.45	(3.78; 5.13)
Other Diseases	−0.26	(−0.87; 0.34)	0.83	(0.42; 1.25)	1.80	(1.50; 2.11)	2.02	(1.79; 2.26)	−1.67	(−1.93; −1.42)

Notes: Mortalities are for people aged 80 and older. CI = confidence interval; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease.
[a]This refers to the cause of death "other cancers" as listed in Table 1.

Table 3. Scaled Deviances of Different Models for Total and Cause-Specific Mortality, by Sex

Scaled Deviance[a]	Men				Women			
	Age	AP	AC	APC	Age	AP	AC	APC
Total Mortality	14,773	52	32	14	83,429	6	11	4
Strongly Smoking-Related Cancers								
Esophagus	1,392	49	28	25	613	76	65	60
Upper resp./digest. system	497	94	86	74	482	92	77	75
Lung	30,838	23	5	2	6,952	15	8	7
Moderately Smoking-Related Cancers								
Pancreas	2,000	22	33	17	1,311	41	37	33
Bladder	1,431	39	33	27	447	93	90	87
Kidney	1,950	27	18	17	944	49	44	43
Other cancers[b]	3,706	14	11	10	862	88	66	60
Other Specific Cancers								
Stomach	14,652	4	4	4	19,646	3	3	2
Colorectum	554	81	88	77	1,302	39	40	35
Breast					645	77	73	68
Prostate	1,917	44	39	35				
Unspecified	2,234	36	55	33	1,589	44	78	40
Cardiovascular Diseases								
IHD	21,417	13	56	6	16,509	9	33	8
Other heart diseases	18,773	10	9	7	46,804	8	11	2
Cerebrovascular diseases	16,899	7	7	5	43,900	8	6	3
Other circulatory diseases	7,155	70	27	13	20,387	8	8	5
Other Causes of Death								
Infectious diseases	5,070	27	64	11	5,966	20	65	8
Pneumonia	19,383	16	46	11	27,661	17	44	9
COPD	13,007	46	15	10	2,971	26	70	21
Accidental fall	2,159	27	36	20	10,919	11	17	5
Other external causes	4,296	13	18	11	1,492	41	49	35
Diseases Strongly Sensitive to Coding Practices								
Diabetes	23,786	8	27	8	8,883	19	16	14
Dementia	7,680	17	66	16	19,980	11	56	10
Senility	13,588	14	27	8	22,328	17	34	7
Other symptoms & ill-defined cond.	7,206	13	22	12	5,285	16	26	16
Other Diseases	4,562	60	50	20	9,852	86	59	12

Notes: Mortalities are for people aged 60 and older. AP = regression model with age and period splines as independent variables; AC = regression model with age and cohort splines as independent variables; APC = regression model with age, period splines, and cohort splines as independent variables; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease.

[a]Expressed as percentage of the scaled deviance of the model including only age.

[b]This refers to the cause of death "other cancers" as listed in Table 1.

Lung cancer and COPD followed a pattern of an increase in the oldest birth cohorts up to 1890–1899, changing to a decrease for those born after 1910. For cancer of the pancreas, bladder, and kidney, the same pattern applies, although it is less clear. Cancer of the esophagus and cancer of the upper respiratory or digestive system followed a different pattern, with a clear stagnation of the mortality decline and an increase among the youngest cohorts.

For total female mortality, the cohort trends did not show an increase in mortality for a particular cohort group but instead a declining trend throughout, with only a modest stagnation of the mortality decline for the youngest birth cohort. The annual percentage changes were −0.45, −1.86, −1.35, −1.57, and −1.08 for the successive cohort groups.

Table 4 shows the period trends that would be observed for all-cause mortality when smoking-related cancers and COPD are excluded. After their exclusion, stagnation of mortality decline during the 1980s and 1990s still prevailed. For men, the annual percentage changes would be −0.21 in the period 1980–1989 and 0.00 in the period 1990–1999. For women, these percentages would be −0.63 and 0.06 in the successive decades. Thus, after a number of causes of death specifically related to smoking were excluded, the trends in all-cause mortality for men and women showed a uniform pattern of a leveling

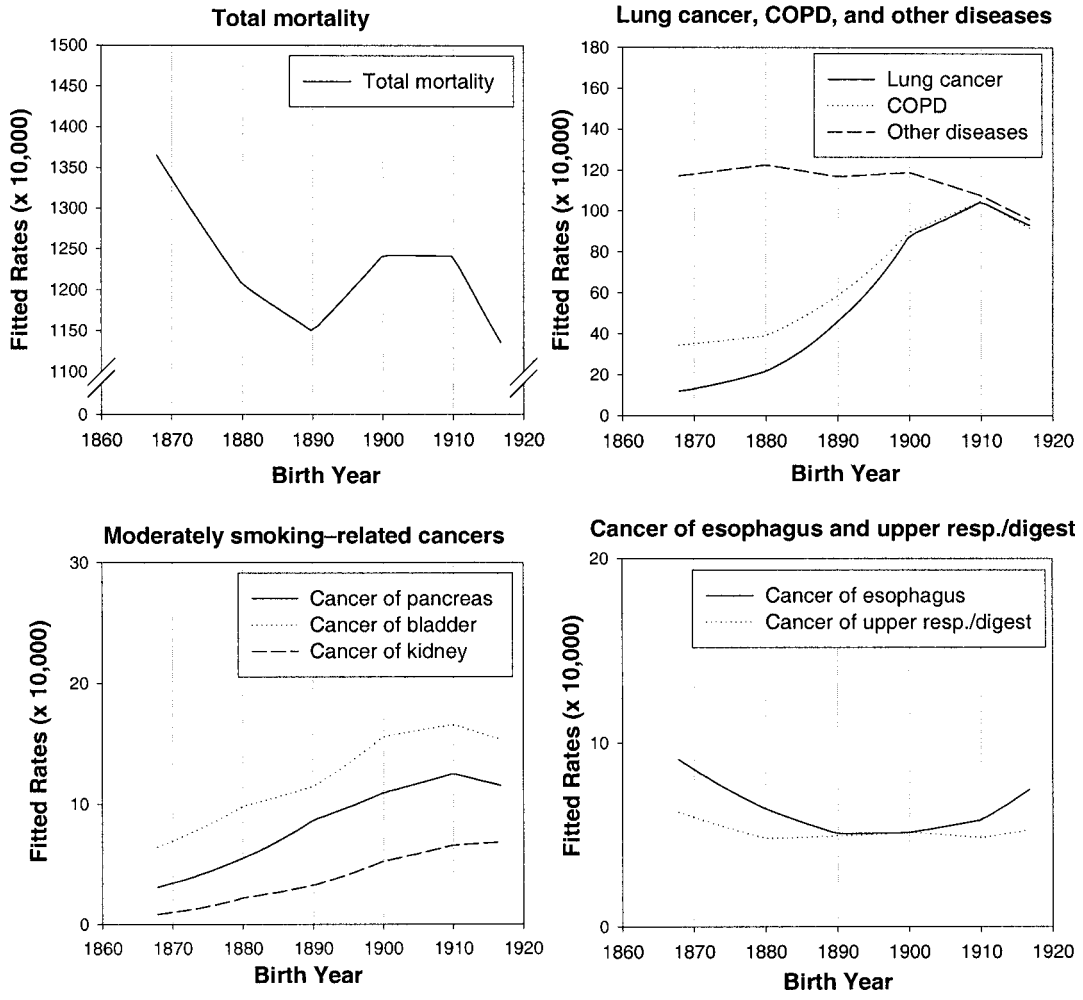

Figure 2. Fitted mortality rates by cohort for total mortality, smoking-related cancers, chronic obstructive pulmonary disease (COPD), and "other diseases" (as listed in Table 1) for men aged 80–84.

off of the mortality decline in the 1980s and complete stagnation in the 1990s.

Further analysis revealed that, when the smoking-related cancers and COPD are excluded, the period and cohort models both can describe the observed trends for all-cause mortality. The scaled deviance for the AP model (as compared with the model with age only) was 6% for men and 7% for women. For the AC model, the scaled deviances were only slightly higher, that is, 11% for men and 10% for women.

Discussion

Compared with previous research (Nusselder & Mackenbach, 2000), this study has provided important new findings on the stagnation of old-age mortality in The Netherlands. First, a sudden reversal occurred around 1980, when the marked mortality decline of the 1970s turned into stagnation and in some cases even an increase during the 1980s and 1990s. Second, the causes of death contributing to the stagnation of the mortality decline are predominantly smoking-related diseases and diseases specifically related to old age. Third, among men, trends for smoking-related cancers and COPD followed a cohort pattern, which suggests an important role for differences between successive generations in exposure to smoking. Fourth, when these smoking-related diseases are excluded, the trends in all-cause mortality were found to follow a pattern of increasing stagnation for both men and women.

These results strongly suggest that, even though cohort changes in smoking exposure influenced the trends in mortality among older men in the 1980s, these changes do not fully explain the recent stagnation of mortality observed among elderly Dutch men and women. Before we can speculate on the role of other specific factors, possible bias caused by data problems or the methods used in our analysis should be evaluated.

Evaluation of Data Problems

The mortality and population data used in this study come from the municipal population registers. Data from the Dutch population registers are

Table 4. Annual Changes (%) by Period for TM and TM After Exclusions, by Sex

Cause of Death	1950–1959		1960–1969		1970–1979		1980–1989		1990–1999	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Men										
Total	−0.57	(−0.72; −0.41)	−0.31	(−0.42; −0.19)	−0.89	(−0.99; −0.79)	0.37	(0.28; 0.47)	−0.18	(−0.30; −0.06)
Total after exclusions	−0.75	(−0.91; −0.58)	−0.68	(−0.80; −0.56)	−1.55	(−1.66; −1.44)	−0.21	(−0.32; −0.11)	0.00	(−0.14; 0.13)
Women										
Total	−1.08	(−1.23; −0.94)	−0.81	(−0.92; −0.70)	−2.67	(−2.76; −2.58)	−0.42	(−0.50; −0.33)	0.06	(−0.04; 0.15)
Total after exclusions	−1.17	(−1.32; −1.01)	−0.85	(−0.96; −0.74)	−2.87	(−2.96; −2.78)	−0.63	(−0.71; −0.54)	0.06	(−0.04; 0.16)

Notes: Exclusions are for smoking-related cancers and chronic obstructive pulmonary disease. Mortalities are for people aged 80 and older. TM = total mortality; CI = confidence interval.

considered reliable and consistent (Condran, Himes, & Preton, 1991). The use of an individual-based register, which is started at the birth of an individual and contains all major demographic events throughout life, ensures that age misstatement cannot have affected our mortality rates. Because both population and mortality data are derived from the same source, the mortality rates are not subject to numerator–denominator bias (Kannisto, 1994).

Analyses of long-term trends in causes of death have to deal with several transitions between ICD revisions. We made considerable effort to bridge these ICD revisions by carefully constructing a concordance table and by controlling for the few remaining jumps in our regression analysis. Further checks showed minimal sensitivity. Thus, even though some residual effects of ICD transitions could not be excluded, we believe that these problems did not affect the results to any substantial extent.

More difficult to tackle were changes within an ICD revision, either in the reporting of causes of death by physicians or in coding practices at the Statistical Office. The causes of death expected to suffer substantial effects are diabetes mellitus, dementia, senility, and "other symptoms and ill-defined conditions." The recent observed increase in mortality from "other symptoms" could indicate less detailed and less accurate diagnoses. The increase in senility and dementia, however, is probably due to the growing propensity of physicians to report these diseases as underlying causes of death. An increase in the doctor's tendency to list only one cause on the death certificate may have the effect that diseases that were formerly reported mainly as secondary causes of death are increasingly listed as primary causes of death. In particular, this might influence trends in mortality from diabetes and pneumonia, which are common secondary causes of death in The Netherlands (Mackenbach, Kunst, Lautenbach, Bijlsma, & Oei, 1995).

In view of these possibilities, we should be cautious about interpreting the marked increases in mortality observed for the causes of death mentioned herein. In addition, these increases in mortality will in some cases have an opposite effect on other diseases. For example, an increasing tendency to report diabetes mellitus as the underlying cause of death may result in an underestimation of an increase (or overestimation of a decrease) in mortality from cardiovascular diseases. However, the potential for bias should not be generalized to all causes. Some causes of death may be relatively resistant to changes in coding practices, especially those diseases that have a more straightforward diagnosis. This applies to most of the smoking-related cancers and probably COPD as well.

Evaluation of Methods

As far as the APC analysis was concerned, we were aware of the identification problem. We solved this problem by assessing predominantly nonlinear trends, using splines within our regression models. Moreover, by comparing the scaled deviances of the AP model and the AC model, we could make valid statements on the role of period or cohort patterns in the trends observed, especially when the scaled deviances of these two models showed large differences. Such a large difference was observed in several cases, including smoking-related cancers and COPD.

Explanations of the Observed Trends

Smoking is frequently mentioned in the literature (Caselli, 1996; Caselli & Lopez, 1996; van der Wilk et al., 2001) to explain some of the unfavorable trends in mortality in The Netherlands compared with other European or low-mortality countries. In our analysis, we found that although smoking contributed to the stagnation of the mortality decline among men in the 1980s, mortality from smoking-related cancers and COPD decreased in the 1990s and among the youngest birth cohorts. In addition, when smoking-related cancers and COPD were excluded from all-cause mortality, the stagnation of mortality still occurred and was consistent among both men and women. It should be noted that only smoking-related diseases with a clear cohort pattern were excluded, thus ignoring the period effects of smoking on some other causes of death. In The Netherlands, the period pattern of recent changes in smoking behavior is likely to have a favorable effect on mortality in the 1980s and 1990s (Barendregt, Looman, & Brønnum-Hansen, 2002), especially for cardiovascular diseases. This is due to a decline in smoking prevalence observed among Dutch men (65+) since the 1970s (Stivoro, 2001). If these period effects were to be taken into account, then an even stronger increase in old-age mortality might become apparent. Thus, to explain the stagnation of old-age mortality in The Netherlands, we should look beyond the role of smoking.

The first possible explanation is that there is simply no room for further improvement in mortality among the Dutch elderly population, because low levels of mortality have already been reached. Although mean life expectancy at age 80 in The Netherlands in the period 1980–1990 was quite high, that is, 7.60 years, this level was already surpassed by other countries, such as Iceland ($e_{80} = 8.18$) and Japan ($e_{80} = 7.67$; Kannisto 1996). Moreover, in those countries with equal or higher levels of life expectancy, the decrease in mortality persisted (Vaupel et al., 1998). This suggests that the unfavorable trends in old-age mortality as observed in The Netherlands cannot be simply understood from low levels of mortality already attained or a limit to life expectancy being approached.

A second possible explanation for the stagnating trends could be mortality selection. As a result of the reduction in old-age mortality in the decades before the 1980s, an increasing proportion of people born in successive generations has reached old age. It is likely that this increasing proportion of elderly people does not include only the fittest but also those who are more frail. Improvements in medical care are frequently mentioned as an important reason for the marked mortality decline in the 1970s (Mackenbach, Looman, Kunst, Habbema, & van der Maas, 1988; Wolleswinkel-van den Bosch, Looman, Van Poppel, & Mackenbach, 1997; Wolleswinkel-van den Bosch, van Poppel, Tabeau, & Mackenbach, 1998), which strengthens our hypothesis on the decline in mortality selection. This decline in mortality selection could perhaps explain the relatively strong increase in mortality from diseases related to frailty—such as infectious diseases—compared with the continued mortality decline in cardiovascular diseases. However, even though mortality selection may have played a role in the stagnation of the mortality decline, it cannot explain why mortality trends are much less favorable in The Netherlands than in other low-mortality countries.

A particular feature of Dutch society is the relatively liberal attitude toward euthanasia and related end-of-life decisions. The most frequently made end-of-life decision for elderly people in The Netherlands is the decision to withhold life-prolonging treatment (van der Maas, van Delden, Pijnenborg, & Looman, 1991). These decisions refer not only to technological interventions but also and most frequently to the withdrawal or withholding of antibiotics and artificial nutrition or hydration (Groenewoud et al., 2000). Whereas in 1990, 33% of all deaths among those aged 80 and older were preceded by a nontreatment decision, this had increased to 36% in 1995 (Groenewoud et al., 2000; Pijnenborg et al., 1995). This increasing incidence might reflect the growing autonomy of patients, who want to decide for themselves whether or not to undergo treatment. However, it is likely that the growing incidence is also the result of increased possibilities for treatment. With more alternatives available, the decision to withhold a particular treatment will be made more often. In addition, the estimated effect of the decision to withhold treatment on the patient's life expectancy was less than 1 month in approximately 90% of cases (Groenewoud et al., 2000). From more detailed data, we estimated that the effect on life expectancy among the Dutch elderly population is a loss of approximately 0.01 year. The effects of medical decisions related to the end of life on Dutch mortality trends thus seem to be negligible.

The abrupt reversal around 1980, from a marked mortality decline in the 1970s to stagnation

thereafter, raises the question of which parallel changes occurred in The Netherlands at the same time or shortly before. In the period 1975–1985, concern focused on health care costs, and budget cuts were proposed by the Dutch government (van der Grinten et al., 1996). When health care resources become limited, elderly people are often the first group to suffer, because medical costs rise exponentially with age. However, it is unclear when and to what extent the concern prevalent in this period had an effect on the health care services delivered to the elderly population.

Changes also occurred in the health care and social services available for elderly people. In The Netherlands between World War II and 1975, care for elders was a central issue of the welfare state. Considerable effort and resources were spent on institutionalization and intramural care for elderly people (Knipscheer, 1996). Since 1975, however, Dutch policies have shifted and the emphasis has changed to facilities for elders that enable them to stay at home longer—in parallel with the growing autonomy among the elderly population. This trend could have made this group more reliant on informal or private care (Knipscheer, 1996). Combined with the increase in the number of elderly people living alone and the decrease in social support with age (Knipscheer, De Jong Gierveld, van Tilburg, & Dykstra, 1995), this may have resulted in more elderly people without sufficient care, which ultimately might have a negative effect on their length of life. In contrast, the decline in institutionalization might also have had positive effects on old-age mortality, for example, as a result of physical activity and self-sufficiency. It is unclear whether these positive effects can outweigh the negative effects.

Although the factors discussed herein remain somewhat speculative, they suggest that several developments contributed to the unfavorable mortality trends among the oldest old in The Netherlands. The stagnation of mortality decline is most likely explained by a combination of the growing frailty of the Dutch elderly population together with changes in the medical and social services available to them. Because these factors are determined by developments that are not necessarily restricted to The Netherlands, this implies that a continuing decline in old-age mortality in other low-mortality countries should no longer be taken for granted. Although mortality at old age is remarkably plastic and has the potential for further reduction (Vaupel, 1997), changes in the possible determinants discussed here may well result in an increase in old-age mortality.

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Appendix

The Concordance Table to Bridge the ICD Revisions From 1950 to 1999

Cause of Death	ICD6/7 (1950–1968)	ICD8 (1969–1978)	ICD9 (1979–1995)	ICD10 (1996–1999)
1. Infectious and parasitic diseases	001–138	000–136	001–139	A00–B99
2. Cancer of the esophagus	150	150	150	C15
3. Cancer of the stomach	151	151	151	C16
4. Cancer of the colorectum	153–154	153–154	153–154	C18–C21
5. Cancer of the pancreas	157	157	157	C25
6. Cancer of the upper resp./ digest. system	140–148, 160, 161	140–149, 160, 161	140–149, 160, 161	C00–C14, C30–C32
7. Cancer of the lung	162–163	162	162	C33–34
8. Cancer of the breast	170	174	174–175	C50
9. Cancer of the prostate	177	185	185	C61
10. Cancer of the bladder	181	188	188	C67
11. Cancer of the kidney	180	189	189	C64–C66, C68
12. Cancers, unspecified	198–199, 230–239	195–199, 230–239	195–199, 235–239	C76–C80, C97, D37–D48
13. Other cancers	Rest (140–239, 294)	Rest (140–239)	Rest (140–239)	Rest (C00–D48)
14. Diabetes mellitus	260	250	250	E10–E14
15. Dementia and Alzheimer's	304–306	290, 293	290, 331	F00, F01, F03, G30
16. IHD	420, 422.1	410–414	410–414	I20–I25
17. Other heart diseases	400–402, 410–416, 421, rest (422), 430–434, 440–447	390–398, 400–404, 420–425, 427–429	390–398, 401–405, 416, 420–429	I00–I13, I15, I27, I30–I52
18. Cerebrovascular diseases	330–334	430–434, 436–438	430–434, 436–438	I60–I69
19. Other circulatory diseases	Rest (400–468)	Rest (390–458, excl. 435 & 446)	Rest (390–459, excl. 435 & 446)	Rest (I00–I99)
20. Pneumonia/influenza	480–483, 490–493	470–474, 480–483, 485–486	480–487	J10–J18
21. COPD	501, 502, 526, 527, 241	490–493, 518	490–494, 496	J40–47
22. Senility	794	794	797	R54
23. Other symptoms & ill-defined cond.	Rest (780–795)	Rest (780–796)	Rest (780–799)	Rest (R00–R99)
24. Other diseases	Rest (001–795)	Rest (000–796)	Rest (001–799)	Rest (A00–R99)
25. Accidental fall	E900–904	E880–887	E880–888	W00–W19, X59
26. Other external causes	Rest (E800–999)	Rest (E800–999)	Rest (E800–999)	Rest (V01–Y98)

Notes: Table concerns only information from The Netherlands. ICD = International Classification of Diseases; IHD = ischemic heart disease; COPD = chronic obstructive pulmonary disease.