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Lack of improvement of life expectancy at advanced ages in The Netherlands

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Background Several countries have reported an increase in life expectancy at advanced ages. This paper analyses recent changes in life expectancy at age 60 and 85 in The Netherlands, a low mortality country with reliable mortality data.

Methods We used data on the population and the number of deaths by age, sex and underlying cause of death for 1970–1994. Life expectancy at age 60 and 85 was estimated using standard life-table techniques. The contribution of different ages and causes of death to the change in life expectancy during the 1970s (1970/74–1980/84) and the 1980s (1980/84–1990/94) were estimated with a decomposition technique developed by Arriaga.

Results Life expectancy at age 60 increased in the 1970s and 1980s, whereas life expectancy at age 85 decreased (men) and stagnated (women) in the 1980s, and has decreased in both sexes since 1985/89. The decomposition by age showed that constant mortality rates in women aged 85–89, and increasing mortality rates at ages 85+ (men) and 90+ (women) have caused this lack of increase in life expectancy. The decomposition by cause of death showed that smaller mortality reductions from other cardiovascular and cerebrovascular diseases, which contributed most to the increase in life expectancy at age 85 in the 1970s, and mortality increases from, amongst others, chronic obstructive pulmonary disease (COPD), mental disorders and diabetes mellitus produced the decrease (men) and plateau (women) in life expectancy at age 85.

Conclusions Life expectancy at advanced ages stopped increasing during the 1980s in The Netherlands due to mortality increases at ages 85+ (men) and 90+ (women). Cause-specific trends suggest that, in addition to (past) smoking behaviour in men, changes in the distribution of morbidity and frailty in the population might have contributed to this stagnation.

Keywords Old-age mortality, life expectancy, cause-of-death, decomposition by age, decomposition by cause of death

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Nowadays, in low mortality countries, increases in life expectancy are often taken for granted. Life expectancy has risen since the eighteenth century in some European countries, including England, France and Scandinavia.[1–3] In The Netherlands, mortality reductions are likely to have started in the nineteenth century.[2] From 1840/51 to 1990/94 life expectancy increased from 36.1 to 74.2 years in men and from 38.5 to 80.2 years in women.[4]

This impressive increase in length of life has been accompanied by substantial changes in the age-at-death and cause-of-death patterns. Changes in the cause-of-death pattern from mainly infectious diseases to chronic diseases were accompanied by a shift in the age pattern of mortality from younger ages to older ages.[5] Since the early 1970s, declines in mortality from chronic diseases at older ages have caused sharp rises in life expectancy of the elderly population.[5–7] Uncertainty abounds as to whether the decline in mortality at older ages will continue to generate substantial increases in life expectancy.

Two opinions are prevalent. One group of researchers, known as the proponents of 'the limited-lifespan paradigm', believes that average life expectancy will not increase beyond 85 years of age.[8–10] Further substantial reductions in death rates at advanced ages are constrained by biological barriers (e.g. senescence) and/or by societal barriers (e.g. environmental deterioration). The increasingly rectangular shape of the survival curve, seen as a manifestation of the fact that the natural limit to human life has almost been completed,[9] and the enormous reductions in mortality rates which would be needed to achieve a life

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expectancy at birth of 85 years[10] are used as arguments in support of this view.

Others, known as proponents of 'the mortality-reduction paradigm',[11–15] argue that the decline in mortality rates will continue and may even accelerate, including also the most advanced ages. A life expectancy at birth of 100 years or more is considered to be within reach somewhere in the near future.[12,13] The observed decrease in mortality at advanced ages of 1–2% per year, and the very low mortality rates in subpopulations with healthy life styles, are used as arguments in favour of substantial future increases in life expectancy.[11,13]

Several studies have reported rapid declines in oldest-old mortality.[7,11,16–18] In the Netherlands, too, a country with traditionally low mortality and reliable mortality data at advanced ages,[19] life expectancy of the elderly (65+) and the oldest old (85+) has increased.[20] This study aims at obtaining a better understanding at the recent changes in mortality in the Dutch elderly population. The central questions are: (1) did the increase in life expectancy of the elderly population accelerate, continue or stagnate in past years and (2) which age- and cause-specific mortality dynamics underlay these recent changes in the life expectancy? We will use total and cause-specific Dutch mortality data of the population aged ⩾60 in 1970/74–1990/94.

Methods

Data

Data on the population and the number of deaths by age, sex and underlying cause of death for 1970–1994 were obtained from Statistics Netherlands.[21,22] Total mortality and population data had originally been derived from municipal population registers and can be considered reliable and consistent. Population and total mortality data by single year-of-age were used, whereas cause-specific mortality data were only available by 5-year age groups, with age ⩾95 as the oldest age group. In 1970–1994 causes of death were classified according to two different revisions of the International Classification of Diseases, Injuries and Causes of Death: the Eighth Revision (ICD-8) for 1970–1978 and the Ninth Revision (ICD-9) for 1979–1994. In order to maximize the comparability over both ICD classifications, we regrouped the causes classified in both revisions into 26 cause-of-death groups (Appendix 1).

Methods

We started with a description of the change in life expectancy at age 60 and age 85 in The Netherlands in 1970/74–1990/94. Life expectancies were estimated from complete life tables with age 105 as oldest age group. These life tables, each covering five calendar years, were constructed for both sexes from total mortality and population data, using standard demographic techniques.[23,24]

Next, we looked for explanations of the change in life expectancy at age 60 and 85 in the 1970s (1970/74–1980/84) and the 1980s (1980/84–1990/94) by examining the contribution of different age groups and causes of death to the change in life expectancy. This contribution was estimated from age- and cause-specific mortality data using a method developed by Arriaga,[25,26] which decomposes the change in life expectancy into the contribution to this change of different age groups and/or causes of death. Although changes in age and cause-specific mortality rates also give an indication of the contribution of different ages and causes to the change in life expectancy, we prefer the Arriaga method for two reasons. First, this method takes into account substitution between competing causes of death. Second, it takes into account the fact that similar changes in mortality rates at different ages influence life expectancy—being a population health measure—to a different extent. The magnitude of the effect of (changes in) age- and cause-specific mortality rates on life expectancy is weighted (1) by the size of the life-table population in a certain age group exposed to the (changed) rate, and (2) the remaining life expectancy of that age group. Due to this implicit weighting in the life table, changes in mortality rates that are not important for the health of the population, for instance because the population at risk being exposed to these rates is rather small, are not weighted heavily. In general, changes at young ages have a larger impact on life expectancy than changes at advanced ages.[27,28] This is due to the fact that (1) only a small proportion of the population is exposed to changes in mortality rates at advanced ages, as not everyone survives up to these ages and (2) the remaining life expectancy at older ages is much smaller, reflecting the high risks of mortality at older ages. It merits attention that life expectancy (and thus changes in life expectancy) is unaffected by the age distribution of the actual population, which enables comparisons to be made over time and between groups (e.g. by sex). The age distribution of the life-table population is only determined by the mortality rates.

Notwithstanding the favourable properties of life table based methods like the Arriaga method, examining changes in age- and cause-specific mortality rates is useful as well. Having assessed which age groups and causes of death contributed most to the change in life expectancy, looking at changes in age- and cause-specific rates will provide more insight into the exact changes. Therefore we also calculated directly standardized death rates (using the population of 1990/94 by 5-year of age up to age 95+ as standard) for each 5-year period. We expressed changes in standardized mortality rates as ratios of comparative mortality figures (CMF). To assess whether these changes in the ratios of CMF were statistically significant, we calculated 95% CI of the CMF ratios.[29] In the presentation of the outcomes of the age-specific changes in total mortality, we focus on the change in CMF by 10-year age groups since 1970/74. Results for specific cause-of-death groups are not shown separately in Tables or Figures. Only cause-specific changes in mortality are presented separately for the age group 85+ in the 1980s, because changes in mortality in the oldest old have been striking since 1980/84 in The Netherlands[30] and deserve a closer inspection.

Results

Change in life expectancy

During the past two decades, life expectancy of the elderly and oldest-old population has increased in The Netherlands. Table 1 shows that life expectancy at age 60 increased from 16.95 to 18.22 years in men and from 20.87 to 23.14 years in women in the period 1970/74–1990/94. Life expectancy at age 85 increased from 4.46 to 4.63 years in men and from 4.96 to 5.82 years in women in the same period. A closer inspection of Table 1 indicates that the gain in life expectancy was not evenly spread across the different 5-year periods. In men, the increase in life

Table 1 Life expectancy at age 60 and age 85, The Netherlands, by sex

	Men		Women	
	At age 60 years	At age 85 years	At age 60 years	At age 85 years
1970/74	16.95	4.46	20.87	4.96
1975/79	17.15	4.74	21.89	5.45
1980/84	17.52	4.85	22.72	5.84
1985/89	17.78	4.74	23.01	5.86
1990/94	18.22	4.63	23.14	5.82

expectancy at age 60 was slightly larger in the 1980s (0.7 years) than in the previous decade (0.6 years), whereas in women the opposite was true (1970s 1.8 years; 1980s 0.4 years). The trend in life expectancy at age 85 was even more remarkable: a gain was seen until 1980/84 (men) and 1985/89 (women), but since then life expectancy at age 85 has declined.

Contribution of different age groups and causes of death to the change in life expectancy

Because changes in age- and cause-specific mortality might give clues to changes in the determinants of mortality, we first assessed the extent to which mortality declines or increases in different age groups and cause-of-death groups contributed to the described change in life expectancy.

Table 2 shows the contribution of different age groups to the change in life expectancy at ages 60 and 85 calculated with the Arriaga method. A 'positive' contribution indicates that a mortality reduction in the relevant age group contributes to an increase in life expectancy, whereas a 'negative' contribution indicates that a mortality increase contributes to a reduction of life expectancy. In the 1970s mortality reductions in all age groups contributed to the increase in life expectancy at age 60 and age 85, although the size of these contributions differed. The most striking development in the 1980s was that mortality changes at age ⩾85 (men) and at age ⩾90 (women) contributed negatively to the increase in life expectancy at age 60. At age 85, the same changes in mortality were responsible for the stagnating increase in life expectancy among women (–0.02 years) and for the decline in life expectancy among men (–0.22 years). That life expectancy at age 60 continued to increase was due to mortality reductions in the age groups between 60 and 84 years of age, which have a larger impact on life expectancy at age 60. For men, larger mortality declines at ages 65–79 produced an even larger increase in life expectancy at age 60 in the 1980s, despite the unfavourable developments at older ages. For women the increase in life expectancy at age 60 was smaller than in the 1970s because the positive impact of mortality reductions below age 90 also shrank.

The contributions of the five causes of death which contributed most, both in a positive and negative sense, to the change in life expectancy at age 60 and age 85 in the 1970s and 1980s are presented in Tables 3a, 3b. Table 3b shows that in the 1980s mortality increases from chronic obstructive pulmonary disease (COPD), mental disorders and diabetes mellitus (and to a lesser extent other cancers [men] and lung cancer [women]) contributed 'negatively' to the increase in life expectancy at age 60. Mortality increases from these diseases, together with those from prostate cancer (men) and ill-defined conditions (women), were also largely responsible for the decline (men) and plateau (women) in life expectancy at age 85 in this period. At age 60, these effects were counterbalanced by mortality reductions from, in particular, ischaemic heart disease (IHD) and cerebrovascular diseases, and from lung cancer (men) and other heart diseases (women). However, at age 85, the negative effect of mortality increases outweighed the positive effect of mortality reductions from other causes.

Table 2 Decomposition of the change in life expectancy at age 60 and age 85 in 1970/74–1980/84 and 1980/84–1990/94, The Netherlands, by sex[a]

	Men		Women	
	At age 60 years	At age 85 years	At age 60 years	At age 85 years
1970/74–1980/84				
60–64	+0.20	–	+0.14	–
65–69	+0.17	–	+0.25	–
70–74	+0.07	–	+0.38	–
75–79	+0.03	–	+0.41	–
80–84	+0.03	–	+0.37	–
85–89	+0.04	+0.20	+0.20	+0.59
90–94	+0.02	+0.12	+0.07	+0.22
95+	+0.01	+0.07	+0.02	+0.07
Total	+0.58	+0.39	+1.85	+0.88
1980/84–1990/94				
60–64	+0.22	–	+0.02	–
65–69	+0.23	–	+0.05	–
70–74	+0.18	–	+0.10	–
75–79	+0.10	–	+0.16	–
80–84	+0.01	–	+0.11	–
85–90	–0.02	–0.08	+0.03	+0.07
90–94	–0.02	–0.08	–0.02	–0.05
95+	–0.01	–0.05	–0.02	–0.05
Total	+0.70	–0.22	+0.42	–0.02

[a] Figures are rounded to 0.01.

Compared to the 1980s, the 1970s had shown both larger positive contributions (1970s: 0.64 [men] and 1.03 [women] versus 1980s: 0.27 [men] and 0.37 [women]) and smaller negative contributions (1970s: –0.25 [men] and –0.15 [women] versus 1980s: –0.48 [men] and –0.39 [women]) to the life expectancy at age 85, which on balance produced the increase in life expectancy at age 85 in the 1970s, and the decrease (men) or stagnation (women) in the 1980s (Tables 3a,3b). Both smaller mortality reductions (or sometimes even an increase in mortality) from cerebrovascular diseases and other cardiovascular diseases—which contributed largely to the increase in life expectancy at age 85 in the 1970s—and (larger) mortality increases from e.g. COPD, mental disorders and diabetes mellitus, together with those from cancer (prostate and other cancers) and ill-defined conditions, explain the reversal of the trend in life expectancy at age 85.

Changes in age- and cause-specific mortality

Figure 1 shows the ratios of the standardized mortality rates (CMF) by 10-year age groups since 1970/74, using 1970/74

Table 3a Decomposition of the contribution of selected causes of death to the change in life expectancy at age 60 and 85 in 1970/74–1980/84, The Netherlands, by sex[a]

Men		**Women**	
At age 60 years			
All causes	+0.577	All causes	+1.847
Increase in life expectancy	+0.961	Increase in life expectancy	+1.915
Ischaemic heart disease	+0.257	Cerebrovascular diseases	+0.417
Cerebrovascular diseases	+0.197	Ischaemic heart disease	+0.391
Pneumonia/influenza	+0.091	Other cardiovascular disease	+0.186
Stomach cancer	+0.083	Pneumonia/influenza	+0.137
Traffic accidents	+0.065	Other heart diseases	+0.134
Rest[b]	+0.268	Rest[b]	+0.650
Decrease in life expectancy	–0.384	Decrease in life expectancy	–0.068
Lung cancer	–0.177	Lung cancer	–0.040
Other heart diseases	–0.079	Other causes	–0.014
Other cancers	–0.052	Breast cancer	–0.006
Prostate cancer	–0.022	Diseases of nervous system	–0.006
Chronic obstructive pulmonary disease	–0.017	Other endocrine	–0.002
Rest[b]	–0.038	Rest[b]	–0.000
At age 85 years			
All causes	+0.387	All causes	+0.878
Increase in life expectancy	+0.641	Increase in life expectancy	+1.031
Other cardiovascular diseases	+0.133	Ischaemic heart disease	+0.193
Cerebrovascular diseases	+0.129	Cerebrovascular diseases	+0.182
Ischaemic heart disease	+0.119	Other cardiovascular diseases	+0.180
Ill-defined conditions	+0.078	Other accidents	+0.110
Pneumonia/influenza	+0.066	Ill-defined conditions	+0.101
Rest[b]	+0.116	Rest[b]	+0.265
Decrease in life expectancy	–0.254	Decrease in life expectancy	–0.153
Lung cancer	–0.054	Genito-urinary	–0.048
Chronic obstructive pulmonary disease	–0.050	Diseases of digestive system	–0.031
Other heart diseases	–0.037	Other causes	–0.026
Diseases of digestive system	–0.028	Other endocrine	–0.021
Diseases of nervous system	–0.017	Diseases of nervous system	–0.014
Rest[b]	–0.068	Rest[b]	–0.013

[a] Figures are rounded to 0.001.

[b] Available from authors on request.

as reference (i.e. 1970/74 = 1). The developments in the 1970s and 1980s in mortality for each age group are clear at a glance. Whereas in the 1970s, mortality rates in all age groups decreased, in the 1980s only mortality rates in the age groups 60–69 and 70–79 continued to decline. In the age groups 80–89 mortality rates stagnated (women) or increased slightly, but not significantly (men). Above 90+ a significant increase was observed in both men and women in the 1980s. As could be expected, the age groups which showed a mortality increase or a decline, are the same as those picked out by means of the Arriaga method. However, comparison of Figure 1 and Table 2 makes it clear that caution should be exercised when looking at changes in mortality rates in order to explain changes in life expectancy. For example, Figure 1 shows that the reduction in the CMF for age group 90+ was largest for men in the 1970s, whereas Table 2 shows that this age group did not contribute most to the increase in life expectancy at age 60. After all, the contribution of age group 70–79 (0.1) was higher than that of 90+ (0.03).

Table 4 focuses on recent changes in mortality rates above age 85 from specific causes. For the ease of interpretation, we expressed the change as the ratio of the CMF in 1990/94 to that in 1980/84 (i.e. 1980/84 = 1). A ratio larger than 1 indicates an increase in mortality as compared to 1980/84, whereas a ratio smaller than 1 indicates a decline. Some causes of death showed mortality declines in the 1980s, but overall the situation was one of mortality increase. Significant increases in mortality above age 85 from mental disorders, diabetes mellitus and other endocrine, nutritional and metabolic diseases, COPD, diseases of the nervous system, diseases of blood and blood-forming organs, ill-defined conditions, prostate and other cancers, infectious/parasitic diseases and pneumonia/influenza took place. These

Table 3b Decomposition of the contribution of selected causes of death to the change in life expectancy at ages 60 and 85 in 1980/84–1990/94, The Netherlands, by sex[a]

Men		Women	
At age 60 years			
All causes	+0.701	All causes	+0.423
Increase in life expectancy	+1.131	Increase in life expectancy	+0.996
Ischaemic heart disease	+0.596	Ischaemic heart disease	+0.442
Lung cancer	+0.144	Cerebrovascular diseases	+0.186
Cerebrovascular diseases	+0.132	Other heart diseases	+0.137
Stomach cancer	+0.072	Stomach cancer	+0.054
Genito-urinary	+0.048	Other accidents	+0.047
Rest[b]	+0.138	Rest[b]	+0.130
Decrease in life expectancy	–0.430	Decrease in life expectancy	–0.573
COPD	–0.079	Mental disorders	–0.131
Diabetes Mellitus	–0.078	Diabetes Mellitus	–0.120
Other cancers	–0.065	Chronic obstructive pulmonary disease	–0.098
Mental disorders	–0.053	Lung cancer	–0.085
Other cardiovascular diseases	–0.039	Diseases of the nervous system	–0.022
Rest[b]	–0.117	Rest[b]	–0.118
At age 85 years			
All causes	–0.215	All causes	–0.022
Increase in life expectancy	+0.266	Increase in life expectancy	+0.371
Ischaemic heart disease	+0.091	Ischaemic heart disease	+0.118
Other heart diseases	+0.081	Other heart diseases	+0.110
Genito-urinary	+0.046	Other accidents	+0.042
Cerebrovascular diseases	+0.018	Cerebrovascular diseases	+0.028
Stomach cancer	+0.016	Stomach cancer	+0.021
Rest[b]	+0.014	Rest[b]	+0.053
Decrease in life expectancy	–0.481	Decrease in life expectancy	–0.393
Chronic obstructive pulmonary disease	–0.102	Mental disorders	–0.152
Mental disorders	–0.064	Diabetes mellitus	–0.062
Prostate cancer	–0.047	Ill-defined conditions	–0.036
Other cancers	–0.044	Chronic obstructive pulmonary disease	–0.031
Diabetes mellitus	–0.039	Other endocrine	–0.023
Rest[b]	–0.184	Rest[b]	–0.089

[a] Figures are rounded to 0.001.

[b] Available from authors on request.

causes also contributed in a negative sense to the decline (men) and plateau (women) in life expectancy at age 85 (Tables 3a, 3b).

Discussion

This study examined recent mortality changes in the elderly population of The Netherlands in the 1970s and in the 1980s. Our results showed that life expectancy at age 60 increased in the 1970s and 1980s, whereas life expectancy at age 85 has declined since 1980/84 (men) and 1985/89 (women). Constant mortality rates in women at ages 85–89, and an increase in mortality rates above age 85 (men) and above age 90 (women) underlay this trend in life expectancy at age 85. Decomposition of the change in life expectancy by cause of death showed that both smaller mortality reductions (or sometimes even an increase in mortality) from cerebrovascular diseases and other cardiovascular diseases—which contributed largely to the increase in life expectancy at age 85 in the 1970s—and mortality increases from e.g. COPD, mental disorders and diabetes mellitus, together with those from cancer (prostate and other cancers) and ill-defined conditions produced the decrease (men) and plateau (women) in life expectancy at age 85. The continuing rise in life expectancy at age 60, on the other hand, was caused by mortality reductions at ages 60–84 which have a relatively large impact on life expectancy at age 60.

Before turning to the meaning and implications of our results, it must be emphasized that the findings, which are based on underlying cause-of-death data, might be subject to coding and classification errors. First, at advanced ages, underlying causes of death are difficult to assess and may therefore be unreliable.[31] Furthermore, estimates of the magnitude of the effects of IHD and other heart diseases might be biased, due to the ICD Revision of 1979. The number of deaths from these causes by calendar year showed a small increase for other heart diseases mirrored by a decrease for IHD between 1978 and 1979. Finally, the effect of diabetes mellitus and mental disorders might be

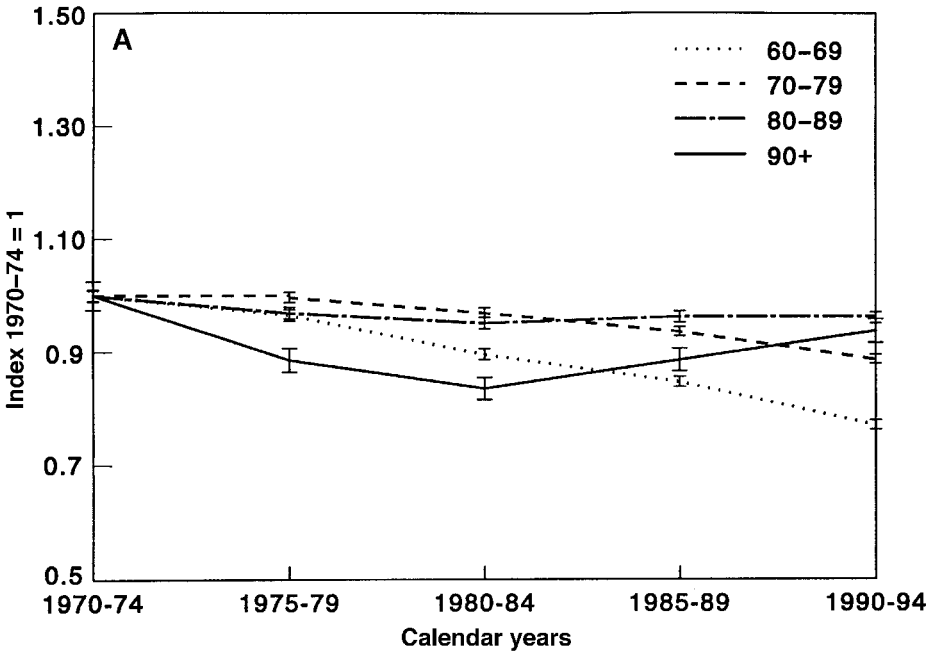

Figure 1a Comparative Mortality Figure (CMF) by 5-year period as a ratio of the CMF in 1970/74 by 10-year age group, The Netherlands, men

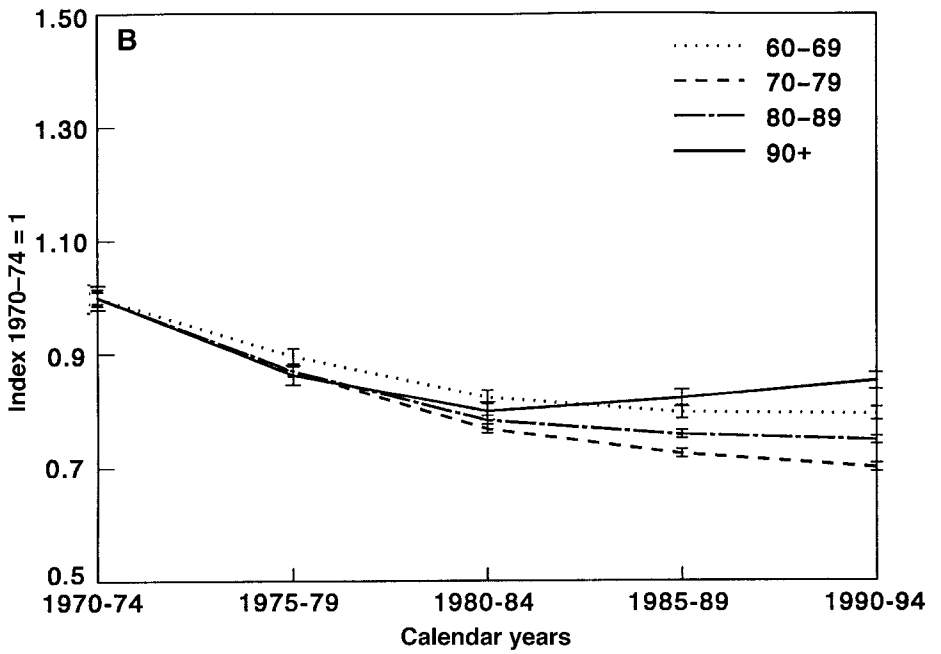

Figure 1b Comparative Mortality Figure (CMF) by 5-year period as a ratio of the CMF in 1970/74 by 10-year age group, The Netherlands, women

overestimated due to a more frequent classification of diabetes mellitus[32] and senile dementia (part of mental disorders; personal communication Statistics Netherlands) as underlying cause of death in The Netherlands since 1983 and 1992, respectively. The number of deaths from diabetes by calendar year showed an increase in diabetes deaths in the years immediately after 1982. For senile dementia the increase started before and continued after the change in classification. Despite these uncertainties related to cause-of-death data, our findings indicating a lack of improvement in life expectancy at advanced ages are based on Dutch total mortality rates. Total mortality rates in The Netherlands are considered to be very reliable even

Table 4 Ratio of comparative mortality figure[a] (CMF) of 1990/94 to CMF of 1980/84 at age ⩾85, by sex

	Men	95% CI	Women	95% CI
Infectious + parasitic diseases	1.63	1.38–1.93	1.51	1.33–1.71
Stomach cancer	0.77	0.70–0.85	0.67	0.62–0.73
Colorectal cancer	0.96	0.88–1.04	0.91	0.86–0.96
Lung cancer	1.21	1.14–1.29	0.97	0.84–1.11
Breast cancer	0.74	0.32–1.71	1.05	0.98–1.12
Prostate cancer	1.34	1.26–1.42	–	–
Other cancers	1.20	1.15–1.26	1.06	1.03–1.10
Diabetes Mellitus	2.22	1.98–2.49	1.98	1.85–2.12
Endocr. + Nutritional	1.52	1.30–1.77	1.71	1.55–1.88
Blood + blood forming	1.88	1.56–2.27	1.56	1.36–1.80
Mental disorders	4.88	4.22–5.64	4.93	4.54–5.35
Nervous system	1.52	1.36–1.70	1.48	1.35–1.62
Ischaemic heart disease	0.85	0.83–0.88	0.83	0.81–0.85
Cerebrovascular diseases	0.96	0.93–1.00	0.97	0.94–0.99
Other cardiovascular diseases	1.14	1.07–1.22	0.91	0.86–0.95
Other heart diseases	0.86	0.84–0.89	0.87	0.85–0.89
Pneumonia/influenza	1.15	1.09–1.20	1.06	1.02–1.10
Chronic obstructive pulmonary disease	1.52	1.45–1.60	1.39	1.31–1.48
Other respiratory	1.17	1.01–1.35	1.04	0.91–1.18
Digestive system	1.06	0.99–1.13	1.03	0.99–1.07
Genito-urinary	0.75	0.71–0.80	0.89	0.85–0.93
Ill-defined	1.28	1.20–1.35	1.20	1.15–1.25
Traffic accidents	0.72	0.56–0.93	0.86	0.57–1.30
Other accidents	0.95	0.88–1.03	0.77	0.73–0.81
Other external causes	0.87	0.71–1.07	0.65	0.51–0.84
Other causes	1.32	1.15–1.51	1.19	1.11–1.27
Total	1.06	1.05–1.08	1.02	1.01–1.03

[a] CMF using the 1990/94 population as standard population.

– Not applicable.

for the oldest-old age groups,[19] because mortality and population data are derived from municipal population registers that have been kept in The Netherlands since 1850.[22] At birth a personal card based on the birth certificate is made and all changes in vital status, including death, are recorded on this card. This guarantees a high validity of age recording and since population registers not only provide data on mortality, but also on the population at risk by single year of age and sex, a single source is used to estimate mortality rates, which avoids biases.

Moreover, differences in the contribution of each age group to the change in life expectancy (based on the Arriaga method) and changes in age-specific mortality rates (based on the CMF method) merit attention. The outcomes of both methods might not always lead to the same conclusion. Comparison of the contribution of different age groups to the change in life expectancy (Arriaga) and the standardizd mortality rates (CMF) by 10-year age groups shows that although the direction of the effect is the same, its relative importance can differ. For a full understanding of the changes in mortality, information derived from both approaches is needed. To explain changes in life expectancy, which was the primary focus of this paper, the Arriaga method is the most appropriate of the two, because, like life expectancy, it takes into account the fact that changes in mortality in different age groups affect life expectancy to a different extent. The magnitude of the effect depends upon the size of the population in a certain age group being exposed to the (changed) mortality rate and the remaining life expectancy of this age group. On the other hand, changes in age-specific mortality rates provide more insight into changes in the age structure and size of the elderly population. In addition, looking at changes in age- and cause-specific mortality rates is indispensable to discovering possible determinants of the changes in mortality.

Studies for other low mortality countries have found no rises in mortality in the oldest old.[6,11,18] Only in Norway did mortality at advanced ages increase slightly between 1986/90 and 1991/94.[33] Explanations for the recent rise in old-age mortality in The Netherlands (and Norway) are still being sought. More research on this topic is needed. As a start, we will elaborate on possible explanations for the recent rise in old-age mortality in The Netherlands. First, the increase in old-age mortality might have been caused by excess mortality due to influenza epidemics in 1989/90 and 1993.[34,35] This is not likely, however. In 1975 and 1978, influenza also produced substantial excess mortality[34] without seriously interrupting the mortality decline among the oldest old. In addition, our results are not very sensitive to annual perturbations due to influenza epidemics, for we used quinquennial data. Second, the alleged liberalization of euthanasia policy could have brought forward the average

age at death. However, considering the low frequency of physician assistance in death at advanced ages (only 1.8% [1.3–2.5%] of all deaths above age 80) and the estimated small decrease in the length of life due to euthanasia (less than one week in 76% of these cases),[36] we do not consider euthanasia a significant factor. Third, the increase in mortality from (lung) cancer and COPD among the oldest old suggests that (past) smoking behaviour might have contributed to the increase in mortality. A reconstruction of smoking prevalence by birth cohort[37] showed that the percentage of (ex)smokers in men aged ⩾85 was probably higher in 1990/94 than in 1980/84. However, although past smoking behaviour might have played a role, the evidence is not conclusive. After all, this factor cannot explain the increase in female mortality at advanced ages, as the percentage of (ex)-smokers aged ⩾85 was too small to have had a significant effect on old-age mortality.

The causes discussed so far cannot fully explain the increase in mortality at advanced ages and thus we should consider other causes, such as those relating to changes in the distribution of morbidity and frailty in the population. Less selection due to decreased mortality may have produced a frailer oldest-old population.[38] The subsequent increase in mortality from mental disorders, ill-defined conditions and influenza/pneumonia might be a manifestation of this increased frailty. In addition, decreased mortality from circulatory diseases might have created a pool of people with circulatory diseases, who run a higher risk of developing severe stages of these diseases and dying from them.[39,40] Finally, reduced mortality from circulatory diseases might have increased the prevalence of diseases that share the same risk factors or are themselves a risk factor for circulatory diseases, such as some cancers or diabetes mellitus. Although it is plausible that these factors have contributed to the increase in old-age mortality, it is not clear why these mechanisms, which may be expected to operate in other countries as well, have not (yet) caused old-age mortality to rise in these countries.

Further investigation into the determinants of the old-age mortality is necessary and may benefit from empirical data on the current developments in old-age mortality in The Netherlands and other low mortality countries. Monitoring of old-age mortality and cross-national comparisons should therefore receive high priority. In addition, an important, but in terms of data requirements very demanding step, would be to disentangle the changes in incidence, disease progression, and fatality of chronic diseases which have caused the mortality increases in the oldest old in The Netherlands.

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Appendix 1 Classification in cause-of-death groups according to the International Classification of Disease

Name of disease category	ICD-Chapter	ICD-8 1970–1978	ICD-9 1979–
Infectious and parasitic diseases	1	001–136	001–139
Cancer of stomach	2	151	151
Cancer of colorectum	2	153–154	153–154
Cancer of trachea, bronchus and lung	2	162–163	162–163;165
Cancer of breast	2	174	174–175
Cancer of prostate	2	185	185
Other neoplasms	2	r(140–239)	r(140–239)
Diabetes mellitus	3	250	250
Other endocrine, nutritional and metabolic diseases	3	240–246;251–269;270–279	240–246;251–259;260–279
Diseases of blood and bloodforming organs	4	280–289	280–289
Mental disorders	5	290–315	290–319
Diseases of the nervous system and sense organs	6	320–389	320–389
Ischaemic heart diseases	7	410–414	410–414
Cerebrovascular diseases	7	430–438	430–438
Other cardiovascular diseases	7	440–448;450–458	440–448;415;417;451–459
Other heart diseases	7	390–398;400–404;420–429	390–398;401–405;416;420–429
Pneumonia/influenza	8	470–474;480–484;486	487;480–486
Chronic obstructive pulmonary disease	8	490–493	490–494;496
Other diseases of the respiratory system	8	r(460–519)	r(460–519);495
Diseases of the digestive system	9	520–577	520–579
Diseases of the genito-urinary system	10	580–629	580–629
Symptoms and ill-defined conditions	16	780–796	780–799
Traffic accidents	17	E800–845;E940–941	E800-E848
Other accidents	17	E880–887;E890–909; E911–929;E943–946;E980–989	E880–888;E890–909; E911–929;E980–989
Other external causes	17	E850–877; E910; E930–999 excl. E940–941 excl. E943–946 excl. E980–989	E850–869;E910; E870–879; E930–999; excl. E980–989
Other causes	11–15	630–678; 680–686;690–709;710–738; 740–759; 760–776	630–676; 680–686;690–709;710–739; 740–759; 760–779