

***Will life expectancy continue
to increase or level off?
Weighing the arguments of
optimists and pessimists***

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Explanation of symbols

.	= data not available
*	= provisional figure
x	= publication prohibited (confidential figure)
–	= nil or less than half of unit concerned
–	= (between two figures) inclusive
0 (0,0)	= het getal is minder dan de helft van de gekozen eenheid
nothing (blank)	= not applicable
2005–2006	= 2005 to 2006 inclusive
2005/2006	= average of 2005 up to and including 2006
2005/'06	= crop year, financial year, school year etc. beginning in 2005 and ending in 2006
2003/'04–2005/'06	= crop year, financial year, etc. 2003/'04 to 2005/'06 inclusive

Due to rounding, some totals may not correspond with the sum of the separate figures.

According to some, the gains in life expectancy that were achieved during the past century will continue at more or less the same rate during the coming century. This will eventually lead to an average life expectancy at birth of 100 years or (much) more. Others expect that the increase will level off to an average life expectancy of about 85 years. This article discusses the various arguments used by these optimists and pessimists, and assesses their potential upward or downward effects on the mortality rates. Using mortality data for the Netherlands, the potential effect of medical breakthroughs is estimated. The calculations show that the future trend in life expectancy will be the composite of modest gains, restrained by modest losses resulting from unfavourable health trends. The net effect is expected to be slightly positive, in the order of a few years rather than a few decades.

1. Introduction

In recent years, the issue of future longevity has attracted increasing attention of (bio)demographers and health professionals. Unlike what has been the case with respect to most other subjects of a demographic nature, the popular media have extensively reported on the relevant research findings, be it in a somewhat selective manner: claims that diet and other life-style changes can add decades to an individual's life, in particular, have repeatedly been front-page news. Popular books with titles like 'Dare to be 100', 'Stopping the clock' and 'Beyond the 120 year diet' have proven bestsellers, convincing many that the increases in life expectancy recorded in the past century will continue unabatedly in the coming century.

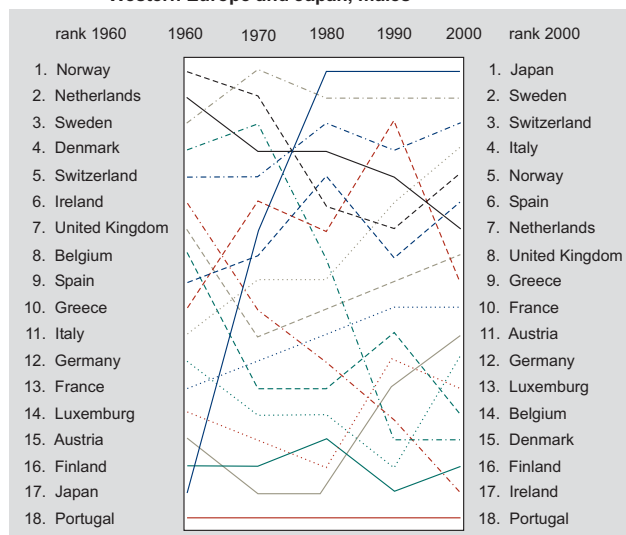
Whether or not the potential of selected individuals to live beyond 100 or even 120 years also implies that extreme longevity is a realistic perspective for the population at large, is much less certain however than suggested by the ever growing numbers of centenarians and supercentenarians.

In the past decade the question of future life expectancy – rather than future longevity of individuals – seems to have split mortality researchers into two camps. One camp, adhering to the 'gerontological' school of thought, postulates that diseases and disabilities typically related to ageing are caused by some, as yet largely unknown, underlying physiological process. Ageing is, in this view, a natural process, only to be influenced to a modest degree. The maximum span of life, presently determined by Jeanne Calment who died at the age of 122 years in 1997, is not likely to change very much, and the life expectancy at birth will gradually level off, to about 85 years for both sexes combined. The biodemographically oriented researchers in this camp, of whom Jay Olshansky is probably the most outspoken representative, stand for the 'traditionalist', 'conservative' or 'pessimistic' movement in mortality research. Other well-known traditionalists are Hayflick (1977), Fries (1980, 1989), Demeny (1984) and Lohman (Lohman et al., 1992). According to some, they embody a minority point of view.

The more or less opposite, 'geriatric' school of thought, expects that mortality reductions and life expectancy will continue their past, highly favourable trends (e.g. Rosenberg et al., 1973; Guralnik et al., 1988; Manton et al., 1991). Life expectancies between 100 and 125 years, or even 150 to 200 years, are seen as goals that can be achieved by the end of this century. Well-known members of this optimistic group are Jim Oeppen and James Vaupel who, given the extraordinary rise in life expectancy and "the demonstrated nearsightedness of expert vision", assert that the forecast of life expectancy should be based on the long-term trend of sustained progress in reducing mortality (Oeppen and Vaupel, 2002). The increase in 'best-practice' life expectancy – i.e. the highest expectancy recorded anywhere in a particular year – amounts to about 2.5 years per decade.

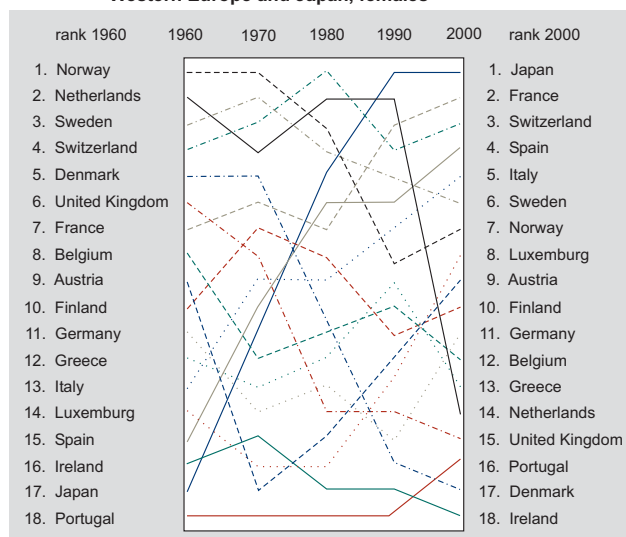
Oeppen and Vaupel (2002) mention three reasons why a continuing upward linear trend is likely. First, experts have repeatedly

Figure 1a. International ranking of life expectancy at birth 1960–2000, Western Europe and Japan, males



Source: Eurostat New Cronos.

Figure 1b. International ranking of life expectancy at birth 1960–2000, Western Europe and Japan, females



Source: Eurostat New Cronos.

asserted that life expectancy is approaching a limit, and have repeatedly been proven wrong. Second, the apparent levelling off of life expectancy in various countries is an artefact of laggards catching up and leaders falling behind (as shown in figures 1a and 1b). And third, if life expectancy were close to a maximum, then the increase in the record expectation of life should be slowing. It is not, according to Oeppen and Vaupel. For 160 years, best-performance life expectancy has steadily increased by a quarter of a year per year, an "extraordinary constancy of human achievement".

An increase in the life expectancy at birth of 0.25 years per year implies that a life expectancy of 100 years would be reached around the middle of this century. Centenarians could become commonplace within the lifetimes of people alive today (Vaupel and Gowan, 1986).

Some gerontologists expect even higher life expectancies by 2100. A Dutch journalist surveying 60 gerontologists world-wide, reported that over a third of them foresee life expectancies at birth of 120 years or more (Richel, 2003). Five gerontologists think that life may then last between 500 and 5000 years. One could imagine that such high estimates partly stem from confusing the

statistical concept of life expectancy with the concept of maximum (individual) life span, but the wide variety of estimates nonetheless show the remarkable lack of agreement between specialists in the field of mortality.

Considering that national population forecasts are strongly influenced by assumptions with respect to mortality, and that apparently trivial differences in the mortality assumptions have a disproportionate effect on the future numbers of elderly persons, the question of future life expectancy is of more than academic interest. On the whole, national population forecasts assume relatively modest increases in life expectancy in the coming decades (table 1). Following a period of only marginal increases, gains in life expectancy became substantial in the 1970s. For all EU-15 countries and both sexes combined, the annual increase in the past three decades has been about 2.3 years per decade, close to the figure mentioned by Oeppen and Vaupel. With the exception of Belgium, none of the EU-15 countries expect that the gains up to 2020 will even approximate those that were recorded in the past. Most national forecasts foresee much lower and diminishing increases in life expectancy. According to some, the officials responsible for making these projections have "recalcitrantly assumed that life expectancy will not increase much further" (Keilman, 1997). The projection for Spain is most pessimistic, with

an annual increase of less than 0.04 years, followed by those for Norway (0.05 years), the Netherlands (0.09 years) and Denmark (0.11 years).

Hence, even though the optimistic expectations of the geriatric school of thought are shared by many researchers in the field of mortality, national forecasts could be considered as remarkably conservative. Should they indeed be too pessimistic (as has generally been the case in the past), the share of elderly persons in the majority of western countries would be strongly underestimated. In particular financial reservations for future health care expenditures, old-age pensions and other benefits might then fall dangerously short.

The questions of future life expectancy is therefore of much more than human interest. This article gives an overview of the major arguments favouring and opposing the likelihood of significant further increases in life expectancy. Following this overview, a number of important health-related trends are highlighted, explaining why the Dutch national population forecast is among the most conservative forecasts in the European Union. A final section estimates the gains in life expectancy that might be realized if truly revolutionary improvements in mortality reduction, defying the effects of present health trends, could be achieved.

Table 1a
Life expectancy at birth in years, males

	1960	1970	1980	1990	2000	2010	2020
Norway	71.6	71.2	72.3	73.4	76.0	77.0	78.0
Sweden	71.2	72.2	72.8	74.8	77.4	79.2	80.4
Finland	65.5	66.5	69.2	70.9	74.2	76.0	77.9
Denmark	70.4	70.7	71.2	72.0	74.5	75.7	77.2
Germany	66.9*	67.3*	69.9*	72.0	75.0	n.a.	n.a.
Netherlands	71.5	70.7	72.7	73.8	75.5	77.0	78.0
Belgium	67.7	67.8	70.0	72.7	74.6	77.2	79.2
Luxemburg	66.5	67.1	69.1	72.3	74.8	n.a.	n.a.
United Kingdom	67.9	68.7	70.2	72.9	75.5	77.4	78.6
Ireland	68.1	68.8	70.1	72.1	73.9	75.2	76.4
Switzerland	68.7	70.7	72.8	74.0	76.9	78.6	79.6
Austria	66.2	66.5	69.0	72.2	75.1	76.8	78.3
France	66.9	68.4	70.2	72.8	75.3	77.3	79.2
Portugal	61.2	64.2	67.7	70.4	73.2	n.a.	n.a.
Spain	67.4	69.2	72.5	73.3	75.7	75.3	76.0
Italy	67.2	69.0	70.6	73.6	76.6	77.9	79.6
Greece	67.3	70.1	72.2	74.6	75.5	76.9	78.2
EU-15	67.4	68.4	70.5	72.8	75.5	n.a.	n.a.
United States	n.a.	n.a.	70.0	71.8	74.2	n.a.	n.a.
Japan	65.3	69.3	73.3	75.9	77.5	n.a.	n.a.

Source: Eurostat New Cronos.

* West-Germany only.

Table 1b
Life expectancy at birth in years, females

	1960	1970	1980	1990	2000	2010	2020
Norway	76.0	77.5	79.2	79.8	81.4	82.4	83.1
Sweden	74.9	77.1	78.8	80.4	82.0	83.0	83.9
Finland	72.5	75.0	77.6	78.9	81.0	82.4	83.6
Denmark	74.4	75.9	77.3	77.7	79.3	79.9	81.0
Germany	72.4*	73.6*	76.6*	78.4	81.0	n.a.	n.a.
Netherlands	75.3	76.5	79.3	80.9	80.5	81.4	81.7
Belgium	73.5	74.2	76.8	79.4	80.8	83.4	85.0
Luxemburg	72.2	73.4	75.9	78.5	81.1	n.a.	n.a.
United Kingdom	73.7	75.0	76.2	78.5	80.2	81.5	82.8
Ireland	71.9	73.5	75.6	77.6	79.1	81.0	82.4
Switzerland	74.5	76.9	79.6	80.7	82.6	84.1	85.0
Austria	72.7	73.4	76.0	78.8	81.1	82.5	84.0
France	73.6	75.9	78.4	80.9	82.7	84.9	86.7
Portugal	66.8	70.8	75.2	77.4	80.0	n.a.	n.a.
Spain	72.2	74.8	78.6	80.3	82.5	83.0	83.7
Italy	72.3	74.9	77.4	80.1	82.5	84.4	86.2
Greece	72.4	73.8	76.8	79.5	80.6	81.8	82.9
EU-15	72.9	74.7	77.2	79.4	81.4	n.a.	n.a.
United States	n.a.	n.a.	77.4	78.8	79.9	n.a.	n.a.
Japan	70.2	74.7	78.8	81.9	84.0	n.a.	n.a.

Source: Eurostat New Cronos.

* West-Germany only.

2. Arguments in favour of large gains in life expectancy

2.1 Historical trends

Over the past decades, the life expectancy at birth has increased in all economically developed countries, but the historical and geographical pattern of the increase has been far from uniform. Countries that used to have the highest life expectancies at birth, have generally shown less impressive gains than those that used to lag behind. This is clearly shown in tables 1 and 2: whereas the north-western European and Scandinavian countries – with the exception of Finnish males – added between 4 and 6 years to their life expectancies in the period 1960–2000, the southern European countries on the whole put on a much better performance. Dutch, Danish and Norwegian men added, over a period of forty years, only between 4.0 and 4.4 years to their lives, while women in these countries increased their life expectancies by 4.9–5.4 years. Large increases, on the other hand, were recorded in Portugal (males 12.0 years / females 13.2 years), Italy (9.4 / 10.2 years), Spain (8.3 / 10.3 years) and France (8.4 / 9.1 years). Outside Europe, probably only Japan has achieved similarly impressive gains: between 1960 and 2000, the Japanese life

expectancy at birth increased by 12.2 years for males and 13.8 years for females. As a consequence, the international ranking of countries by life expectancy has strongly changed, as shown in figure 1. The Japanese, often regarded as leading the way in achieving health gains, obtained the first position about two decades ago and have maintained their lead ever since. Norwegian males, on the other hand, dropped from 1st to 7th place between 1960 and 1990, although they have improved their position somewhat in recent years. Dutch males dropped from 2nd to 7th place, whereas the position of Danish men deteriorated most spectacularly between 1970 and 1990, from 3rd to 15th place. Norwegian, Dutch and Danish women lost ground in a comparable manner, with the fastest decline registered in the 1990s among Dutch women (from 2nd to 14th position).

Around 1970, the annual increases in life expectancy in economically developed countries started to pick up, to above 0.2 years for both men and women (tables 2a and 2b). This increase followed a period of slower health gains, especially among men. The unfavourable trends in the 1950s and, even more so, in the 1960s, were strongly related to post-war life style changes, in particular with respect to smoking and diet. The accompanying 'diseases of civilization', such as ischaemic heart disease and CVA, reached

Table 2a
Increase in life expectancy at birth in years, per decade, males

	1960–1970	1970–1980	1980–1990	1990–2000	2000–2010	2010–2020
Norway	-0.4	1.1	1.1	2.6	1.3	1.0
Sweden	1.0	0.6	2.0	2.6	1.8	1.3
Finland	1.0	2.7	1.7	3.3	1.8	1.8
Denmark	0.3	0.5	0.8	2.5	1.2	1.5
Germany	0.4*	2.6*	2.4	3.0	n.a.	n.a.
Netherlands	-0.8	2.0	1.1	1.7	1.7	0.9
Belgium	0.1	2.2	2.7	1.9	2.2	2.0
Luxemburg	0.6	2.0	3.2	2.5	n.a.	n.a.
United Kingdom	0.8	1.5	2.7	2.6	1.5	1.2
Ireland	0.7	1.3	2.0	1.8	1.4	1.3
Switzerland	2.0	2.1	1.2	2.9	1.5	1.0
Austria	0.3	2.5	3.2	2.9	1.4	1.5
France	1.5	1.8	2.6	2.5	2.1	1.9
Portugal	3.0	3.5	2.7	2.8	n.a.	n.a.
Spain	1.8	3.3	0.8	2.4	1.2	0.7
Italy	1.8	1.6	3.0	3.0	1.3	1.7
Greece	2.8	2.1	2.4	0.9	1.2	1.3
EU-15	1.0	2.1	2.3	2.7	n.a.	n.a.
United States	n.a.	n.a.	1.8	2.4	n.a.	n.a.
Japan	4.0	4.0	2.6	1.6	n.a.	n.a.

Source: Eurostat New Cronos.

* West-Germany only.

Table 2b
Increase in life expectancy at birth in years, per decade, females

	1960–1970	1970–1980	1980–1990	1990–2000	2000–2010	2010–2020
Norway	1.5	1.7	0.6	1.6	1.0	0.8
Sweden	2.2	1.7	1.6	1.6	1.0	0.9
Finland	2.5	1.6	1.3	2.1	1.4	1.2
Denmark	1.5	1.4	0.4	1.6	0.6	1.1
Germany	1.2*	3.3*	1.8	2.6	n.a.	n.a.
Netherlands	1.2	2.8	1.6	-0.4	0.9	0.3
Belgium	0.7	2.6	2.6	1.4	1.8	1.6
Luxemburg	1.2	2.5	2.6	2.6	n.a.	n.a.
United Kingdom	1.3	1.2	2.3	1.7	0.9	1.3
Ireland	1.6	2.1	2.0	2.5	1.6	1.4
Switzerland	2.4	2.7	1.1	1.9	1.3	0.9
Austria	0.7	2.6	2.8	2.3	1.3	1.4
France	2.3	2.5	2.5	1.8	2.0	1.8
Portugal	4.0	4.4	2.2	2.6	n.a.	n.a.
Spain	2.6	3.8	1.7	2.2	1.1	0.7
Italy	2.6	2.5	2.7	2.4	1.9	1.8
Greece	1.4	3.0	2.7	1.1	1.0	1.1
EU-15	1.8	2.5	2.2	2.0	n.a.	n.a.
United States	n.a.	n.a.	1.4	1.1	n.a.	n.a.
Japan	4.5	4.1	3.1	2.1	n.a.	n.a.

Source: Eurostat New Cronos.

* West-Germany only.

very high prevalences at relatively young ages, influencing life expectancy in a downward manner. In the Netherlands, for example, the highest rates of mortality due to ischaemic heart disease were recorded around 1970, and the highest rates for CVA a few years earlier. Since then, ischaemic heart disease mortality has halved and CVA mortality has decreased by 30 percent.

Over the past three decades, the average annual increase in life expectancy in Western Europe has indeed been close to the increase of 0.25 years mentioned by Oeppen and Vaupel (2002), and even higher in Japan. The gains have been decreasing somewhat over time, especially in Japan. This may however be a temporary phenomenon, that will end when – for example – new and effective cancer therapies become available.

The improvements in survival are increasingly concentrated in the advanced ages, a process that is in line with the fourth stage of the epidemiologic transition (Olshansky and Ault, 1986). This stage is characterized by a substitution of the ages at which degenerative diseases tend to kill. The historical pattern of a widening gap in longevity between the sexes is projected to come to an end during this stage.

Since the late 1980s and early 1990s, the gap between the sexes has indeed narrowed somewhat in Western Europe. For all EU-15 countries combined, the difference was 5.8 years in 2002, against a maximum of 6.7 years in 1991 (Eurostat, 2004). On the whole, the narrowing started earlier and at a faster pace in Scandinavia than in the Mediterranean countries. Interestingly, the sex gap has, up to present, continuously grown in Japan, the country that is generally considered to lead the way in longevity. In 2002, Japanese females lived 6.8 years longer than Japanese males, against 4.9 years in 1960. Japan is now the only low-mortality country in which the sex gap in life expectancy is still increasing (Moslé, 2004).

In a number of experiments using laboratory animals (Carey et al., 1992; Curtsinger et al., 1992) a decrease, rather than an increase, in death rates with progressing age has been demonstrated. In different types of fruit fly mortality rates were shown to level off at older ages. In a number of western populations, such as those of Finland, Ireland, Japan and (western) Germany, the rate of increase in life expectancy has, for the same reason, also been found to accelerate, leading to a more than linear increase in the proportion of surviving octogenarians (Kannisto et al., 1994). A decrease in death rates has even been demonstrated for persons aged 100–104 years in Japan (Robine et al., 2003).

As a consequence, the share of elderly persons in most Western European countries has strongly increased in recent years. This is particularly noticeable in the oldest old, the octogenarians and nonagenarians (table 3). The number of deaths occurring in these age groups has, in the past decades, shown a remarkable increase. In 1950, 23 percent of all deaths in the Netherlands were at age 80 or above, against 49 percent in 2003. A continuing above-average reduction in the mortality rates at the highest ages will therefore concern an ever-growing segment of the population.

Table 3
Number of octogenarians and nonagenarians per 1000 inhabitants, selected European countries, 1990 and 2003

	Octogenarians		Nonagenarians	
	1990	2003	1990	2003
Norway	32	39	n.a.	7
Sweden	37	45	5	8
Finland	25	31	2	5
Denmark	32	34	4	6
Germany	34	34	n.a.	n.a.
Netherlands	25	29	3	5
Belgium	31	33	4	6
Switzerland	33	35	n.a.	7
Austria	32	33	n.a.	n.a.
France	33	34	4	8
Spain	26	34	3	6
Greece	27	28	3	4

Source: Eurostat, 2004.

2.2 High life expectancies in subpopulations

Much higher than average life expectancies have been demonstrated in various subpopulations. Without exception, these subpopulations show health behaviours that are more conducive to long life than those of the general population. A cohort-study among Californian Seventh-Day Adventists, for example, concluded that the male study subjects had a life expectancy at age 30 that was 7.3 years longer than that of other Californian men. The studied women lived 4.4 years longer (Fraser and Shavlik, 2001). Commonly observed combinations of diet, exercise, body mass index, past smoking habits, and hormone replacement therapy (in women) can account for differences of up to 10 years of life expectancy among Adventists. Their longevity experience probably demonstrates the beneficial effects of more optimal behaviours.

A study among members of the Church of Jesus Christ of Latter-day Saints (LDS, Mormons) in Utah showed a similar increase in life span (Manton et al., 1991). According to this study, life expectancy was 77.3 years for LDS males against 70.0 for non-LDS males, and 82.2 years for LDS females against 76.4 years for non-LDS females. Although, according to Merrill (2004), religious activity may have an independent protective effect against mortality, better physical health and social support as well as healthier life style behaviours can explain most of the differences. Various other studies have demonstrated the positive correlation between religious activity and both mental and physical health (e.g. Koenig et al., 1992; Koenig et al., 1999).

As the abovementioned religious groups generally adhere to rather strict rules with respect to life style, in particular the consumption of alcohol and tobacco, they form ideal subpopulations for the study of the effect of behaviour on life expectancy. The measured effects are, in the two mentioned studies, lower than they would be if the present life style were adhered to by all subjects during the whole life span. Many Mormons and Seventh-Day Adventists are adult converts who have, for instance, a history of smoking.

A number of studies have also demonstrated positive life style effects in other, non-religious but otherwise exclusive groups. Large differences in life expectancy between a healthy living non-religious group in Alameda County (California) and the general population have, for example, been demonstrated by Kaplan et al. (1987). The male study subjects in their longitudinal study (aged 60–94 years at baseline) reached an average age of 98.0 years, 24.2 years longer than the average US male population, with a remaining life expectancy at age 85 of 20.0 years (Manton et al., 1991).

Even within the general population, differences in life expectancy between the subgroups with the lowest and the highest socioeconomic status (SES) are very large. This fact has been demonstrated in several classic studies (e.g. Kitagawa and Hauser, 1973; Townsend and Davidson, 1982). Since then, these differences have, in many western countries, increased rather than decreased. This widening of the socioeconomic gap has even happened in the relatively egalitarian Scandinavian countries (Valkonen, 1998; Mackenbach et al., 2003).

In the Netherlands, the most recent data show a difference in life expectancy of 4.9 years between males with the lowest and males with the highest SES. A considerably smaller gap of 2.6 years is observed among females (Van Herten et al., 2002). This inequality is largest among persons aged 50–59 years. The poorest 20 percent of them run a risk of mortality that is 2.5 times as high as that of the richest 20 percent (Van Duin and Keij, 2002). Although the Dutch government aims to reduce this socioeconomic gap, the differences in life expectancy have not yet shown a consistent tendency to decrease (Van der Lucht, 2002).

The fact that a much higher life expectancy is observed among groups adhering to prescribed or self-imposed rules with respect to life style as well as among subpopulations for which a healthy

life style is rather a matter of course, demonstrates the potentially large improvements in life expectancy that could be achieved if a health promoting behaviour were more widely adopted. At the population level, a more favourable life style could strongly increase the average life expectancy, as the subgroups with suboptimal behaviour form a substantial and increasing segment of the total population. The most important subgroups in this respect are the young and elderly persons, foreigners and persons with a low SES (Jansen et al., 2002). Within these groups, the potential for improvements is large. A quarter of all elderly Dutch males, for example, smokes, whereas 60 percent of all elderly persons are overweight (Van den Berg Jeths, 2004). A change in behaviour, furthermore, pays off after a relatively short period, even at the higher ages. Those who quit smoking at age 30 gain, on average, 10 years of life expectancy, but at age 60 cessation still adds 3 years (Doll et al., 2004).

2.3 Biomedical arguments

A favourable life style may increase life expectancy, but the life spans of all living organisms are also, to some extent, determined by their genetic make-up. The genetic contribution to longevity is estimated at about 25 or 30 percent (Skytthe et al., 2003; Moran and Wolff, 2004). This explains – at least partly – why the chance of a centenarian's brother to reach the age of 100 is 17 times larger than that of the average American, while a sister has an 8-fold chance (Perls et al., 2002). With such a substantial component of genes in longevity, advances in gene therapy could strongly increase the life expectancy in the coming decades. Mortality is, furthermore, not programmed in our genes. There is no 'death gene', nor a simple combination of genes to serve the same purpose (Kirkwood, 1999). If this were the case, incomplete replication of DNA would, every so often, cause an individual to be born without this gene or combination of genes, and to be virtually immortal. Death is, in other words, not a genetic inevitability.

Experiments have repeatedly shown the potentially large effect of gene manipulation, in particular in *Caenorhabditis elegans* (a species of roundworm) and *Drosophila melanogaster* (a species of the common fruit fly). In 1998, *C. elegans* became the first organism with a completely sequenced genome. One study of *C. elegans*, a one millimetre long nematode with a genome sharing many characteristics with that of humans (Kenyon, 1988), compared several gene mutations with a normal control group. Whereas all worms in the control group had died by the age of 24 days, the mutants were found to have a three- to fourfold increased life span (Larsen et al., 1995).

The exact mechanisms behind this life span increase have not yet been disentangled. According to some, a single 'life span gene' or a limited number of interactive genes may be the key to a long life, while others consider cumulative cell damage due to oxidation to be the most likely mechanism. One of the candidate genes determining longevity is P53; a cancer suppressor gene that causes apoptosis (sudden cell death) once a certain degree of cell damage has been reached. P53 is, in its turn, influenced by the SIR2 gene, connected to calorie restriction, metabolism and ageing in various organisms. The free radical theory, on the other hand, considers ageing to be the result of cumulative damage to cells and tissue caused by the aerobic metabolism in the mitochondria. Several lines of evidence to support this theory have been found. The variation in life span, for example, seems to be correlated with the rate of metabolism (and thereby the production of oxidants), damage due to oxidant activity increases with age and reduced calorie intake leads to a reduction in oxidants and an increase in life span (reviewed by Wickets, 2001). Definitive proof that free radicals are the primary cause of ageing is still lacking, however.

Long-lived *Drosophila* and *C. elegans* mutants have proved to be resistant to oxidative stress, showing a link between the longevity

gene theory of ageing (also known as planned obsolescence theory or genetic control theory) and the free radical theory of ageing. Other *C. elegans* mutants that are long-lived appear to have altered hormonal signalling. Similar processes have been discovered in *Drosophila*, illustrating the strong bimolecular homology between different organisms. Recent scientific evidence therefore supports that ageing is based on multiple interactive mechanisms (Guarantee and Kenyon, 2000; Wickets, 2001), but that these mechanisms may be similar in lower and higher organisms.

Even without gene manipulation, remarkable increases in life expectancy have been proven possible. More than seventy years ago, McKay et al. (1935) demonstrated that caloric restriction experiments in rodents could increase the maximum life span by 30 percent or more. A significant higher life expectancy has been achieved by a calorie reduction of 40 percent, maintaining adequate levels of micronutrients, vitamins and amino acids (Roth et al. 2001). Similar experiments have been repeated in fruit flies and nematodes, in which even a threefold extension of the life expectancy has been proven possible. Caloric restriction experiments are presently carried out in monkeys, but it will still take many years before the definitive effect on hominids can be determined.

Why animals that are given healthy but low-calorie diets live longer is still uncertain. Slower metabolism may reduce oxidative cell damage, lower blood glucose levels may lessen the potential for biochemical processes implicated in the ageing of cells, or a lower body temperature may slow down cumulative genetic damage (Moran and Wolff, 2004).

Caloric restriction and, probably more importantly, a shortage of essential nutrients in utero and during infancy may also have a harmful effect on longevity, as it is thought to program the development of risk factors for several important diseases of middle and old age (Barker et al., 1989; Barker, 1995). Barker's original hypothesis related to the risk of ischaemic heart disease and has led to the idea of the 'thrifty phenotype' (Barker and Hales, 1992). Due to undernutrition in utero, permanent endocrine and metabolic changes occur which would be beneficial if nutrition remained scarce after birth. If this is not the case, these changes predispose to obesity and impaired glucose tolerance. Barker's hypothesis has been confirmed in several consecutive studies (Robinson, 2001; Iliadou et al., 2004). The fact that the maternal-fetal state of nutrition has continuously improved over the past century – with the exception of a relatively short period during the Second World War – would therefore imply that fewer and fewer adults are burdened by harmful 'fetal memories' (Anonymous, 2003). According to some, the apparent stagnation in the increase of mortality rates by age among the elderly could be (partly) ascribed to this trend.

Many more theories of ageing than those mentioned above have been advanced, from the wear and tear theory (late 19th century) to the relatively recent telomerase theory. Some other well-known theories are: the neuroendocrine theory (elaborating on the wear and tear theory by focusing on the gradually deteriorating effectiveness of the hypothalamus to regulate hormone release); the waste accumulation theory (the accumulation in the cells of toxins and waste products, in particular lipofuscin, gradually interfering with normal cell function); the Hayflick limit theory (stating that the number of cell divisions is limited, but that nutrition influences the length of time between divisions); the death hormone (DECO) theory (with increasing age, DECO is released by the pituitary gland, influencing metabolism and accelerating ageing); the thymic stimulating theory (the thymus stimulates the immune system, but shrinks with age); the errors and repairs theory (the DNA repair processes become less effective and precise with age); the cross-linkage theory (the cross-linking of proteins increasing with age, leading to tissue changes and decreasing the capacity to clean out excess glucose molecules in the blood); and the autoimmune theory (the ability to produce antibodies to fight disease declines with age, eventually becoming self-destructive).

Although there is probably no true longevity gene, many genes can indirectly influence our health and life expectancy. All the abovementioned theories imply in some manner that biochemical processes at the cell level influence longevity to a greater or lesser degree. The completion of the Human Genome Project and the rapid innovations in technology promise to enable the identification of such 'longevity-assurance genes' in humans (Barzilai and Shuldiner, 2001). Clonal senescence, the process leading to the death of somatic cells, seems to be under genetic control. This control disappears in neoplastic transformation: if left alone, cancer cells are immortal. Only a few genes – possibly tumour-suppressor genes or oncogenes – are involved in the difference between mortality and the immortal neoplastic condition. With a better identification and understanding of these genes, breakthroughs in the prevention and therapy of cancer are likely to occur.

Medication to reduce or prevent cell damage, or to stimulate the effectiveness of longevity-assurance genes, may eventually lead to a drastic increase in life expectancy. In spite of many claims to the contrary, scientifically proven antiaging medicines are not yet available, but important scientific efforts are underway to develop them (De Grey et al., 2002).

Last but not least, medical advances have greatly improved the chances of survival for seriously diseased persons. Better medication and improved surgical procedures have strongly reduced the risk to die of cardiovascular diseases and most forms of cancer, for example. Important further improvements are expected to occur in the coming decades.

2.4 Life style arguments

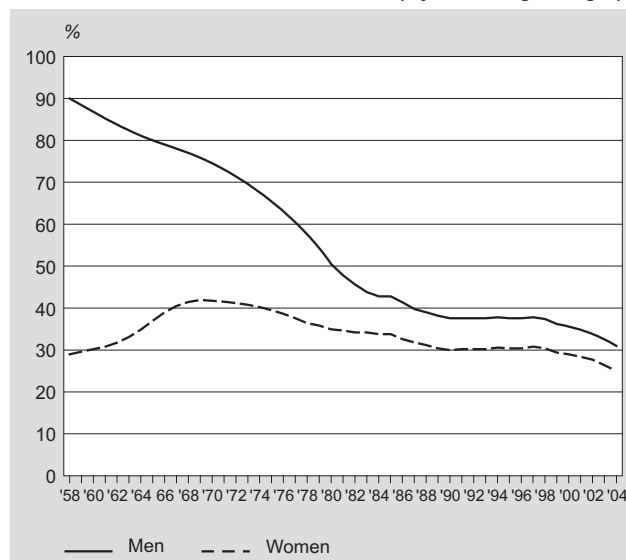
Where biomedical breakthroughs hold an exciting promise for future longevity, variations in life style account, at least up to present, for most of the historical, geographic and socioeconomic differences in life expectancy. Tobacco consumption, nutrition and physical exercise are the major health-discriminating aspects of life style. Of these, smoking is today probably the most clearcut and undisputed factor. Consecutive studies have shown an ever-increasing detrimental effect on health (Peto et al., 2000). Nonetheless, the effect of smoking on health at the population level seems to have decreased in the past few decades, at least with respect to lung cancer. The number of male lung cancer deaths in the Netherlands has, in spite of a steadily ageing population, decreased from about 7.5 thousand in the mid-1980s to 6.5 thousand in 2004. The total number of female lung cancer deaths has increased though, but this has not (yet) led to a strong increase in total lung cancer mortality. Favourable trends in smoking behaviour are strongly related to these mortality trends. In the late 1950s, almost all Dutch adult men were smokers, but by 1980 only half of them smoked. Since then, the share of male smokers has further decreased, to less than a third in 2004 (figure 2).

Considerably fewer women smoked in the 1950s, and their share started to increase much later than among men. A maximum of just over 40 percent was reached around 1970, followed by a relatively slow decline. At present, about a quarter of all adult Dutch women smoke. The most recent data on tobacco consumption suggest a further downward trend, caused by much stricter legislation and price increases in 2004 (Draper, 2005).

The consumption of cigarettes per head of the Dutch population (aged 15 years and above) has decreased by a third since the mid-1970s, from almost 10 to less than 6 cigarettes per day. This is largely due to the growing share of non-smokers in the population. Since the late 1970s, smokers consume on average about 20 cigarettes per day (figure 3).

The trends in smoking as shown in figure 2 are clearly reflected in the lung cancer incidence in the Netherlands by age and sex (figure 4), considering the fact that smoking may take, on average,

2. Percentage of persons aged 15 years or above who are smoking, men and women, the Netherlands, 1958–2004 (5-year moving averages)

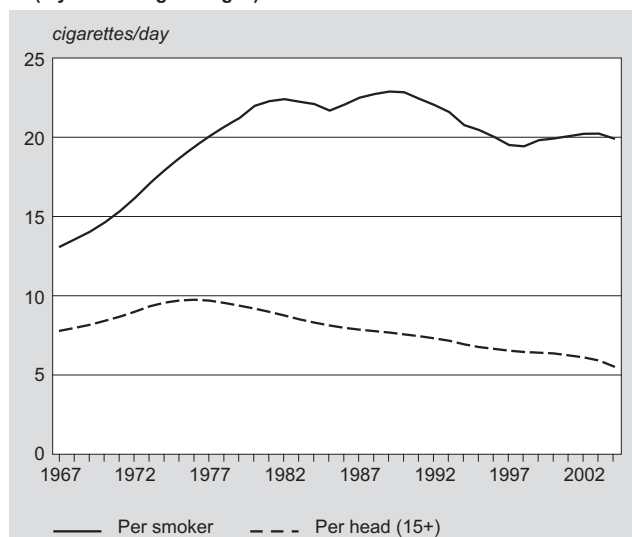


about three decades to lead to lung cancer. The trend for middle-aged men shows a continuous decline over the past three decades; the highest rates among men aged 65–79 years were reached in the early 1980s, while the incidence for men of 80 years or above commenced their marked decrease about six years later. The rates have more than halved for middle-aged men, and have decreased by a quarter to a third among older men. Further decreases are likely to occur in the coming decades. Among women of all ages, lung cancer trends are less favourable. The absolute rates, however, are much lower than those of men. Furthermore, female rates are unlikely ever to reach the historic rates for men, as smoking has never been (almost) universal among women. Around 1970, over four in every ten women smoked, a share that has fallen to below three in ten at present.

Important health gains and improved survival can also be achieved by changing dietary habits. On the whole, the average Dutch diet has become healthier during the past decades, a trend that has contributed to the increase in life expectancy (Van Kreijl and Knaap, 2004). Cardiovascular mortality, in particular, accounting for about 45 percent of all deaths in the period 1955–1985, has in the past two decades been reduced by improved dietary habits. In addition, lower tobacco consumption has contributed to the reduction of cardiovascular diseases. At present, one third of all deaths in the Netherlands are (primarily) caused by ischaemic heart disease (IHD) and cerebrovascular accidents (CVA). This group of diseases is still the leading cause of death – as it has been during the whole of the past century – followed by cancer, presently representing about 27 percent of total mortality. If recent trends continue, cardiovascular deaths will be replaced by cancer as the most important cause of death in the Netherlands somewhere in the first half of the 2010s (Garssen and Hoogenboezem, 2005).

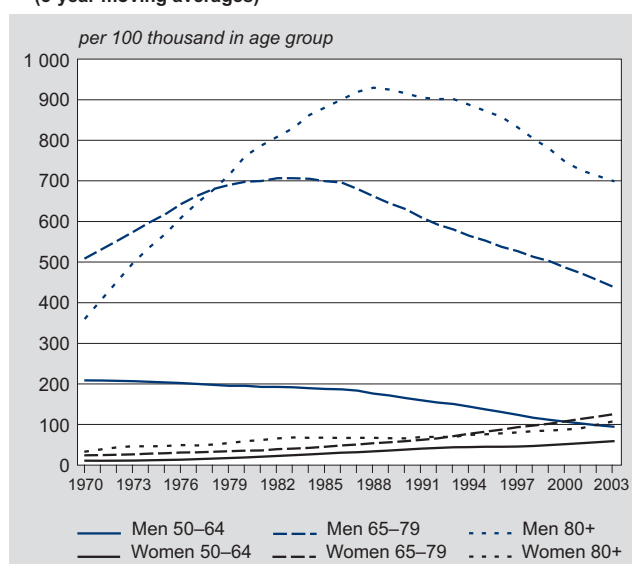
Life style changes, in combination with improved medical care, have not only led to lower cardiovascular mortality (figure 5), but also to a significant rise in the age at death of the victims of these diseases. The age at which the largest number of male deaths from ischaemic heart disease occurred was 82 years in 2003, against 72 years in 1970. The share of middle-aged men and women among those dying from IHD has likewise decreased. The percentage of men aged 40–69 years of the total male mortality from IHD fell from 47.4 in 1970 to 32.9 in 2003; among women this share decreased from 23.7 to 13.3 percent. The share of such relatively young persons among CVA victims has shrunk in a similar manner: from 25.2 percent (men) and 18.4 percent (women) in 1970 to 19.7 and 9.3 percent respectively in 2003.

3. Cigarette consumption per day, the Netherlands, 1967–2004 (5-year moving averages)

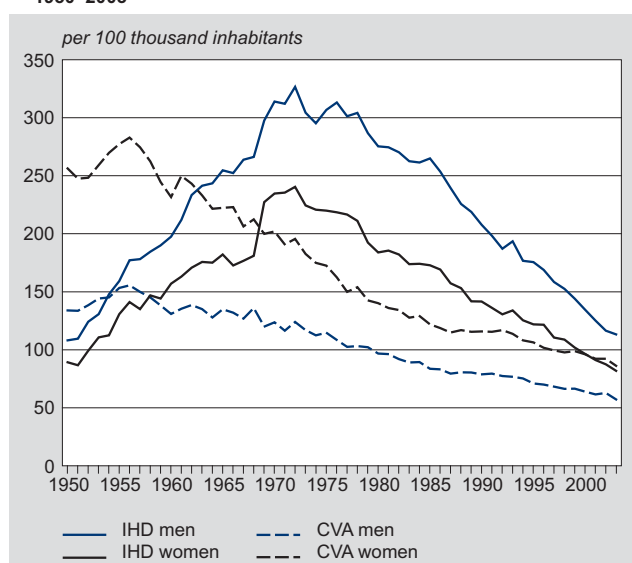


Calculated on basis of Stivoro, 2005.

4. Lung cancer mortality by age and sex, the Netherlands, (5-year moving averages)



5. Standardized mortality rates, IHD and CVA, the Netherlands, 1950–2003



Although health losses caused by unhealthy dietary habits are comparable to those caused by smoking, the effects on mortality are probably somewhat smaller. The potential gains in survival are nonetheless significant, as about half of the diet-related mortality can be prevented by public health interventions (Van Kreijl et al., 2004). The intake of trans fatty acids, generally known to contribute to arteriosclerosis, has decreased by about 60 percent in the period 1988–1998 (Gezondheidsraad, 2002). This is partly due to a conscious choice of consumers, substituting high fat products by leaner alternatives, and partly to the food industry, striving to limit the use of animal and hydrogenated vegetable fat in their products. Further contributions by the industry are under way, and the potential to achieve improvements, either voluntarily or enforced by law, is large and probably easier to realise than changes in the behaviour of consumers. Further product modifications, resulting in a healthier diet even in the absence of diet changes, hold great promise for the future. The food industry could strongly contribute by restricting the supply of unhealthy products, lowering the prices of healthier alternatives, reducing the size of food portions and restricting or banning commercials directed at children.

The effects will of course be even greater if consumers adopt a healthier diet. In addition to restricting their intake of saturated fats, Dutch consumers could easily increase their consumption of fish, an important source of essential polyunsaturated (omega-3) fatty acids, promoting cardiovascular health and possibly lowering the risk of certain forms of cancer. A diet containing one or two portions of fish per week has been shown to reduce the risk of IHD by about 25 percent (Whelton et al., 2004). The consumption of fish in the Netherlands is still relatively low, but shows a favourable trend: the consumption in 2001 was 17 percent above that in 1995 (Bijman et al., 2003). A further shift from the traditional Dutch cuisine to a more Mediterranean one, already visible, will increase longevity. Knuops et al. (2004) have demonstrated that elderly persons, aged between 70 and 90 years, have a 20 percent lower mortality risk if they adhere to a Mediterranean diet. Non-smoking, moderate alcohol intake and moderate to intensive physical exercise each lead to a 20-35 percent lower risk, and a positive score on all four of these aspects of a healthy life style result in a reduction of the risk to die within a period of ten years by more than 60 percent.

The case of alcohol is less straightforward than that of smoking, diet and exercise, as it has both a positive and a negative effect on public health. About 1.3 percent of the total mortality in the Netherlands is alcohol-related; in about half the number of cases alcohol is the primary cause of death (Verdurmen et al., 2004). A clear increase in alcohol-related mortality is observed among young adult women (CBS, 2001), especially those with a higher level of education (Verdurmen et al., 2003). This trend is also visible in other European countries (Alcohol Concern, 2003), although the (reported) levels may differ considerably. Bartecchi et al. (1994) showed that alcohol contributes to 5 percent of all deaths in the United States. The harmful effect of tobacco was found to be about four times as high. Although alcohol consumption is on the increase among young women, the consumption per head of the population has been rather stable in the Netherlands since the early 1990s, and the most recent figures indicate a slight decrease (PGD, 2004).

On the other hand, alcohol has a protective effect on health if consumed in small to moderate amounts. The cardioprotective effect has been known for at least a century (Cabot, 1904), and more recent studies have repeatedly shown a J-shaped curve if alcohol consumption is plotted against cardiovascular and all-cause mortality risk (e.g. Doll et al., 1994). Considering the fact that moderate alcohol consumption is associated with a 30 to 60 percent reduction in coronary heart disease risk in various case-control and cohort studies, while the gross effect on all forms of cancer combined is small or possibly even favourable, it can be conservatively concluded that the widespread use of alcohol has no gross negative effect on public health.

In recent years, the negative effects of a lack of physical exercise on health have drawn increasing attention. The effects of greater physical activity on health are large and long-lasting: if the number of inactive Dutchmen would decrease by 4 percent point and if the number of those who are sufficiently active would increase by 10 percent point, 48 thousand fewer persons would die over a period of twenty years, and 30 thousand myocardial infarctions, 28 thousand strokes, 27 thousand cases of type 2 diabetes and 4 thousand cases of colon cancer would be prevented (Bemelmans et al., 2004). The potential of life style changes in this respect is therefore very high.

Health and longevity are strongly associated with socioeconomic status (SES), and future changes in the composition of the population by SES will therefore affect the overall risk of mortality. This is even more so because the highest gains in life expectancy can be achieved by persons of the lowest SES who enter the next higher SES-category (Backlund et al., 1996; Ecob and Smith, 1999). The potential of a healthier life style for persons of the highest SES are much smaller.

The most important element of SES in this respect is the level of education. According to Joung et al. (2000) the expected rise in educational level alone will counteract, in the coming decades, the expected increases in ill-health based on population ageing to a substantial degree.

In view of the present suboptimal life style of the population and the high potential of life style changes, significant improvements in health can still be achieved. Specific public health interventions with respect to nutrition, considered to be of a realistic nature, may result in an annual reduction of 20 thousand cases of cardiovascular disease in the Netherlands. Interventions aimed at reducing overweight may bring down the annual number of new cases of diabetes by 5 thousand and the number of new cases of cardiovascular disease by 4 thousand (Ocké and Hulshof, 2004).

It is, furthermore, never too late to adjust one's life style and improve one's health by doing so. The effect of life style for elderly persons appears to be generally underestimated. A quarter of all men aged 65 or above smoke (women 15 percent), six in ten do not meet the norm of physical activity for the elderly (Koek et al., 2003) and nutritional habits – in particular with respect to the intake of saturated fats – are far from optimal (Jansen et al., 2002).

3. Arguments against large gains in life expectancy

3.1 The argument of slowing life expectancy gains

The average annual increase in life expectancy in Western Europe may have been close to the increase of 0.25 years mentioned by Oeppen and Vaupel (2002), but a closer look at the trend reveals that the average increase is levelling off. The annual increase per 5-year period for all EU-15 countries combined, shown in figure 6, indicates that this downward trend may have started in the early 1980s among women. The rather marked decrease among men is of a more recent nature. In Japan, the country with the highest female life expectancy, the gains in life expectancy are also decreasing.

Dutch women show a more or less similar pattern (figure 7), in a somewhat amplified manner. The increase was above the EU(-15)-average in the late 1970s and has, since the early 1980s, been consistently below that average. This eventually led to the marked drop of Dutch women in the international ranking of life expectancy, shown in figure 1b.

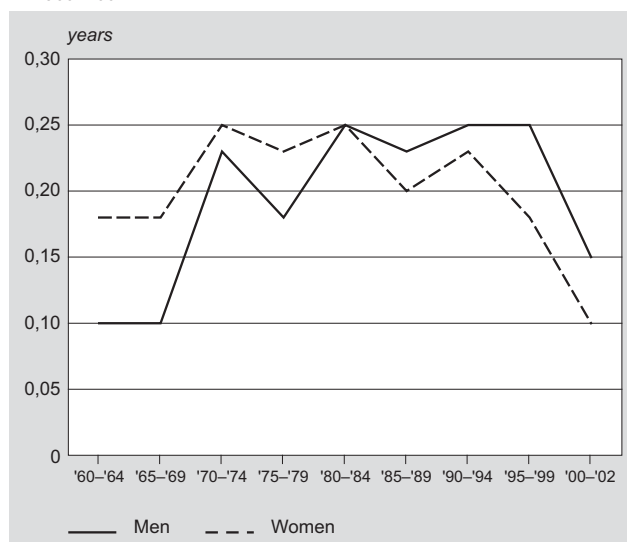
Dutch men have, on the whole, caught up on Dutch women since the early 1980s, narrowing the gap in life expectancy between the sexes. With the exception of the late 1970s and the most recent years, their gains in life expectancy have been more modest than the EU-average, explaining the drop in their ranking shown in figure 1a.

The most spectacular improvement in mortality risk among both sexes has, in the past half century, clearly been the reduction in infant mortality. Fifty years ago, this risk was about six times as high as today. Between 1950 and 2003, the reduction in infant mortality contributed about one third to the increase in male life expectancy recorded over the same period. The contribution to female life expectancy was considerably smaller (about one fifth). Had the infant mortality rates not declined since 1950, the life expectancy at birth would have been 1.9 and 1.6 years shorter for men and women respectively.

The gains in life expectancy that are due to improved survival of the newborn largely occurred in the past, however. Since the mid-1990s, the infant mortality rate has been more or less stable, around 5 per thousand. Even if further improvements could be achieved, the effect on life expectancy would only be very small. Today, the (obviously unrealistic) total elimination of infant mortality would increase male life expectancy by 0.4 years, and female life expectancy by 0.3 years.

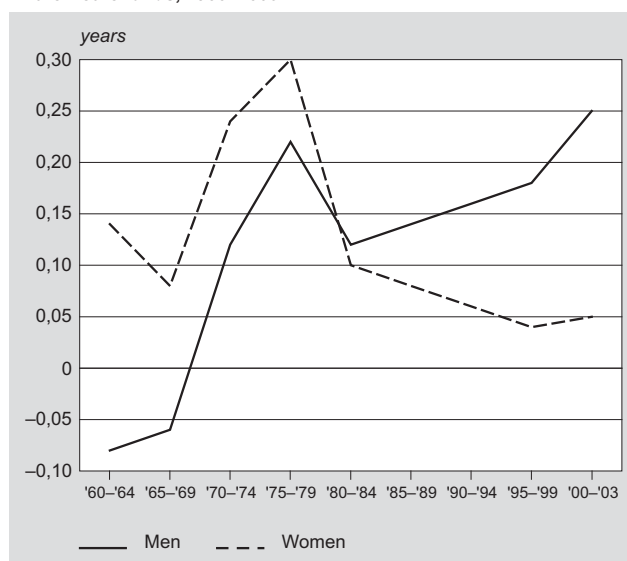
The changes over time among young adults and the middle-aged show a less uniform pattern, in particular among men. For 20-year old men, the characteristic hump in the 1960s and 1970s reflects the epidemic of traffic accidents, reaching its zenith in the early

6. Average annual increase in life expectancy by 5-year period, EU-15 1960–2002



Source: Eurostat.

7. Average annual increase in life expectancy by 5-year period, the Netherlands, 1960–2003



1970s. The mortality risk of young adult men was, at that time, 2 to 3 times as high as it is today. A similar but much weaker pattern is visible for young adult women. Their mortality risk was, around 1970, about 1.5 to 2 times as high as it is today.

The annual decreases in the mortality risk of young men have, since the late 1980s, been relatively small. A more substantial reduction is visible for women since the late 1990s, but room for further improvements is small in view of their already low mortality rates. Further mortality reductions at these ages will have even less effect than reductions among infants. Eliminating the excess mortality of men – largely due to traffic accidents – in the age group 15–29 years, would only result in a gain in life expectancy at birth of 0.05 years. The small size of the potential gains in mortality reduction between the ages of 15 and 30 years can be demonstrated by the effect of a total elimination of mortality; the life expectancy of men would then increase by 0.44 years, and that of women by 0.25 years.

Mortality reductions at higher ages will, considering the larger numbers involved, have a stronger effect, but the strength of this effect is partly offset by the reduction in additional life-years with progressing age. Even spectacular mortality reductions at high ages therefore result in modest increases in life expectancy at birth. This explains the fact why mortality reductions at the middle ages concerned a much larger number of persons, yet had a similar effect on life expectancy as the reduction in infant mortality: since 1950, the decrease in risk at ages 40–69 explains about 30 percent of the increase in life expectancy, for both men and women. The potential of mortality reductions at the middle ages should not be overrated, however. A truly spectacular halving of the risk at all ages between 40 and 70 years, would result in an extension of the life span of men by 2.2 years; women would then live, on average, 1.7 years longer.

The trends depicted in figures 8a and 8b indicate that such reductions are not likely to occur anywhere in the near future. Among women, the trend has even been unfavourable since about 1990, largely as a consequence of cigarette smoking. This unfavourable trend will still continue for several years (De Jong, 2005a).

The most unfavourable trends can be observed among elderly men, between the ages of about 70 and 85 years. At the age of 70 years, in particular, mortality has for a long time been higher than that recorded in 1950, again reflecting the effects of unhealthy behaviour. No such trend is visible among women, who in earlier decades smoked considerably less than men. At all advanced ages, however, the general impression is one of stag-

nation. At the highest ages (age 90 and above), rates are even slightly increasing. For males, falling rates at age 70 and 80 may be a forebode of mortality improvements at higher ages in the near future, but such a cohort effect is unlikely to occur among women.

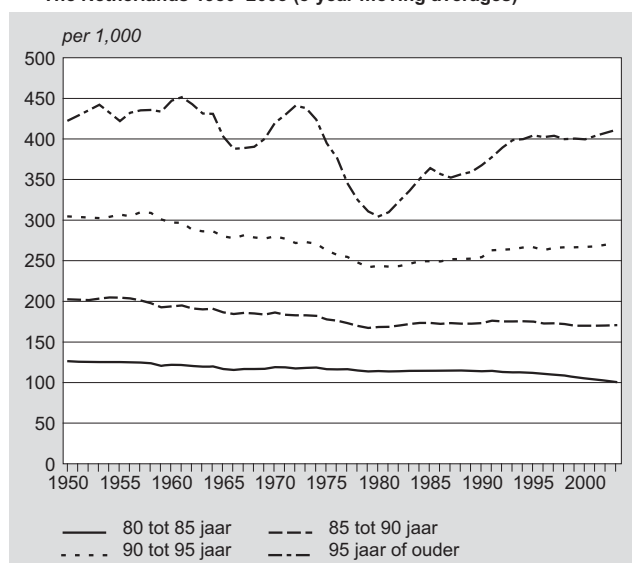
Even though centenarians presently form the largest growing age group in most Western European countries, it should not automatically be concluded that this is caused by improved survival at the highest ages. The observation by Vaupel and Jeune (1995) that the proliferation of centenarians in Scandinavian countries is due to better survival from ages 80 to 100, does not apply to the Netherlands. Dutch centenarians also form the fastest growing age group (table 4), but this has come about in spite of deteriorating survival at the highest ages (see figures 8a and 8b). Almost all of the increase between 2000 and 2004 can be ascribed to earlier improvements in survival at younger ages (Garssen, 2005). About 5 percent of the increase is due to the historic increase in birth rates (between 1900 and 1904).

It should, furthermore, be noted that more attention is paid by many researchers to the growing numbers of centenarians than is warranted by their significance to the life expectancy of the general population. This significance is, in fact, minimal in view of the fact that reaching one's 100th birthday is still exceptional. Today, centenarians form only 0.009 percent of the Dutch population, and even a strong increase will have a negligible effect on the overall life expectancy. In the words of Finch et al. (2000): "While longevity records are entertaining, they have little relevance to our own lives because genetic, environmental and lifestyle diversity guarantees that an overwhelming majority of the population will die long before attaining the age of the longest-lived individual".

3.2 Theoretical considerations

The fact that a large number of – often conflicting – theories on longevity have been formulated over the past decades is, in itself, an indication of the uncertainty among experts that any of these theories may eventually solve more than a fraction of the puzzle of longevity. In addition to the various theories that suggest the possibility of significant increases in the average life span, roughly summarized in section 2.3, some theories point in the opposite direction: the maximum life span is determined by biological laws, and circumventing these laws will not be possible for a long time, if at all. This would not imply that future gains in life expectancy are impossible, but that these gains are limited by a law of dimin-

8a. Annual risk of mortality for elderly men, by age group, The Netherlands 1950–2003 (5-year moving averages)



8b. Annual risk of mortality for elderly women, by age group, The Netherlands 1950–2003 (5-year moving averages)

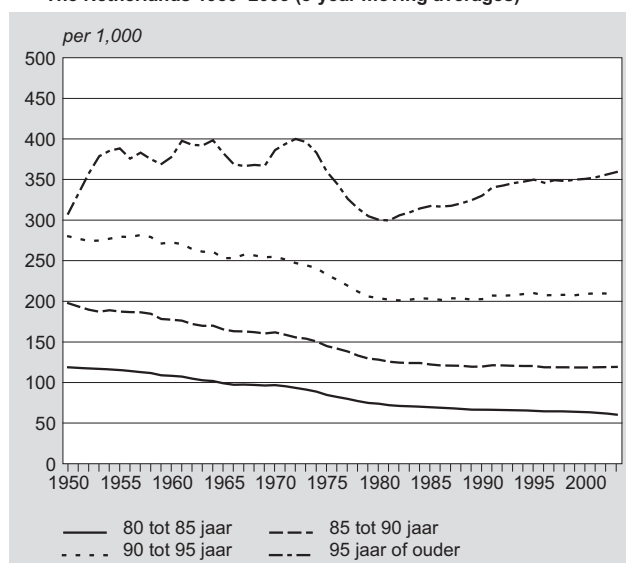


Table 4
Population size and growth by sex and age group, the Netherlands, 1970–2004

	1970	1975	1980	1985	1990	1995	2000	2004
Men								
	<i>number x 1,000</i>							
60–69 years	480.5	507.6	515.3	560.6	602.8	624.0	663.3	718.9
70–79 years	268.2	288.4	310.9	332.0	343.2	385.3	423.0	445.9
80–89 years	87.5	94.4	101.4	110.2	118.7	129.8	136.8	159.8
90–99 years	7.4	8.9	11.8	12.7	13.2	13.6	14.4	15.8
100 years or above	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
	<i>annual increase in preceding 5-year period (%)</i>							
60–69 years	1.7	1.1	0.3	1.8	1.5	0.7	1.3	1.7
70–79 years	1.4	1.5	1.6	1.4	0.7	2.4	2.0	1.1
80–89 years	2.7	1.6	1.5	1.7	1.5	1.9	1.1	3.4
90–99 years	6.6	4.0	6.6	1.5	0.9	0.6	1.2	2.0
100 years or above	16.4	4.0	16.1	5.2	6.6	–0.9	–3.7	3.5
Women								
	<i>number x 1,000</i>							
60–69 years	560.9	598.9	607.4	655.7	696.0	691.0	704.7	739.9
70–79 years	346.6	398.2	452.3	493.2	505.6	552.0	584.6	583.7
80–89 years	116.1	141.0	177.8	218.9	257.7	285.7	294.8	323.8
90–99 years	10.6	13.8	20.5	28.4	37.3	45.6	53.3	57.5
100 years or above	0.1	0.2	0.3	0.4	0.6	0.8	0.9	1.1
	<i>annual increase in preceding 5-year period (%)</i>							
60–69 years	2.1	1.4	0.3	1.6	1.2	–0.1	0.4	1.0
70–79 years	3.2	3.0	2.7	1.8	0.5	1.8	1.2	0.0
80–89 years	4.4	4.3	5.2	4.6	3.5	2.2	0.6	2.0
90–99 years	6.7	6.1	9.7	7.7	6.3	4.5	3.3	1.6
100 years or above	10.9	13.3	10.1	11.9	8.6	6.0	3.8	3.5

ishing returns. The room for improvement would then largely be determined by the contribution of behaviour to longevity. Considering that genes contribute to between a quarter (Vaupel et al., 1998) and 30–40 percent (Skytthe et al., 2003) of longevity, this room would still be considerable, but fighting diseases and disorders that appear in older ages will be a never-ending battle, becoming more and more difficult as death rates decline (Tabeau, 1996).

One of the most important biological laws related to life span was revealed by Hayflick and Moorhead (1961). They noted that the process of cell division in normal human cell cultures start to slow down after about fifty divisions. As some copying errors occur in each division, the cumulative cell damage activates a mechanism that stops further division ('apoptosis', sudden cell death). This was thought to be an built-in mechanism to prevent an unrestrained copying of defective cells. Martin et al. (1970) later found evidence to support Hayflick's contention that cell ageing and human ageing are linked, by showing that the number of cell divisions declined with the age of the cell donor. The effect of caloric restriction (see section 2.3) could also be demonstrated in vitro: underfed cells took up to three times as long as normal cells to divide.

The interpretation of these findings is not straightforward, however. According to some, the 'Hayflick limit' is an artefact of in vitro culture, with no relevance to in vivo cell physiology. A relation to senescence would be unlikely: cells from old donors (aged 80–90 years) still have about twenty passages of proliferative capacity, but the donors are, nonetheless, obviously senescent.

On the other hand, the 'Hayflick limit' clearly suggests that ageing is rooted in biological processes that are not easily manipulated. In order to slow ageing, the copying process in cell division should be improved to prevent cumulative cell damage. Only then could 'growing chaos', the hallmark of ageing according to Westendorp (Köhler, 2004), be stopped.

The observation that the continuous loss of physiological capacity with age leads to an increased vulnerability to specific causes of death, has inspired Hayflick and Moody (2002) to their provocative

statement that no one over the age of, say, 75 has ever died from any of the 130 ICD-causes of death. The ultimate cause of death should in fact be 'old age', the ICD-category that was abolished many years ago. What is legally written on the death certificate is, according to them, simply irrelevant detail. One of the consequences of this practice would be that research has paid too much attention to the elimination of specific diseases, and too little to the underlying cause, the ageing process itself. According to Hayflick and Moody, the probability of resolving the ageing process as a cause of death is close to zero because, even with the most advanced technology known today, we cannot control the rate of ageing in something as infinitely less complicated as our own automobiles.

The reason why we grow old and die is, according to Kirkwood (1977, 1999), that our bodies are 'disposable'. Copying the protein chains in our cells requires a large amount of energy. Perfect replication demands even more energy, and this high precision procedure is only followed in our germ cells. An energy saving method operates in our somatic cells, allowing a small number of copying errors at each replication. This 'dual energy mode' inspired Kirkwood to formulate his Disposable Soma Theory. The theory elaborates upon the earlier work of Hart and Setlow (1974), who noted an inverse relation between the investment in reproduction and the investment in somatic maintenance. Organisms exposed to high risk (like mice) invest more in reproduction and less in somatic maintenance (hence their high cancer risk). Organisms that are much less threatened (like elephants) do the opposite. Survival beyond the reproductive years and, in some cases, raising progeny to independence, is not favoured by evolution because limited resources are better spent on strategies to achieve sexual maturity rather than longevity (Kirkwood, 1977).

As our ancestors, humans living under primitive conditions, were not destined to lead very long lives, human somatic maintenance is far from perfect. Once the minimum age that determines the survival of the human species has been passed, cumulative DNA-damage is inevitable, gradually leading to ageing and increased susceptibility to disease. Having learned how to reduce environmental threats to life, the majority of the human population lives far beyond the required minimum age for group survival, and

the relationship between fertility and longevity has blurred. The relationship appears to have been rather distinct in the not too distant past, however, as shown by Westendorp and Kirkwood (1998). Using historical data on the British aristocracy, up to about the mid-18th century, they showed a significant negative correlation of female longevity with the number of progeny and a positive correlation with age at first birth. Their findings do not imply a likely causative mechanism between childbirth and longevity, but rather a reflection of the fact that women with a very active immune system are generally less fertile; their bodies recognize implanted embryos, containing proteins of the father, as non-self.

The recent publications on human genome sequences have fuelled speculations that this new knowledge would reveal genes that could be manipulated in order to intervene directly in the process of ageing. Yet, although it is likely that advances in molecular genetics will soon lead to effective treatments for some inherited and age-related diseases, it is unlikely that scientists will be able to influence ageing directly through genetic engineering (Rattan, 1997). The reason is simply that there are no genes directly responsible for the processes of ageing. According to Wickens (2001), ageing is likely to be a multifactorial process and not reducible to any one single cause. Recent compelling evidence supports a role for important genetic and environmental interactions on longevity, even in lower organisms (Barzilai and Shuldiner, 2001).

Centuries of selective breeding experience has revealed that genetic manipulations designed to enhance one or only a few biological characteristics of an organism frequently have adverse consequences for health and vigour. As such, there is a very real danger that enhancing biological attributes associated with extended survival late in life might compromise biological properties that are important to growth and development early in life (Olshansky et al., 2002).

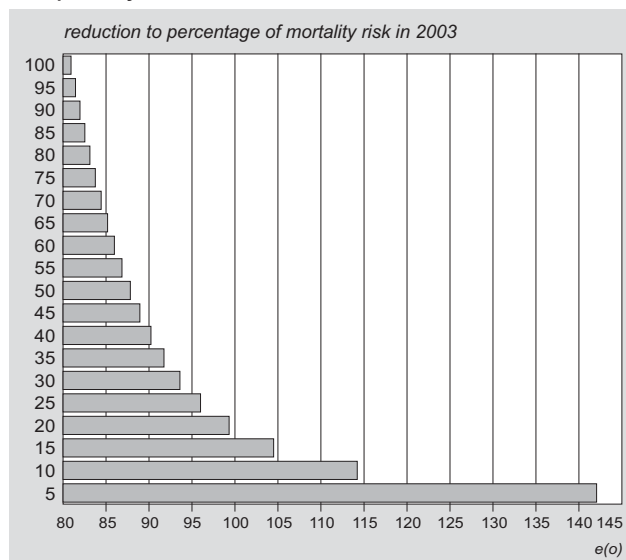
3.3 The unlikelihood of sustained mortality reductions

The relationship between mortality risk and life expectancy is of a non-linear nature. Halving the risks at all ages therefore does not result in a doubling of the life expectancy, but in a far more modest increase. This is shown, for Dutch females, in figure 9. A halving of the mortality risk at all ages would increase their life expectancy by less than 9 percent, to 87.8 years. A doubling of the present female life expectancy at birth would require a reduction in the mortality risk at each age to 3.7 percent of its present value. The death rates of women aged 55 would then be as low as the already extremely low rates at age 5; women aged 95 would run the same risk as women aged 40 today.

The claims made by the adherents of the optimistic geriatric school of thought that, for instance, American children born in the early 1980s already had a life expectancy of about 100 years, could be considered as an act of faith. As can be seen in figure 9, the mortality rates at each age should be less than a fifth of their present values in order to make such a life expectancy possible. As the cohorts that were born about twenty years ago so far have not achieved even a fraction of the required health improvements, their gains at higher ages would have to be even more impressive if they are to live, on average, for 100 years.

In what is probably the most prominent recent article originating from the geriatric school of thought, Oeppen and Vaupel (2002) argue that the 'best practice' life expectancy – i.e., the life expectancy of the country that holds the world record in a given year – has shown a linear trend over the past one and a half century and does not show any signs of levelling off. The slope of the linear increase corresponds to an annual overall reduction in mortality risks of about 2 percent. A projection of their linear plot suggest a best practice life expectancy of 95 years by 2040. By following the same procedure, Sanderson and Scherbov (2004) demonstrated that the UN forecasts for countries that presently have high life expectancies are all lower than calculated on basis of Oeppen and

9. Effect of mortality reductions at all ages on female life expectancy at birth, the Netherlands



Vaupel's method. For Japanese women in 2100, Sanderson and Scherbov show a median life expectancy of 105 years.

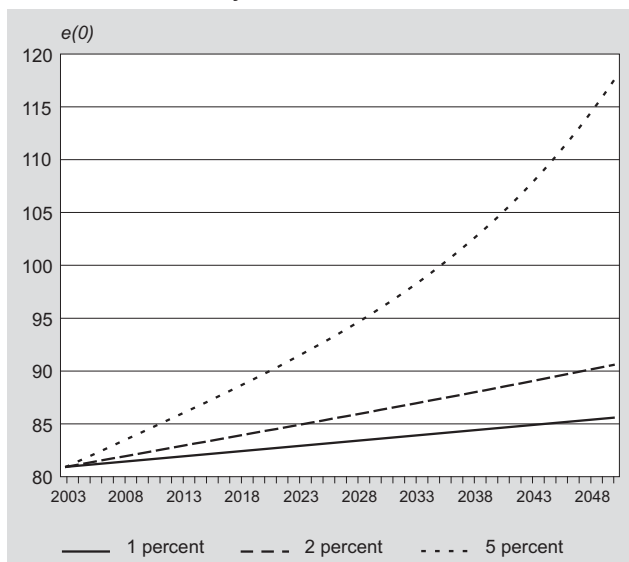
The effect of applying an annual reduction of 2 percent in the overall mortality risk to Dutch women is shown in figure 10. By 2050, the average female life expectancy in the Netherlands would then be just over 90 years. Reductions by 2 percent have, in the past decades, however never been achieved in all years and all age groups. Projecting an average reduction of 1 percent per year, being closer to the observed improvements during the past decades, would increase the life expectancy of Dutch women to 85.6 years in 2050, still much above the most recent official forecast of 82.5 years (De Jong, 2005b).

Well before the publication of Oeppen and Vaupel's high-profile article, Olshansky and Carnes (1994) critically reviewed the 'best practice method' for the projection of future life expectancies. They pointed at the fact that Vaupel's calculations are based on the extrapolation of an annual decline in the gross mortality rates of 2 percent at each age during all of the coming century. This decline is derived from the observed reduction in cardiovascular mortality in the United States in the period 1968–1992. However, a 2 percent decline occurred only rarely, and only at selected high ages. According to Olshansky and Carnes, the age group of 60–89 years recorded increases, rather than decreases, in cardiovascular mortality in a third of all years. The chosen period and cause of death have furthermore been atypical, both for the United States and Western Europe: between 1968 and 1982 an impressive, above-average reduction in cardiovascular mortality was achieved in the United States, from a share of 56 percent in total mortality to 49 percent; the coinciding rise in the share of cancer, on the other hand, was disregarded.

This criticism by Olshansky and Carnes, in other words, suggests that optimistic mortality experts intentionally selected a period and a cause of mortality to arrive at unusually high rates of decrease (of 1.5 percent for men and 1.7 percent for women), that were rounded off to 2 percent for all years and all age groups.

Why a 2 percent reduction in cardiovascular mortality should be applied to mortality in general, and particularly the mortality of younger people, remains unclear (Van Poppel and De Beer, 1996). The 2 percent-hypothesis eventually leads to unrealistically low mortality rates, that seem to defy the law of diminishing returns. Olshansky and Carnes (1994) showed that a 2 percent decrease would result in mortality rates for children and adolescents that are close to zero in 2080 (implying a total elimination of endogenous causes of death, and a near total elimination of exogenous

10. Increase in female life expectancy at birth for specified annual reductions in mortality risk, the Netherlands, 2003–2050



causes). The infant mortality rate in the United States would then be 1.4 per thousand, a rate that is considered unrealistic by medical experts. In the Netherlands, where the infant mortality rate is lower than in the United States, the same unrealistically low infant mortality rate would be achieved in 2050, at the much lower life expectancy of 90.6 years (see figure 10).

By 2080, American 30–70 year olds would be subjected to the mortality rates of today's children and teenagers. The 70–90 year olds would experience a level of mortality comparable to the present level of persons in their thirties and forties, and persons aged 95 would run the same mortality risks as those who are 65 today.

Oeppen and Vaupel's method is an application of extreme value statistics. Such statistics represent the end of a known distribution and can, over time, only move in an upward direction. The analogy to Olympic records is obvious: the records on the 100 metres sprint have improved since they were officially recorded, but the average person today is not running any faster than a century ago. The longevity record has furthermore been held by Japanese women for the past decade and a half, with no obvious contestant in sight. The recent slowing of their life expectancy (see section 3.1.) could therefore lead to a discontinuation of the linear increase in the best practice life expectancy.

Calculations such as those carried out by Oeppen and Vaupel (2002) and Sanderson and Scherbov (2004) are based on mathematical models that make limited or no use of cause of death statistics and information on epidemiological trends. The subjective discussion on realistic minimum mortality levels can be avoided in this manner, but extrapolations based on such models result, in the long run, in mortality profiles that would be considered utopic by medical experts. An alternative procedure to assess possible gains in life expectancy, using information on causes of death for the Netherlands, will be followed in section 4.

The methods discussed so far, are furthermore highly optimistic about the future state of the general population. That there is also reason for concern will be outlined in section 3.6.

3.4 Subpopulations and animal experiments

The much higher life expectancies of certain subpopulations, such as Seventh-Day Adventists and Mormons, show the considerable contribution of behaviour-related risk factors to survival. A combination of improved health behaviour and medical therapy has also

been the driving force behind the above-mentioned decline in cardiovascular mortality in the United States and Western Europe, showing the plastic nature of life expectancy. By extrapolating such mortality reductions to the general population, various researchers (i.a. Ahlburg and Vaupel, 1990) have made projections of the life expectancy that are considerably higher than those used in official population forecasts. Other researchers (i.a. Manton et al., 1991) have selected the lowest mortality rates in any subpopulation and any age group, and have applied this composite risk profile to an imaginary cohort.

A serious drawback of most studies in small subpopulations is their large degree of extrapolation in the higher age groups. The health effects are generally observed among young adults and then applied to a life table population to estimate the effects on the elderly. On the whole, the smaller and more exclusive the group is, the larger are the estimated increases in life expectancy. Studies such as that carried out by Manton et al. (1991) implicitly assume that the relative mortality advantage of exceptionally healthy 30-year olds will be maintained during the rest of their life-span. In doing so, the genetic variation within the population is neglected. This variation may be large, and even in genetically homogenous populations (such as fruit flies) subpopulations may differ in their response to risk factors (Curtsinger et al., 1992). This may also explain the observation, both in some human populations and in fruit flies, of a mortality rate that apparently levels off at the highest ages. If the frailer individuals die at earlier ages, the population at the oldest ages may have been more robust all along.

Calculations such as outlined above are obviously useful to assess the extent to which healthy behaviour could extend the average life span at present conditions. The results should, however, not be confused with realistic possibilities. Over the past decades, the increase in life expectancy has, on the whole, not resulted from a narrowing of the health gap between the worst and best performing subpopulations; there are even indications that the relative socioeconomic inequalities are increasing in a number of European countries (Mackenbach et al., 2003). Hence, to suggest that narrowing or closing the health gap is a realistic method to increase the life expectancy in the foreseeable future, lacks a sense of reality. Even more utopic would be a society in which all members have adopted a behaviour similar to that of orthodox Seventh-Day Adventists or Mormons.

The various laboratory animal experiments that have been conducted since 1935, have shown that caloric restriction results in a longer life in rodents and lower animals. Food restriction has been associated with reduced or delayed incidence of tumours and reduced levels of atherosclerosis and autoimmune lesions. The long-term effects in higher animals are still unknown, but the fact that, over the past seventy years, not even a small group of human beings has managed to subject itself to the necessary caloric restriction for a long period, is a clear indication that a near-starvation diet is intolerable to those who are free to decide what to eat. They are, in other words, not prepared to swap quality of life for quantity of life. A practical dilemma is furthermore that a low-calorie diet is progressively less effective the later in life it is begun (Weindruch and Walford, 1982), but that it is harmful in children and adolescents. Finally, the experiments may well have exaggerated the life expectancy gains, as the control animals may have been fed more than animals in the wild, predisposing them to an early death (Olshansky et al., 2002).

In the short run, gene therapy will only be really successful for a few rare diseases, with little effect on the life expectancy of the total population. Most experts think that gene therapy for more general diseases will positively affect longevity of cohorts that are born after 2010. In 2050 these generations are only 40 years old and in a stage of life in which the death rates are still very low (Van der Maas, 2000). Until that time, gene therapy will therefore not have a very strong effect on the life expectancy at birth.

3.5 Approaching a limit to life?

Using data for the period 1950–1992, Nusselder and Mackenbach (1996) demonstrated that the survival curves of Dutch men and women assume an increasingly rectangular shape. This rectangularisation took place in both an absolute and a relative sense: the number of deaths occurring within a certain age interval around the average age at death has increased, and the age range in which a certain share of all deaths occurred has decreased. This has also been shown for other European countries by Kannisto (2001), who noted that as the modal age at death moves to higher ages, the dispersion above the modal age is steadily getting smaller. According to Kannisto, the transition from high to low mortality is accompanied by massive compression, which later slows down.

As a more rectangular shape of the survival curve implies that the average age at death increases at a faster pace than the longest recorded life span, this phenomenon is often considered to prove that life expectancy is approaching a biological limit. It is, however, only justified to consider it as circumstantial evidence, rather than proof, since it is not possible to determine whether the remaining variability in the age at death is caused by environmental factors or by the effect of selection (Nusselder and Mackenbach, 1996).

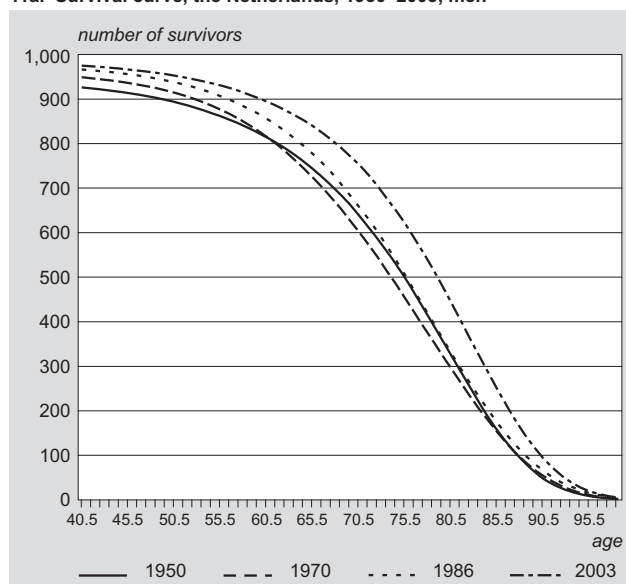
Over the past century, the socio-economic and environmental conditions have almost continuously improved. According to some, this has caused a larger number of relatively frail persons to survive to high ages, but to have a shorter life expectancy at these high ages due to their frailty. According to others, the opposite is true: because the conditions have improved for everyone, later birth cohorts are less damaged than earlier cohorts, and will consequently have a longer remaining life expectancy. If the latter assumption is true, death rates for the elderly should continue to decline.

The stagnation of death rates of people aged 80 and above, shown by Nusselder and Mackenbach (1996) for the period up to 1992, would appear to support the first hypothesis, at least for the Netherlands. A comparison of mortality trends in seven European countries, on the other hand, suggests that such selection effects have probably not had a strong impact on the mortality trends at the highest ages (Janssen et al., 2004).

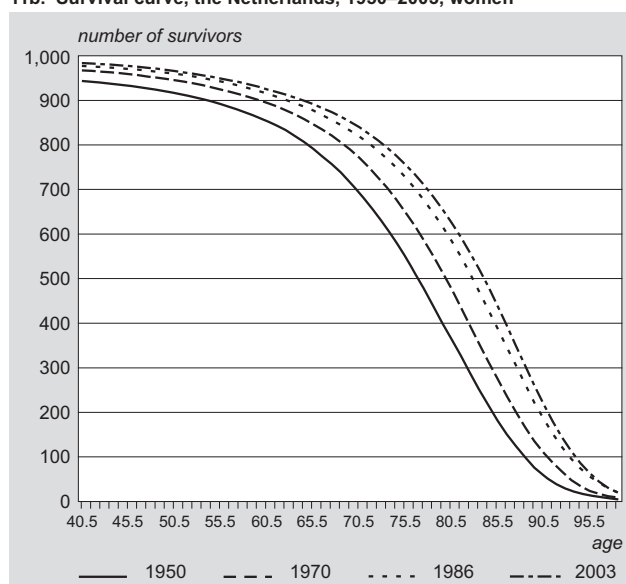
The more recent data discussed in section 3.1. show that this stagnation of the mortality risks at the highest ages was not short-lived: at all advanced ages, the general impression is one of stagnation, and at the highest ages the death rates are even slightly increasing. Since 1980, the remaining life expectancy at age 95 has decreased by 0.18 and 0.09 years for men and women respectively. The increasing prevalence of euthanasia and other medical end-of-life decisions over time (Onwuteaka-Philipsen, 2003) have had a negligible impact, considering the estimation of its life-shortening effect (Janssen, 2005).

Between 1950 and 2003, the modal age at death in the Netherlands has increased by 4.4 years for men and 7.1 years for women (the modal age being the age at which 50 percent of a birth cohort has died). This increase has been stronger than that of the longest recorded life span (about 4 and 5 years, respectively). Men and women show very different trends, however (figures 11a and 11b). The increase in the modal age at death among women was large between 1950 and the mid-1980s and small thereafter, whereas the opposite is true among men. Since the mid-1980s, the increase for men has been three times as strong as that for women. This is, on the one hand, due to the stagnation, from the late 1960s to the early 1980s, of the survival chances of men, leaving considerable room for improvement. On the other hand, women took advantage of medical progress and a healthier lifestyle much earlier than men. This has left less room for improvement, and an increasingly 'male' pattern of health behaviour has further contributed to the recent unfavourable trend among women.

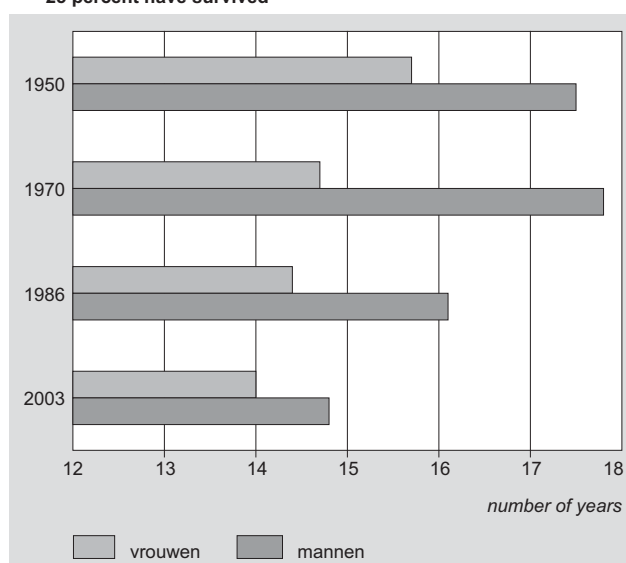
11a. Survival curve, the Netherlands, 1950–2003, men



11b. Survival curve, the Netherlands, 1950–2003, women



12. Number of years in life table between the ages at which 75 and 25 percent have survived



The increasing rectangularisation of the survival curves of both men and women is more clearly shown in figure 12, representing the interquartile range in the life tables. This range is the number of years that has elapsed between the moment at which a quarter and three quarters of a certain birth cohort has died. In 1970, for example, one quarter of the male cohort had died by the age of 64.2 years and three quarters by the age of 81.9 years (an interquartile range of 17.8 years). In 2003, one quarter of all males had died by the considerably higher age of 70.6 years, and three quarters by the (less strongly) increased age of 85.4 years (an interquartile range of 14.8 years). Among men, the range started to narrow later than among women, but once it had started, it progressed at a much higher speed.

The narrowing of the gap in life expectancy between men and women that is related to these developments, is not typical for the Netherlands. In fact, Japan is the only developed country in which this sex gap is still increasing; the most recent data suggest that this exceptional position may soon come to an end. The narrowing started in the early 1970s in the Anglo-Saxon countries, followed by Scandinavia around 1980. Finally, by the mid-1990s, this difference started to decrease in France and the Southern-European countries. This again shows that it took many years before the negative health effects of the emancipation, starting in the 1960s, became visible. As mentioned above, women have been able to compensate for these effects for many years, since they were earlier adopters of, for example, preventive screening and a healthier diet.

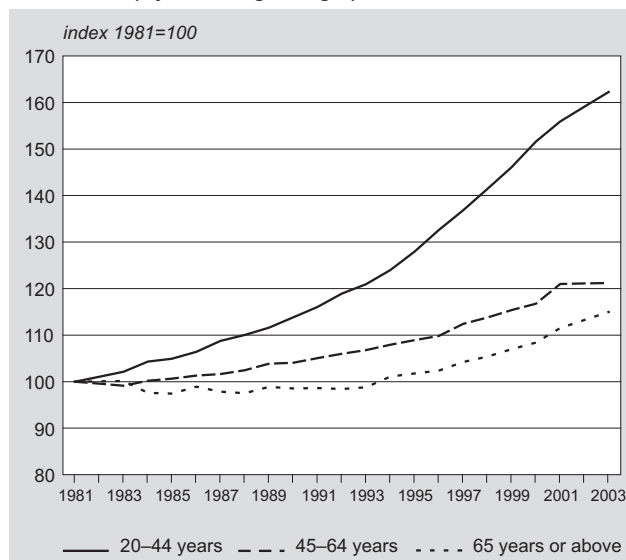
3.6. Unfavourable health trends in the general population

One of the unfavourable health-related trends that has attracted increasing attention over the past decade, is the continuous increase in the share of the population that is overweight. This trend, occurring in all developed countries, shows a clear geographical pattern in which the wealthiest countries tend to be forerunners. In the United States, two thirds of all adults and more than a third of all children are at present overweight. All countries, however, are following in the same direction, and there are no signs of a stabilisation or decline in the proportion of overweight people anywhere. Particularly worrying is the fact that the dietary habits of children and adolescents show a more adverse trend than that of the adult population.

In the past twenty years, the share of the Dutch population being overweight (with a body mass index (BMI) of 25 or above) has increased from a third to a half (data: permanent survey on living conditions, Statistics Netherlands). The share of obese people (with a BMI of 30 or above) has doubled, to about one in ten (men) and one in eight (women). Obviously, obesity occurs less frequently than moderate overweight, but its prevalence is increasing at an above-average rate (figure 13). With respect to obesity, men show a more unfavourable trend than women (figure 14). The trend in moderate overweight, on the other hand, does not show a significant difference between the sexes.

One in seven Dutch children aged 2–19 years is presently overweight. This proportion increases with age, with almost 60 percent of all persons of 65 years or older having a BMI of 25 or higher. The trend, however, is relatively more unfavourable at the younger ages (figure 13). The most recent data, furthermore, show that the situation is quickly worsening among young adults (figure 15). The strongest increase in obesity is recorded in the youngest age groups (Frederiks, 2004). Between 1980 and 1997, the proportion of obese 6-year old boys increased from 0.2 to 1.7 percent (girls: 0.6 to 2.7 percent). For the time being, a stabilisation appears to occur at the middle ages, but at the higher ages overweight increases with age again. The official Dutch health policy aims at a stabilisation of the present prevalence of overweight, yet experts expect a continuing increase in overweight and (even more so) obesity. Bemelmans et al. (2004) expect that the number of obese persons in the Netherlands will show a 50 percent increase by 2020.

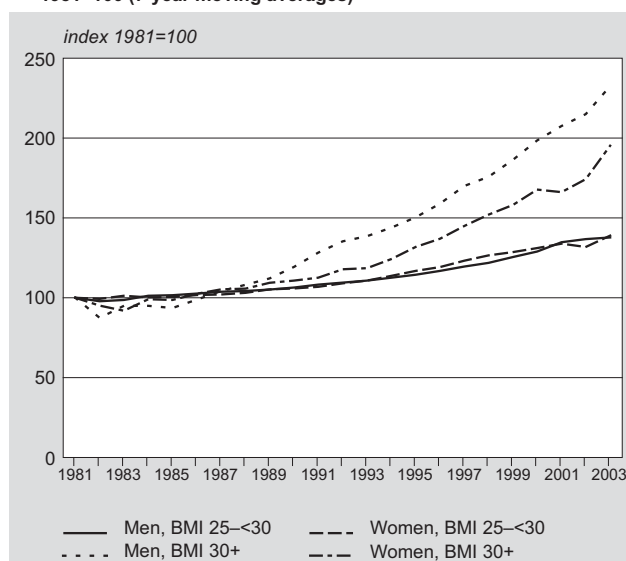
13. Trend in moderate overweight and obesity by age, the Netherlands, 1981=100 (7-year moving averages)



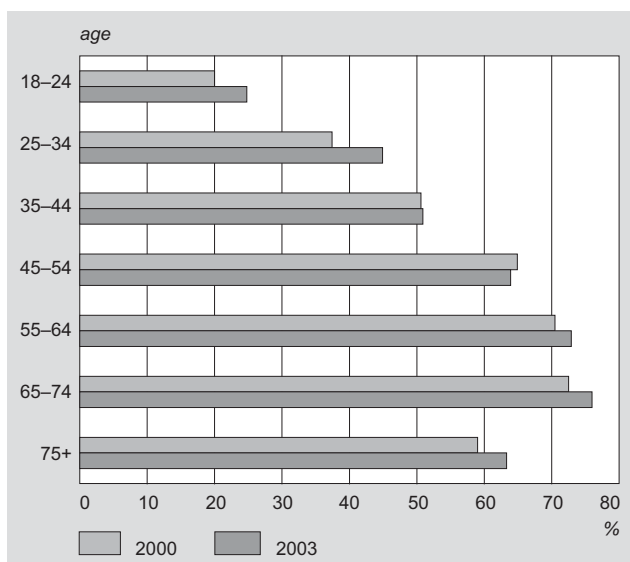
Whereas the general trend will have a negative impact on future health, the situation of children is especially worrying. A review of the (somewhat less recent) literature has shown that childhood obesity persists into adulthood in 30 to 60 percent of all cases (Serdula et al., 1993). More recent research has found much less tracking from childhood overweight to adult obesity when using a measure of fatness that is independent of build. Only children who are obese at 13 show an increased risk of obesity as adults (Wright et al., 2001). The most recent literature shows a somewhat stronger relation of childhood BMI to adult adiposity again (Freedman et al., 2005).

The unfavourable trends among the young and the elderly will result in increased morbidity and mortality. This effect is likely to be more delayed among those who are still young, but is unlikely to be averted, as only a minority is eventually capable to lose weight in a drastic and lasting manner. An important physiological explanation for this inability is offered by the fact that the number of adipose cells is determined by weight gains during certain periods of the childhood development. Later dieting may affect the size of the adipose cells, but not their number. Prevention of overweight is therefore essential (Gezondheidsraad, 2003).

14. Trend in moderate overweight and obesity by sex, the Netherlands, 1981=100 (7-year moving averages)



15. Prevalence of overweight and obesity by age, the Netherlands, 2000 and 2003



In particular increased morbidity and mortality from type-2 diabetes, cardiovascular diseases, diseases of the musculoskeletal system and various types of cancer (such as cancer of the colon, breast (after the menopause), uterus, kidney and oesophagus) have been demonstrated among persons who are overweight (IARC, 2002). A recent study in Japan among persons aged 40 and above measured an about 50 percent increased risk of obese persons to develop cancer (Kuriyama et al., 2004). Similar results were presented for the American population by Calle et al. (2003). In both men and women, the BMI was found to be significantly associated with higher rates of death due to cancer of the oesophagus, colon and rectum, liver, gallbladder, pancreas and kidney. Higher rates of death were also found for non-Hodgkin's lymphoma, multiple myeloma, stomach and prostate cancer and cancer of the breast, uterus, cervix and ovary in women. Calle et al. estimated that current patterns of overweight and obesity in the United States could account for 14 percent of all deaths from cancer in men and 20 percent of all deaths from cancer in women.

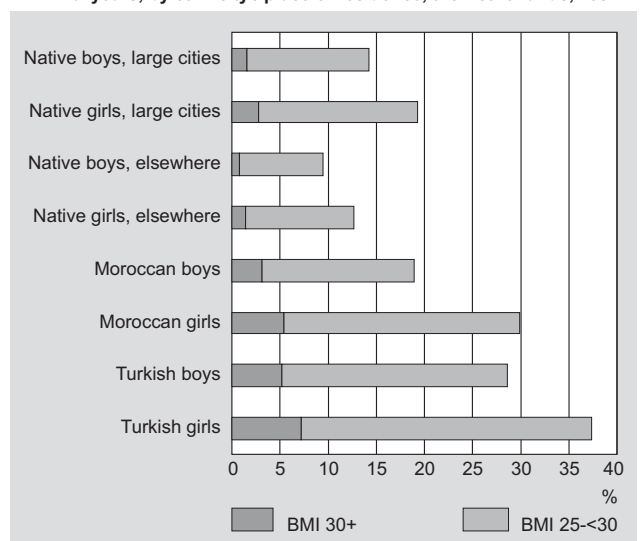
Obese adults have a 5–12 times increased risk of developing type-2 diabetes. Although the prevalence of type-2 diabetes in the Netherlands is possibly somewhat lower than in most other European countries (Van der Wilk and Gijsen, 2005), the percentage of known cases is relatively low as well, making the various estimates rather uncertain. The increase in diabetes that has been recorded in the past years may be partly due to the greater alertness of family physicians, leading to more screening. Nonetheless, considering the strong correlation between overweight and diabetes, a real increase has undoubtedly taken place, and a further strong increase is expected. The various prevalence studies that have been carried out suggest that at least half a million inhabitants of the Netherlands have diabetes, and that each year at least 60 thousand new cases are recorded (Gijsen et al., 2004a). Almost half is older than 70 years, although the average age of new patients is rapidly falling. On the basis of demographic changes alone, Gijsen et al. (2004b) expect an increase in diabetes of 36 percent between 2000 and 2020. The accompanying increase in overweight, however, will almost certainly lead to a much stronger increase in diabetes-related mortality. This will eventually be reflected in the mortality statistics (Van der Meulen, 2005). The future mortality rates for the general population will also be negatively influenced by the present trends in overweight. A study conducted by Gunnell et al. (1998) over a 57 year period in Great Britain, found a direct association between childhood BMI and adult cardiovascular disease mortality, and a more general association between childhood obesity and adult increased mortality from all causes.

Apart from ageing, two other general demographic trends will also push the mortality figures upward. Unlike ageing, they will also have a somewhat negative impact on the life expectancy of the population. The first and least important demographic trend is related to the increasing instability of social relations, leading to larger numbers of adults who are, temporarily or permanently, living alone. The total effect of postponing cohabitation, separation or divorce, and ageing will be an estimated increase in the number of single-person households in the Netherlands from 2.5 million at present to 3.5 million in 2035 (Nicolaas, 2005). On average, persons who are living alone have a poorer life expectancy, as has been demonstrated in many (international) studies over the past century (Van Hoorn and Garssen, 1999). Unmarried 50-year old Dutch men have a remaining life expectancy that is about four years shorter than that of married men; for women, the difference is about two years (De Jong, 2002). The decrease in life expectancy, which is especially noticeable among divorced men, has a strong behavioural component (Joung et al., 1996). In particular, their mortality from non-natural causes (accidents, suicide, homicide), diabetes, chronic liver diseases and cirrhosis is significantly above average. Tobacco-related diseases (various cancers, cardiovascular diseases) also have a higher prevalence among persons who are not married (Verweij and Kardaun, 1994).

The second, more important demographic trend counteracting the increase in life expectancy is the changing ethnic composition of the population. The share of persons of non-western origin in the total population has, in particular in the past decade, strongly increased in all Western European countries, and this trend will continue in the coming decades. According to the most recent Dutch population forecast, this share will grow from 10.4 percent at present to 16.6 percent in 2050; the share of foreigners of western origin – partly from economically less developed countries in Eastern Europe – will increase from 8.7 to 13.2 percent (Alders, 2005).

With the exception of Moroccans, all major non-western groups in the Netherlands are exposed to mortality risks that are considerably higher than those of the native population (Garssen et al., 2003; Bos et al., 2004, 2005a). The differences are only partly explained by differences in SES, and do not appear to diminish significantly with increasing duration of residence (Bos et al., 2005b). The long-term prospects are, furthermore, not very bright. The majority of Turkish and Moroccan women, for example, is overweight, and the second generation is clearly heading in the same direction (figure 16). In the Netherlands, between 80 and 90 percent of all Turkish and Moroccan women aged 35 or above are overweight (Blokstra and Schuit, 2003). Of all native adult women,

16. Prevalence of moderate overweight and obesity among persons aged 2–20 years, by ethnicity / place of residence, the Netherlands, 1997



Source: Fourth national growth survey, 1997

12 percent is obese; in the major non-western groups, this share varies from 20 percent among Antilleans to 26 percent among Turks (Lindert et al., 2004).

Overweight and obesity are more common in groups with a low SES (Blokstra and Schuit, 2003) and a low level of education (Van Kreijl and Knaap, 2004), but the trends are upward in all sub-groups. Children in single parent families and children of parents who are both employed, groups that are growing as well, are also showing unfavourable trends (Frederiks, 2004). The nutritional patterns of children and adolescents are furthermore deteriorating more rapidly than those of adults (Ocké and Hulshof, 2004). The consumption of wholemeal bread, fruits and vegetables have fallen to levels that are considered far too low (Voedingscentrum, 2004). The dietary habits of elderly people are different, yet far from optimal (Van Kreijl and Knaap, 2004). Their consumption of fruits and vegetables is more substantial, but they also tend to consume too many saturated fats and trans fatty acids. Many inactive elderly persons, mostly in institutions, eat too little, resulting in an insufficient intake of essential nutrients such as calcium and vitamins.

The contribution of a suboptimal diet to mortality may be even twice as large as that of overweight. About 10 percent of the annual mortality in the Netherlands is estimated to be caused by diet, and 5 percent by overweight (Van Kreijl and Knaap, 2004). In terms of the remaining life expectancy at age 40, this would imply a loss of 1.2 and 0.8 years due to diet and overweight respectively. According to Van Kreijl and Knaap, a continuation of the present trends in nutrition and weight may eventually lead to a decline in the life expectancy of the Dutch population.

A trend that is closely related to the increase in overweight is the decline in physical activity among both children and adults. This trend is thought to be more important as a determinant of overweight and obesity than caloric intake. In fact, the average caloric intake in the Netherlands has, in the period 1988–1998, decreased by 5 percent (Van Kreijl and Knaap, 2004). The growing imbalance between food consumption and exercise, in which the United States are leading the way, is the main cause of the present obesity epidemic. Curbing the trend in overweight is therefore far more complicated than adjusting the diet, as it is related to the general life style in which laboursaving devices (escalators and elevators, cars, mopeds etc.) are increasingly penetrating everyday life and in which energy-consuming activities (playing outside, sports) are replaced by physically inactive pastimes (computer games, television). Even though the detrimental effects have been known for decades (Dietz and Gortmacher, 1985), it has so far proven impossible to change the unfavourable trends in a significant manner.

A uniform trend in inactivity over time is difficult to detect in the various, largely incomparable data. The trend by age is clear, however. Between the ages of 13 and 17 years, the Amsterdam Growth and Health Longitudinal Study shows a strong decline, followed by a continuously low level in the early adult years (Kemper et al., 1999). According to the most recent data of Statistics Netherlands, only about a quarter of all boys (12–17 years) and a fifth of all girls meet the official norm of sufficient exercise for young persons. About half of them meet the much lower norm for adults (Ooijendonk et al., 2002). The most recent action plans of the Dutch National Institute for Health Promotion and Disease Prevention (NIGZ) and various other organisations are therefore aimed at promoting the physical activity of school children in everyday life. Failing to do so would, according to the director of NIGZ, soon lead to the replacement of cancer and cardiovascular diseases by obesity as the major public health threat (Steenhorst, 2005).

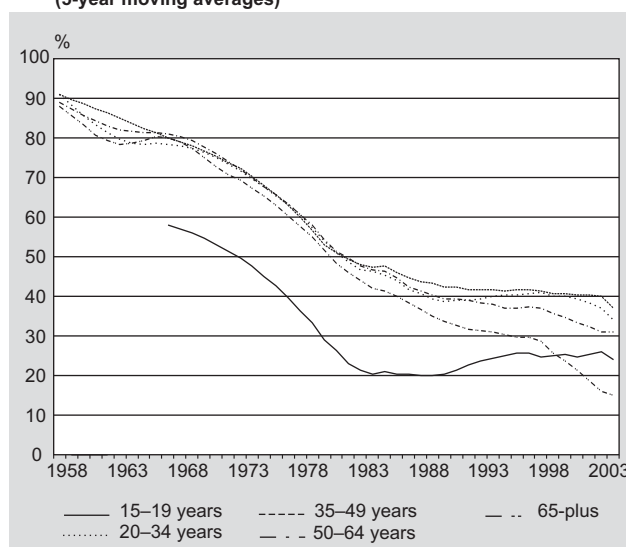
The share of smokers among adolescents has somewhat increased since the 1980s, but the most recent data suggest a slight decrease (figures 17a and 17b). At the higher ages, the long-term trend is downward, most markedly among elderly men.

The data for the age groups obscure a negative trend in the youngest group, however. Within the age group of 12–19 years, the share of smokers increases from 2 percent among 10–12-year old boys to almost 50 percent among boys of 17–19 years (Stivoro, 2005). These shares are somewhat lower among girls, and suggest that the prevalence of smoking will not decrease significantly in the coming years.

Young persons who are smoking, are also much more likely to drink alcohol (Smit, 2002). Since the late 1980s, drinking has become commonplace among adolescents, with an increase among 16- and 17-year olds from 67 to 86 percent. One in ten is classified as 'heavy drinker'. Since the late 1980s, the strongest increase has been recorded in this young age group, with 19 percentage points. The share of those among them who consume an average of three or more alcoholic drinks per day has doubled to about one in five. As is the case with smoking, native adolescents are somewhat more likely to drink than adolescents of foreign origin (GGD, 2003; Monshouwer, 2004).

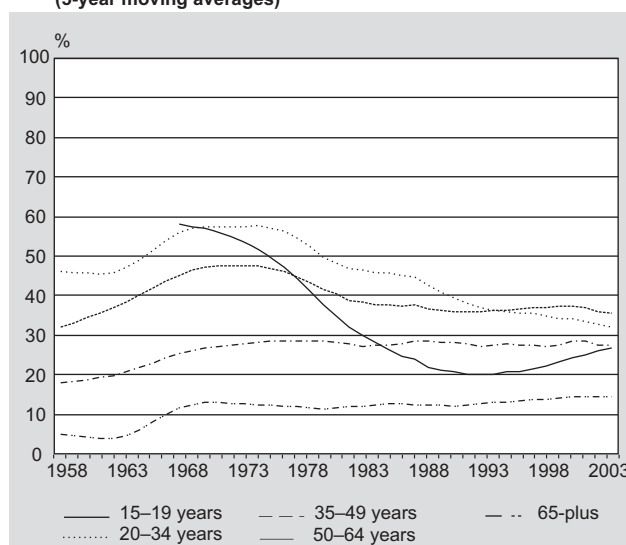
With respect to other drugs, the by far most popular psychotropic drug, cannabis, is consumed by a steadily growing number of users. Between 1997 and 2001, the number of present users of cannabis in the Netherlands increased from 326 thousand to 408

17a. Percentage smokers by age, the Netherlands, men (5-year moving averages)



Source: Stivoro

17b. Percentage smokers by age, the Netherlands, women (5-year moving averages)



Source: Stivoro

thousand (about 2.5 percent of the total population). The large majority of users consists of adolescents and young adults. In spite of the traditionally liberal (though increasingly repressive) Dutch policy on soft drugs, the prevalence of drug use in the Netherlands is more or less average if compared to other European countries (Van Laar et al., 2003). The extent to which (soft) drugs will have a negative impact on public health is still subject of discussion. On the whole, experts seem to be less convinced of the long-term harmlessness of cannabis than a decade ago. While experimental users of cannabis seldom experience negative (physical and psychological) consequences of the substance, intensive, regular and long-term use can much more often lead to therapeutic needs (Steinberg et al., 2002).

4. The potential effect of medical breakthroughs

Apart from the generally positive effect of improved living conditions, better preventive and curative medical care have contributed to the increase in life expectancy recorded in the past century. Considering the negative trends described in the previous section, and the strongly decreased room for further improvement among children and young and middle-aged adults, it will be more and more difficult to achieve further large gains in life expectancy. As shown in section 3.1., the largest overall effects occur with mortality reductions at the youngest ages.

The most obvious candidate causes are therefore the external causes (in the Netherlands at present composed of 65 percent accidents, 28 percent suicide, 4 percent homicide and 3 percent other external causes). About half of all deaths among adolescents and young adults are due to external causes, mostly traffic accidents. One might therefore assume that reducing these causes would lead to significant gains in life expectancy. The net effect, however, is small, as shown in figure 18. Halving the number of deaths from external causes would increase the life expectancy at birth by 0.40 years (men) and 0.22 years (women). An – obviously unrealistic – total elimination would lead to life expectancy gains of only 0.82 and 0.44 years respectively. The room for improvement is twice as large for men as for women, since men are strongly overrepresented in accidents, suicide and homicide in all age groups up to about 80 years. Women are only overrepresented in accidents at the highest ages (mostly accidental fall).

Whereas possible breakthroughs in preventive and curative medicine will have little effect on the frequency of external causes, the

potential is much larger in the case of the main causes of death, cancer and cardiovascular diseases. It is, however, reduced again by the much higher average ages at death. Men who die of cancer, for example, are almost twenty years older than men who die from external causes (the difference is much smaller for women).

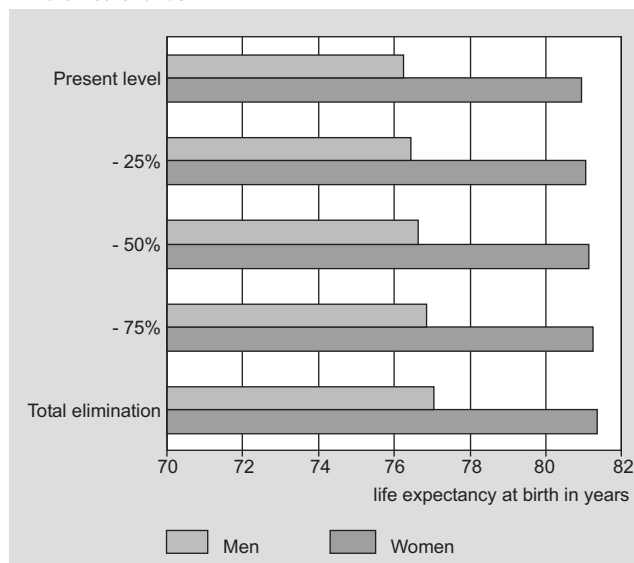
The share of cancer in total mortality has increased continuously during the past century, from about 5 percent in 1900 to about 27 percent in 1980. Since then, its share has remained more or less constant. This does not imply that there has been little progress in cancer therapy, though. Where the incidence of other important causes of mortality, such as infectious and cardiovascular diseases, has been reduced, cancer has increasingly become a geriatric disease. Since 1970, the average age at death of cancer patients has increased by about three years to almost 71 years. The general trend furthermore obscures positive developments in certain specific forms of cancer. The incidence of lung cancer is declining among men since the mid-1980s (but is increasing among women), and the trend in breast cancer is favourable (Van der Meulen, 2004). More widespread screening (Otto et al., 2003) and improved therapy (Jatoi and Miller, 2003) have probably both played a role in curbing breast cancer.

Since the second half of the 1980s, when the highest overall (age-standardized) cancer mortality rates were recorded for both sexes, the rates have decreased by 22 percent (men) and 11 percent (women). Most of this decrease was due to the reduction in lung cancer (men) and breast cancer, with the highest relative gains in the youngest age groups.

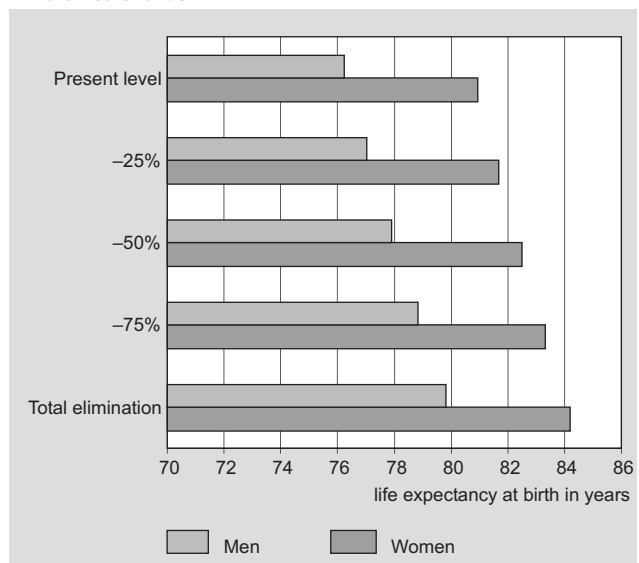
Although cancer is responsible for more than one in four deaths, the effect on life expectancy of a continuing decrease in cancer mortality, or even a much stronger decrease that might result from innovative therapies, should not be overrated. Halving the present cancer mortality rates would add 1.66 years to the life expectancy of men, and 1.56 years to that of women. A total elimination of cancer would result in life expectancy gains of 3.57 and 3.26 years respectively.

Since about 1970, when the highest age-standardized rates of cardiovascular mortality were recorded, the reduction in cardiovascular mortality has been stronger than that of any other major cause of death in the Netherlands. Largely due to the prevention and better treatment of ischaemic heart diseases, overall declines of 50 percent (men) and 55 percent (women) were realized over a period of 35 years. Nonetheless, the share of cardiovascular mortality in total mortality remains considerable (33 percent, down from 45 percent in 1970), hence the potential of further reductions is considerable as well. Over the past decades, new therapeutic

18. Potential effect of reduction of external causes on life expectancy, the Netherlands



19. Potential effect of reduction of cancer on life expectancy, the Netherlands



20. Potential effect of reduction of cardiovascular diseases on life expectancy, the Netherlands

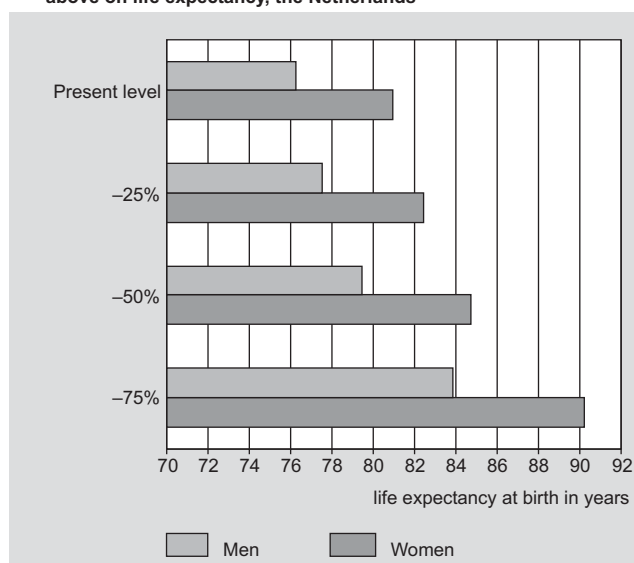


measures have very strongly lowered the risk of dying from a heart attack, and a continuation of this favourable trend is expected.

Although the total mortality from cardiovascular diseases is higher than that from cancer, the potential gains in life expectancy that result from further reductions are comparable (figure 20). This is due to the fact that victims of cardiovascular disease are older, on average, than victims of cancer. The average age at death of men dying from IHD is almost three years higher than that of men dying from cancer (73.3 years versus 70.5 years). Among women, the difference is even much larger (80.5 years against 70.8 years; this is reflected in the somewhat lower potential gains in life expectancy). Men and women dying from CVA are even older (77.0 and 82.4 years respectively).

With almost two third of all deaths occurring at the age of 75 years or older (men 54 percent, women 72 percent), a reduction in mortality due to geriatric diseases would concern the largest absolute numbers, although the average gain in life expectancy per person would of course be shorter than for non-geriatric diseases. As six in ten elderly persons are overweight, their general nutritional behaviour and activity patterns are far from optimal and a quarter

21. Potential effect of reduction of total mortality at ages 75 and above on life expectancy, the Netherlands



of all elderly men smoke (Van den Berg Jeths, 2004), there is considerable room for health improvement at the highest ages. Yet, again, the effects on the life expectancy at birth are only modest. Unlike cancer, a total elimination of geriatric mortality is even theoretically impossible, and a truly spectacular halving of the mortality risk at all ages from 75 upwards, will only add 3.20 years to the average life span of men and 3.80 to that of women. Such reductions would imply the redefinition of geriatric diseases as exogenous rather than endogenous causes of death (as done by Manton et al., 1991), that can be tackled by medical technology (including the cure of Alzheimer's and Parkinson's disease). Such a redefinition conflicts with the evolution theory which predicts the inevitability of ageing due to cumulative DNA-damage (Carnes and Olshansky, 1993).

As outlined in section 3.1., a reduction in the death rates at the highest ages is unlikely to occur in the near future, and considering the unfavourable health trends in the elderly, increasing the average life span by 3-4 years by means of halving the mortality risks at ages 75 and above, is highly unrealistic.

A more or less linear increase in mortality risk with body mass index has been demonstrated in various studies (Manson et al., 1995; Shaper et al., 1997; Calle et al., 1999). The relative risk was shown to be about 1.5 for persons with a BMI between 25 and 30 and 2.0 for persons with a BMI of 30 or above (Manson et al., 1995). Using these relative risks and projecting the present trend in overweight and obesity in the Netherlands up to 2050, the (minimum and maximum) effects of overweight on future life expectancy have been estimated (figure 22). In the calculation of the minimum effect, a 50 percent higher mortality risk is assumed for obese persons; a doubled risk is assumed to yield a maximum estimate. This results in a downward effect caused by overweight and obesity of 0.91 – 1.75 years in men and 0.66 – 1.29 years in women.

It is obviously incorrect to add and subtract the various cause-specific reductions and increases, as the mortality risks are concurring and competing to a very large extent. Not only do certain causes, especially at the highest ages, occur jointly at death, but also does the reduction in the risk to die from, for example, a cardiovascular disease necessarily lead to an increased risk to die from, for example, cancer. A very large share of the geriatric diseases shown in figure 21, is furthermore composed of cancer (figure 19) and cardiovascular diseases (figure 20). Estimates that are based on the cumulative effect of cause-elimination, consequently lead to much higher estimates of future life expectancy than more realistic estimates, assuming dependence of the

22. Potential effect of present trend in overweight and obesity on life expectancy in 2050, the Netherlands



causes of death. Life expectancy gains that are calculated by eliminating cardiovascular and respiratory diseases, in particular, are strongly biased by the effect of competing causes (Mackenbach et al., 1997).

The considerations and calculations given above, strongly suggest that the future trend in life expectancy – in the Netherlands as well as in other low-mortality countries – will be the composite of modest gains, restrained by modest losses that result from unfavourable health trends. The net effect is expected to be slightly positive: the latest official Dutch population forecast expects a further increase in life expectancy between 2004 and 2050 of 3.15 years for men (from 76.41 to 79.56 years) and 1.53 years for women (from 81.09 to 82.62 years; De Jong, 2005c).

5. Summary and discussion

With respect to future life expectancy, experts seem to be divided into two distinct camps, with little field in-between. The gerontological camp considers ageing as a natural process that can be influenced to only a modest degree. The 'pessimistic' experts in this camp foresee a gradual levelling off of the life expectancy in low-mortality countries to about 85 years. The geriatric camp, on the other hand, expects that the past, favourable trend in life expectancy will continue more or less unabatedly in coming decades, eventually leading to life expectancies of 100 years or more. Should these 'optimists' be right, the national population forecasts – in particular those of Spain, Norway, the Netherlands and Denmark – would fall dangerously short in predicting the number of future pensioners. The negative consequences of the underestimates, based on the official population forecasts, on, for example, pension schemes, health care and other social provisions would be considerable. The question of future life expectancy is therefore far from trivial.

Various arguments support the position of the optimists. The trend in life expectancy of developed countries has increased in a more or less linear manner over the past three decades. In a number of countries, the rate of increase has even accelerated, leading to a more than linear increase in the population of surviving octogenarians. For certain religious and health-conscious subpopulations, life expectancies of close to 100 years have been demonstrated. Gene manipulation and nutritional experiments in animals have shown that the maximum life span can be considerably lengthened. The general nutritional status of the population has strongly improved in the second half of the past century, and smokers have become a minority. In the Netherlands as well as in other European countries, the survival curves are assuming an increasingly rectangular shape, but this does not necessarily imply that life expectancy approaches some natural biological limit (Janssen, 2005). A further gain in life expectancy, due to medical and biomedical progress, is therefore likely to occur.

Finally, many theories on ageing and advances in molecular biology and human genetics nourish high hopes of increasing the human life span in a significant manner.

On the other hand, just the fact that there are more than three hundred, partly conflicting theories on ageing (Medvedev, 1990), shows both how complex the process of ageing is and how long and uncertain the 'road to longevity for all' will be. Apart from this, the more pessimistic researchers have a number of valid arguments to justify their conservative position. A closer look at international trends shows that the increases in life expectancy are levelling off. Further increases are only possible by reducing the mortality risks at the highest ages, where the effect on life expectancy is lowest: even spectacular mortality reductions at these ages lead to only modest increases in life expectancy. The various theories that promise a longer life, are counterbalanced by theories that suggest that ageing is firmly rooted in biological processes that are not easily manipulated. As the relationship between mortality risk and life expectancy is of a non-linear

nature, a continuous reduction in the overall mortality risk results in a gradual levelling off of the life expectancy. The risk reductions on which the best-known optimistic extrapolations are based, have been shown to be exaggerated. Applying these reductions to all ages, as has been done in these extrapolations, soon leads to mortality levels that are unrealistically low in several age groups. The calculations that demonstrate high life expectancies in certain long-living subpopulations, are flawed to a varying extent: they all suffer from a large degree of extrapolation in the highest age groups.

Finally, the overall health trends over the past half century may, on balance, have been positive, but more recent trends are worrying, and show no sign of reversing. In the economically most developed countries, an increasing proportion of the population is overweight and physically inactive. The negative trends are, furthermore, strongest among children and adolescents. These trends are amplified by social changes that have a momentum of their own, such as the growing share of non-western foreigners and one-person and lone parent households.

The potential gains in life expectancy that can be achieved by reducing mortality at the youngest ages are small. Halving the risk of death from external causes would, in the Netherlands, lead to an increase of the life expectancy at birth of 0.40 years (men) and 0.22 years (women). Cancer and cardiovascular diseases take their toll at higher ages, but are far more common as causes of death. Nonetheless, halving the present cancer mortality rates would add only 1.66 years to the life expectancy of men, and 1.56 years to that of women. With respect to cardiovascular diseases, the gains are of the same order of magnitude.

As almost two thirds of all deaths occur at the age of 75 years or above, a reduction in mortality due to geriatric diseases would concern the largest absolute numbers. Yet, a truly spectacular halving of the mortality risk at all ages from 75 upwards, would only add 3.20 years to the average life span of men and 3.80 years to that of women. Considering the trends over the past decade, even a smaller reduction is unlikely to occur in the near future. Unfavourable health trends contribute to this negative trend, and concern the highest ages as well. If all other circumstances would remain the same, the trend in overweight would, by the year 2050, have had an estimated downward effect on life expectancy of 0.91 – 1.75 years (men) and 0.66 – 1.29 years (women).

The calculations presented in this article are necessarily based on subjective assumptions with respect to mortality reductions that might 'realistically' be achieved in the future.

Nonetheless, these calculations, and the various theoretical considerations, strongly suggest that the future trend in life expectancy – in the Netherlands as in other low-mortality countries – will be the composite of modest gains, restrained by modest losses resulting from unfavourable health trends. The net effect, up to the middle of the present century, is expected to be slightly positive, in the order of a few years rather than a few decades.

Whether or not one should consider this scenario as 'pessimistic' is subject for debate. A much longer life expectancy may be accompanied by a longer period of morbidity and dependence, increasingly taxing the health care budget. Most probably, the economically inactive life span will increase at a faster rate than the economically active life span, resulting in a higher 'grey pressure'. The social and health care budgets could, instead, be used to improve the quality rather than the quantity of life, and in doing so add life to our years rather than years to our life.

Revolutionary technologies to circumvent the 'natural' biological limit to life, will eventually lead to serious social and ethical dilemmas. As the various biomedical interventions to increase the life span will no doubt be expensive, the socioeconomic health gap would probably widen even further than is already the case. The gap in life expectancy between rich and poor countries would also increase, to an even greater extent.

Finally, existing generations would, for no other than self-centred reasons, extend their stay at the expense of future generations.

The presently low fertility levels should, after all, be reduced much further in order to maintain a balance between births and deaths. At the very high life expectancies that are mentioned by some of the optimists, a pessimistic scenario of a government-controlled one-child – and maybe even zero-child – policy looms up as the only method to prevent that the forthcoming silver boom will turn into a grey bomb.

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