National Institute of Public Health, Copenhagen

Social differences in the burden of long-standing illness in Denmark

Submitted: 27 June 2005
Accepted: 7 March 2006

Summary

Objectives: To estimate the impact of diseases on social differences in life expectancy and expected lifetime with illness among Danes in 1995–99.
Methods: Expected lifetime with and without long-standing illness were calculated for groups with low, medium and high educational levels. Estimates based on observed rates of mortality and prevalence of illness were compared with those based on rates from which a specific disease had been eliminated.
Results: Partial life expectancy (age 30–75) would increase by almost 1.5 years if cancer were eliminated. Expected lifetime without long-standing illness would increase by approximately 1 year. Elimination of cardiovascular diseases would increase partial life expectancy, mainly among men with a low educational level. If diseases of the musculoskeletal system were eliminated the benefit would be greatest for persons with a low educational level.
Conclusions: The gain in life expectancy to be expected by eliminating certain diseases decreased with educational level. Elimination of cancer would extend lifetime both with and without illness for all educational levels.

Keywords: Education – Health expectancy – Life expectancy – Long-standing illness – Social inequality

Disease patterns differ between social groups, and persons with a low educational level, a low income or low socioeconomic status have shorter lives and can expect to live more years in poor health than people with a high social status (Brønnum-Hansen, 2000; Andersen, Lauersen, & Petersen, 2001; Brønnum-Hansen, Andersen, Kjøller, & Rasmussen, 2004). In Denmark, changes in mortality rates for different occupational groups have been assessed since 1970 by Statistics Denmark. Mortality has declined among economically active men, but the higher mortality among unskilled workers than in other occupational groups has increased (Andersen et al., 2001). Although the decline in mortality rates among economically active women was less distinct than for men (Andersen et al., 2001), this closely reflects the transition of housewives to the labour market. Disease-specific mortality also differs considerably among groups. Generally, mortality from heart disease in Denmark is higher among workers than among salaried employees, and mortality from lung cancer is high among workers and low among farmers and among persons with high salaries (Andersen et al., 2001). The prevalence of long-standing illness differs among occupational groups, but the social differences are clearer when educational groups are compared (National Institute of Public Health, 2002). Thus, the prevalence of self-reported disease of the circulatory system varies between 2.3 % and 3.4 % in groups of economically active persons and is 4.2 % among the unemployed, whereas the prevalence according to educational group varies from 4.1 % among Danes with at least 15 years of education to 12.4 % among those with less than 10 years (National Institute of Public Health, 2002). Life expectancy at age 30 in Danish men with low, medium and high educational levels is 43.5, 45.5 and 47.8 years, respectively, and expected lifetime with long-standing illness is 21.4, 20.6 and 18.6 years (Brønnum-Hansen et al., 2004). For 30-year-old Danish women, life expectancy at the three educational levels is 48.6, 50.4 and 51.3 years, respectively and expected lifetime with long-standing illness is 24.8, 23.3 and 23.2 years (Brønnum-Hansen et al., 2004).

Life expectancy is a widespread health indicator but cannot be used to measure the health consequences of non-fatal

Soz Praventiv Med 51 (2006) 221–231
0303-8408/06/040221–11
DOI 10.1007/s00038-006-5081-y

Table 1 Selected diseases with high prevalence or mortality rates

Disease group	ICD-10[a] code
Neoplasms	C00–D48[b]
Endocrine, nutritional and metabolic diseases	E00–E90
Mental and behavioural disorders	F00–F99
Diseases of the nervous system	G00–G99
Diseases of the circulatory system	I00–I99
Chronic obstructive lung disease	J40–J44
Diseases of the musculoskeletal system and connective tissue	M00–M99

[a] International Classification of Diseases, tenth revision
[b] Mortality data included only deaths with ICD codes C00–D09

diseases. Health expectancy is derived by combining mortality and morbidity into a summary measure. This indicator expresses average lifetime in various states of health and can be used to determine the impact of fatal and non-fatal diseases on health; it is thus a useful tool for health planning. Potential changes in health expectancy resulting from elimination of specific diseases have been estimated for some populations (Colvez & Blanchet, 1983; Manton & Stallard, 1991; Nusselder et al., 1996; Mathers, 1999), but to our knowledge estimates for groups of different social status have not been compared. The purpose of the study was to quantify the health impact of diseases with a high prevalence or mortality and to evaluate social differences in the burden of long-standing illness. The diseases chosen were cancer; endocrine, nutritional and metabolic diseases; mental and behavioural disorders; diseases of the nervous system; diseases of the circulatory system; chronic obstructive lung disease; and diseases of the musculoskeletal system and connective tissue.

We estimated health expectancy, expressed as average lifetime between the ages of 30 and 75 with and without long-standing, limiting illness by combining life tables and prevalence data. The results derived from observed data and hypothetical data, established by the cause-elimination life table technique and cause-deleted prevalence of illness, were compared to evaluate the burden of long-standing illness. Furthermore, we investigated social differences in disease burden by comparing groups with low, medium and high educational levels in Denmark.

Material and methods

On the basis of the unique personal identification code assigned to all Danish citizens, life tables for the period 1995–99 were constructed for three educational groups by linking national registers for vital status and education at Statistics Denmark. Diseases that are highly prevalent or are associated with high mortality rates were selected (Table 1). The sex- and age-specific numbers of persons at risk and the numbers of deaths from the selected diseases during the period 1995–99 for each educational group were extracted from the Cause-of-death Register and linked to Statistics Denmark registers. We constructed cause-deleted life tables as described by Preston et al. (2003) and summarized in Appendix 1 (available upon request, see end of text). We used underlying cause-of-death data on the assumption of independent causes of death. As data on education were not available for persons over 75, the analysis was restricted to persons younger than 75.

We defined three levels of education: low for persons with a maximum of 10 years of schooling and only semi-skilled training, basic vocational training or business school (first year); medium for persons with either a maximum of 10 years of schooling and further vocational or other training or with post-secondary schooling but no higher education; and high for persons with any type of higher education.

In the Danish Health Interview Survey in 2000, a sample of 22 486 persons aged 16 or more was drawn from the Danish Civil Registration System. In order to eliminate seasonal variation, the interviews were conducted in three rounds, in February, May and September, with 6 557, 6 797 and 9 132 persons, respectively. Professionals from the Danish National Institute of Social Research interviewed 16 690 persons (74.2 % of the sample). The details and results of the survey have been reported previously (National Institute of Public Health, 2002; Davidsen & Kjøller, 2002). Questions about schooling, vocational training and further education were asked in order to classify the interviewees by educational level. Only persons aged 30 or more were included in the present study, on the assumption that most people have finished their education by that age.

Long-standing illness was measured from answers to the question 'Do you suffer from any long-standing illness, long-standing after-effect of injury, any disability, or other long-standing condition?' Whenever long-standing illness was reported, up to four diseases were described in more detail. Thus, the interviewees were asked if the disease implied restrictions on daily life or at work. The nature of a disease was clarified by means of an open question, and the answers

Table 2 Partial life expectancy (expected lifetime between age 30 and 75), partial expected lifetime with and without long-standing, limiting illness and percentage of partial expected lifetime without long-standing, limiting illness – Men at age 30 by educational level before and after hypothetical elimination of specific diseases

Eliminated disease	Level of education	Partial life expectancy (years)	Partial expected lifetime without long-standing illness (years)	(95 % CI)	Partial expected lifetime with long-standing illness (years)	(95 % CI)	Percentage of partial expected lifetime without long-standing illness (%)	(95 % CI)
None	High	41.7	33.6	(32.7,34.5)	8.1	(7.2,9.0)	80.6	(78.5,82.7)
	Medium	40.3	29.3	(28.7,30.0)	11.0	(10.3,11.6)	72.8	(71.2,74.4)
	Low	38.6	26.6	(25.6,27.6)	12.1	(11.1,13.0)	68.8	(66.3,71.3)
	All	39.9	29.6	(29.1,30.0)	10.4	(9.9,10.8)	74.0	(72.9,75.1)
Neoplasms	High	42.8	34.6	(33.7,35.5)	8.2	(7.3,9.2)	80.8	(78.6,82.9)
	Medium	41.6	30.4	(29.7,31.1)	11.3	(10.6,11.9)	73.0	(71.4,74.6)
	Low	40.0	27.7	(26.7,28.7)	12.4	(11.4,13.4)	69.1	(66.6,71.6)
	All	41.3	30.6	(30.2,31.1)	10.6	(10.2,11.1)	74.2	(73.1,75.4)
Endocrine, nutritional, metabolic	High	41.8	33.8	(32.9,34.7)	8.0	(7.1,8.9)	80.9	(78.8,83.0)
	Medium	40.4	29.7	(29.0,30.3)	10.7	(10.1,11.4)	73.5	(71.9,75.1)
	Low	38.8	27.0	(26.0,27.9)	11.8	(10.8,12.8)	69.5	(67.0,72.0)
	All	40.1	29.9	(29.4,30.3)	10.2	(9.7,10.6)	74.6	(73.5,75.7)
Mental and behavioral disorders	High	41.8	33.9	(33.0,34.8)	7.9	(7.0,8.8)	81.2	(79.1,83.3)
	Medium	40.4	29.7	(29.0,30.3)	10.7	(10.1,11.4)	73.4	(71.8,75.0)
	Low	38.8	27.1	(26.1,28.1)	11.7	(10.7,12.7)	69.9	(67.4,72.4)
	All	40.1	29.9	(29.5,30.4)	10.1	(9.7,10.6)	74.7	(73.6,75.8)
Nervous system	High	41.8	34.6	(33.7,35.4)	7.2	(6.4,8.1)	82.8	(80.7,84.8)
	Medium	40.4	30.1	(29.5,30.8)	10.2	(9.6,10.9)	74.7	(73.1,76.3)
	Low	38.7	27.6	(26.7,28.6)	11.1	(10.2,12.1)	71.3	(68.9,73.8)
	All	40.0	30.5	(30.0,30.9)	9.6	(9.1,10.0)	76.1	(75.0,77.2)
Circulatory system	High	42.5	34.9	(34.0,35.8)	7.6	(6.7,8.5)	82.1	(80.1,84.2)
	Medium	41.4	31.1	(30.5,31.8)	10.3	(9.6,11.0)	75.1	(73.5,76.7)
	Low	40.0	28.5	(27.6,29.5)	11.4	(10.4,12.4)	71.4	(69.0,73.9)
	All	41.1	31.3	(30.9,31.8)	9.8	(9.3,10.2)	76.2	(75.1,77.3)
Chronic obstructive lung disease	High	41.8	33.8	(32.9,34.7)	8.0	(7.1,8.9)	80.9	(78.8,83.0)
	Medium	40.4	29.5	(28.8,30.1)	10.9	(10.3,11.6)	72.9	(71.3,74.5)
	Low	38.8	26.7	(25.7,27.7)	12.1	(11.1,13.1)	68.8	(66.2,71.3)
	All	40.1	29.7	(29.3,30.2)	10.4	(9.9,10.8)	74.1	(73.0,75.3)
Musculoskeletal system and connective tissue	High	41.7	35.6	(34.8,36.4)	6.1	(5.3,6.9)	85.4	(83.5,87.3)
	Medium	40.3	32.8	(32.2,33.4)	7.5	(6.9,8.1)	81.4	(80.0,82.8)
	Low	38.6	29.9	(29.0,30.8)	8.7	(7.9,9.6)	77.4	(75.1,79.7)
	All	40.0	32.6	(32.2,33.0)	7.4	(7.0,7.8)	81.6	(80.6,82.6)

were coded according to the World Health Organization's *International Classification of Diseases*. About 96 % of cases of disease were reported to have been diagnosed by a physician (National Institute of Public Health, 2002). A person was considered to be suffering from a long-standing, limiting illness only if restrictions to daily life or at work were stated. The sex-, age- and educational level-specific prevalences of long-standing illness with and without elimination of a specific disease were assessed, as, in cases of co-morbidity, a person might still report a long-standing, limiting illness after a specific disease has been eliminated.

For each educational level, partial life expectancy, i. e. expected lifetime between the ages of 30 and 75, and expected lifetime with and without long-standing, limiting illness between the ages of 30 and 75 were estimated. Calculations were made for the observed life tables and health survey prevalence data and for the hypothetical life tables and prevalence data, from which death and illness due to a specific cause was eliminated, assuming independence between the diseases and between causes of death. We used Sullivan's method (1971), by combining life table figures and health survey data: the expected numbers of years lived in the age intervals 30–34, 35–39, …, 70–74 were multiplied by the age-specific proportions of long-standing, limiting illness. The expected lifetime of 30-year-olds up to the age of 75 with long-standing illness was then calculated by adding these years for all age groups and dividing the sum by the number of survivors at age 30. By relating expected lifetime without long-standing illness to partial life expectancy, the percentage of lifetime between the ages of 30 and 75 without long-standing illness was established. Sullivan's method is summarized in Appendix 2 (available upon request, see end of text)

Table 3 Partial life expectancy (expected lifetime between age 30 and 75), partial expected lifetime with and without long-standing, limiting illness and percentage of partial expected lifetime without long-standing, limiting illness – Women at age 30 by educational level before and after hypothetical elimination of specific diseases

Eliminated disease	Level of education	Partial life expectancy (years)	Partial expected lifetime without long-standing illness (years)	(95 % CI)	Partial expected lifetime with long-standing illness (years)	(95 % CI)	Percentage of partial expected lifetime without long-standing illness (%)	(95 % CI)
None	High	42.5	32.0	(30.9,33.1)	10.6	(9.5,11.7)	75.2	(72.6,77.7)
	Medium	42.0	29.8	(29.0,30.6)	12.3	(11.5,13.1)	70.8	(69.0,72.7)
	Low	40.9	25.4	(24.4,26.4)	15.6	(14.5,16.6)	62.0	(59.6,64.5)
	All	41.6	29.1	(28.6,29.6)	12.5	(12.0,13.0)	69.9	(68.8,71.1)
Neoplasms	High	43.9	33.0	(31.9,34.2)	10.8	(9.7,12.0)	75.3	(72.7,78.0)
	Medium	43.5	31.0	(30.1,31.8)	12.5	(11.7,13.3)	71.2	(69.3,73.1)
	Low	42.5	26.5	(25.5,27.5)	16.0	(15.0,17.1)	62.3	(59.8,64.7)
	All	43.1	30.3	(29.7,30.8)	12.8	(12.3,13.3)	70.2	(69.1,71.4)
Endocrine, nutritional, metabolic	High	42.6	32.2	(31.2,33.3)	10.3	(9.3,11.4)	75.7	(73.1,78.3)
	Medium	42.1	30.1	(29.3,30.9)	12.0	(11.2,12.8)	71.5	(69.7,73.4)
	Low	41.0	25.8	(24.8,26.8)	15.2	(14.2,16.2)	63.0	(60.5,65.4)
	All	41.7	29.4	(29.0,29.9)	12.2	(11.7,12.7)	70.7	(69.5,71.8)
Mental and behavioral disorders	High	42.6	32.3	(31.2,33.4)	10.3	(9.2,11.4)	75.9	(73.3,78.5)
	Medium	42.1	30.2	(29.4,31.0)	11.9	(11.1,12.7)	71.7	(69.9,73.6)
	Low	41.0	25.9	(24.9,26.9)	15.1	(14.1,16.1)	63.1	(60.7,65.6)
	All	41.6	29.5	(29.0,30.0)	12.2	(11.7,12.7)	70.8	(69.6,71.9)
Nervous system	High	42.6	33.0	(31.9,34.1)	9.6	(8.5,10.7)	77.5	(75.0,80.0)
	Medium	42.1	30.6	(29.8,31.4)	11.5	(10.7,12.3)	72.7	(70.8,74.5)
	Low	41.0	25.9	(24.9,26.9)	15.2	(14.2,16.1)	63.1	(60.6,65.5)
	All	41.7	29.8	(29.3,30.3)	11.9	(11.4,12.3)	71.6	(70.4,72.7)
Circulatory system	High	42.8	32.9	(31.8,34.0)	9.9	(8.9,11.0)	76.8	(74.3,79.3)
	Medium	42.5	30.5	(29.8,31.3)	11.9	(11.1,12.7)	71.9	(70.1,73.8)
	Low	41.6	26.4	(25.4,27.4)	15.2	(14.2,16.2)	63.5	(61.0,65.9)
	All	42.1	30.0	(29.5,30.5)	12.2	(11.7,12.7)	71.1	(70.0,72.3)
Chronic obstructive lung disease	High	42.6	32.0	(30.9,33.2)	10.6	(9.5,11.7)	75.2	(72.6,77.8
	Medium	42.2	30.0	(29.2,30.7)	12.2	(11.4,13.0)	71.0	(69.2,72.9)
	Low	41.2	25.6	(24.6,26.6)	15.6	(14.6,16.6)	62.2	(59.7,64.6)
	All	41.8	29.3	(28.8,29.7)	12.5	(12.0,13.0)	70.0	(68.9,71.2)
Musculoskeletal system and connective tissue	High	42.6	35.7	(34.8,36.7)	6.9	(5.9,7.8)	83.9	(81.7,86.1)
	Medium	42.1	33.8	(33.1,34.5)	8.3	(7.6,9.0)	80.2	(78.6,81.9)
	Low	41.0	30.3	(29.4,31.2)	10.6	(9.7,11.5)	74.1	(71.9,76.3)
	All	41.6	33.1	(32.6,33.5)	8.5	(8.1,9.0)	79.5	(78.4,80.5)

For each educational group, the health impact of specific diseases was estimated in absolute terms by subtracting the hypothetical specific disease-eliminated expected lifetime with long-standing, limiting illness from that actually observed. We also subtracted the actual observed expected lifetime without long-standing illness from the hypothetical specific disease-eliminated lifetime without long-standing illness.

Elimination of highly lethal diseases lengthens life expectancy but probably at the expense of more years with long-standing illness. Thus, measured in absolute terms, the health gain from disease elimination might be negative. Elimination of chronic diseases with low mortality, however, has little impact on life expectancy but adds healthy years to life. Many diseases affect mortality and morbidity, and disease elimination might result in a longer lifetime in both poor and good health. In relative terms, the disease burden was assessed by comparing the observed and the hypothetical specific disease-eliminated percentage of lifetime without long-standing illness.

Results

Partial life expectancy, i.e. the expected lifetime of 30-year-olds before the age of 75, was 39.9 years for men and 41.6 years for women; it differed by 3.1 years for men and 1.6 years for women for those with a low and a high educational level (Tables 2 and 3). Partial life expectancy was 41.7 years

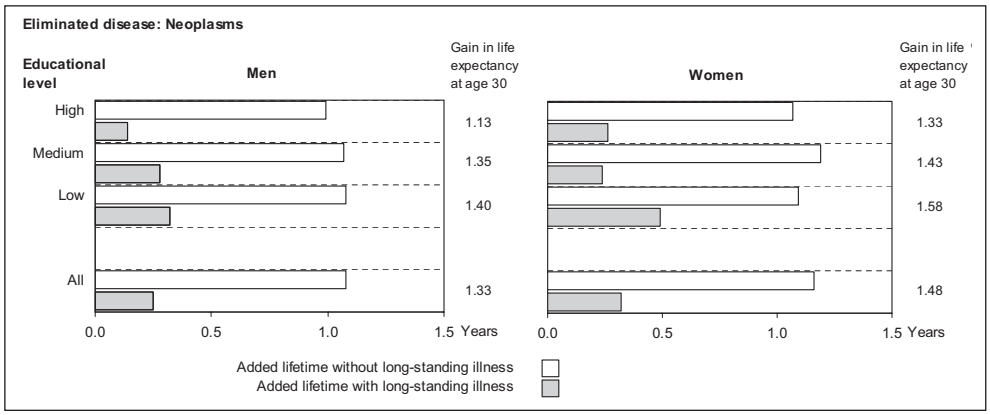

Figure 1 Gain in partial life expectancy (expected lifetime between the ages of 30 and 75) and changes in partial expected lifetime at age 30 with and without long-standing, limiting illness after elimination of neoplasms, by educational level

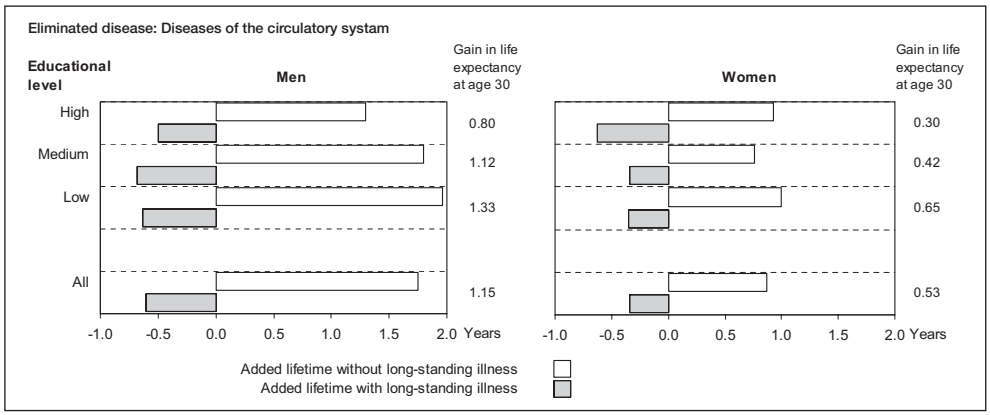

Figure 2 Gain in partial life expectancy (expected lifetime between the ages of 30 and 75) and changes in partial expected lifetime at age 30 with and without long-standing, limiting illness after elimination of diseases of the circulatory system, by educational level

for 30-year-old men with a high educational level, 33.6 of which were expected to be spent without long-standing, limiting illness and 8.1 with long-standing, limiting illness. Among men with a low educational level, partial life expectancy was 38.6 years, with 26.6 years without and 12.1 years with long-standing illness (Table 2). Similar social differences in expected lifetime with and without long-standing, limiting illness were seen for women (Table 3).

Elimination of cancer would increase partial life expectancy by 1.3 years for men and 1.5 years for women; however, lifetime with long-standing, limiting illness would be extended and more so for persons with a low rather than a high educational level. At the same time, the percentage of expected lifetime without long-standing illness would increase if cancer were to be eliminated (Tables 2 and 3). Figure 1 shows the gain in partial life expectancy and years added with and without long-standing illness.

While elimination of cancer would lengthen lifetime with long-standing illness, elimination of other diseases would in general lead to fewer years with illness. If, for instance, diseases of the circulatory system were eliminated, a longer life and fewer years with long-standing illness would be expected (added lifetime with long-standing illness is negative). For men, the benefit would be greater for those with a low educational level than for those with a high level, whereas for women the benefit tended to be greatest for those with a high educational level (Fig. 2).

Elimination of diseases with low fatality would transform lifetime with long-standing illness to lifetime without illness. For instance, elimination of diseases of the musculoskeletal system and connective tissue would make life healthier, particularly for persons with a low educational level (Fig. 3). Figure 4 and 5 indicate that elimination of endocrine, nutritional and metabolic diseases and of mental and behavioural disorders would reduce social differences in lifetime with and without long-standing, limiting illness, as the benefit decreased by level of education.

In general, the gain obtained by eliminating diseases with low fatality rates would be highest for persons with a low educational level. One exception was the effect of eliminating diseases of the nervous system: the greatest reduction in expected lifetime with long-standing, limiting illness would be achieved by women with a high educational level (Fig. 6). For men, elimination of chronic obstructive lung disease would lead to increase social differences in long-standing illness.

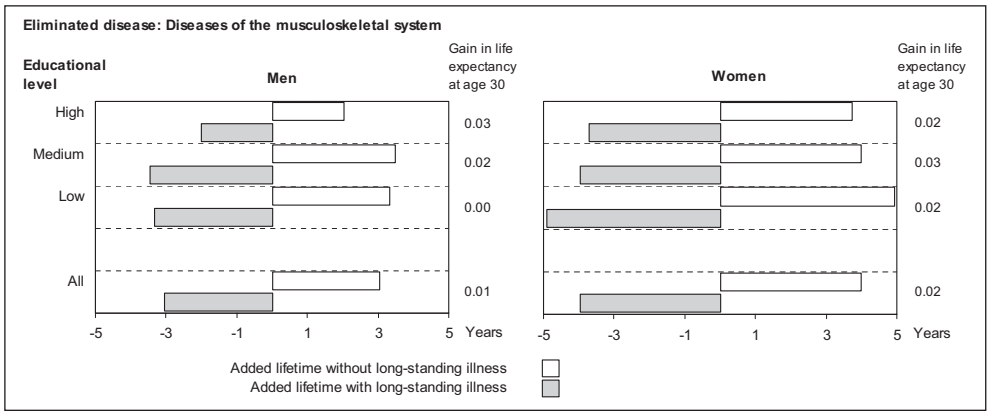

Figure 3 Gain in partial life expectancy (expected lifetime between the ages of 30 and 75) and changes in partial expected lifetime at age 30 with and without long-standing, limiting illness after elimination of diseases of the musculoskeletal system and connective tissue, by educational level

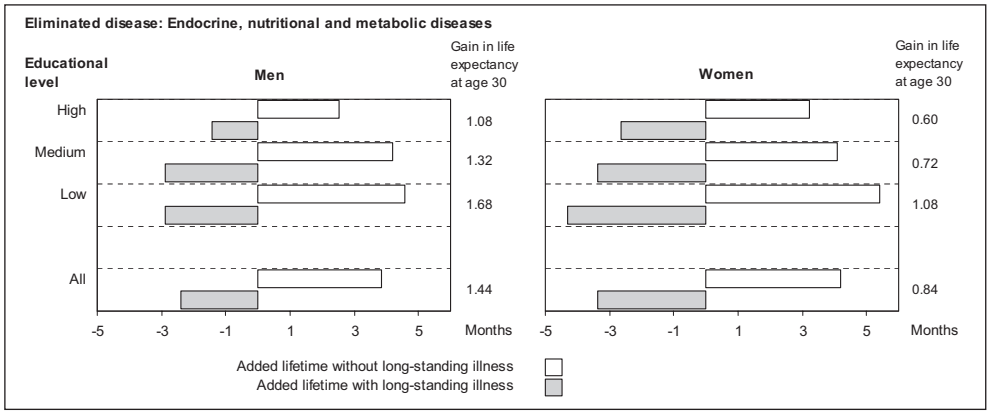

Figure 4 Gain in partial life expectancy (expected lifetime between the ages of 30 and 75) and changes in partial expected lifetime at age 30 with and without long-standing, limiting illness after elimination of endocrine, nutritional and metabolic diseases, by educational level

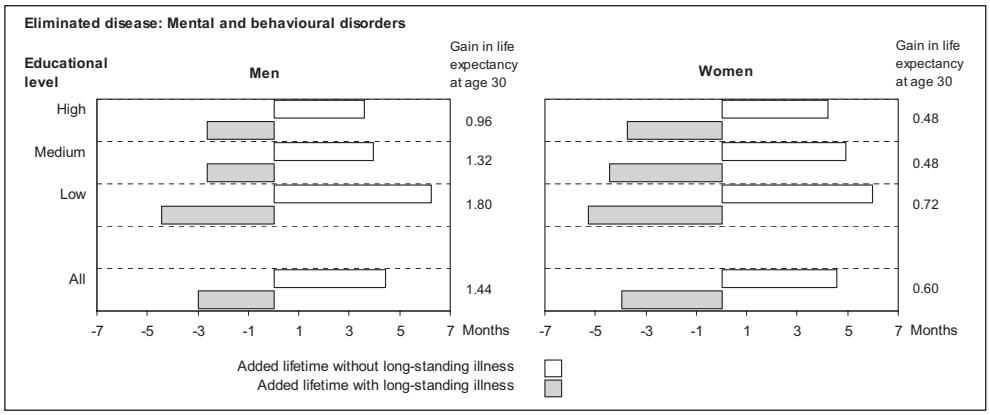

Figure 5 Gain in partial life expectancy (expected lifetime between the ages of 30 and 75) and changes in partial expected lifetime at age 30 with and without long-standing, limiting illness after elimination of mental and behavioural disorders, by educational level

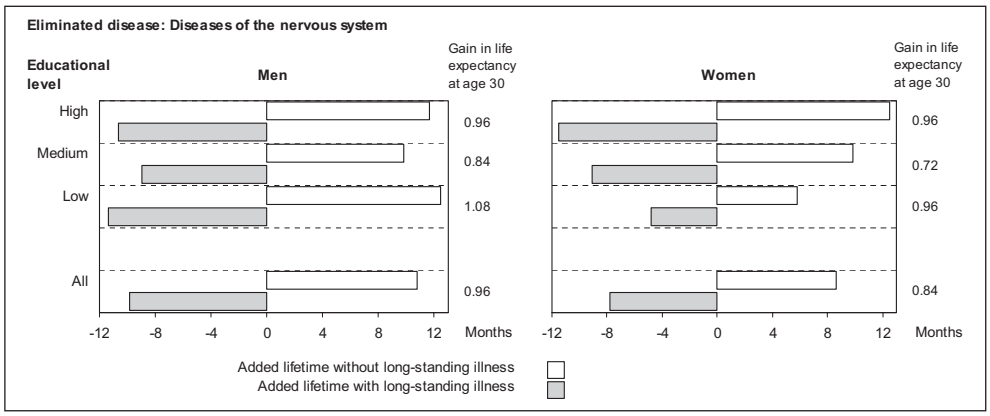

Figure 6 Gain in partial life expectancy (expected lifetime between the ages of 30 and 75) and changes in partial expected lifetime at age 30 with and without long-standing, limiting illness after elimination of diseases of the nervous system, by educational level

Discussion

We found that persons with a low educational level have more long-standing, limiting illness than people with a high educational level. The gain in partial life expectancy achieved by elimination of cancer decreased by educational level, but the excess lifetime gained by persons with a lower educational level would be in years with long-standing illness. A similar phenomenon was seen for women if cardiovascular diseases were eliminated: women with a low educational level would have more years added than women with a high level, but the reduction in lifetime with long-standing illness would be greatest for women with a high educational level. With the exceptions of diseases of the nervous system for women and chronic obstructive lung disease for men, we found a social gradient in the burden of all major diseases with low fatality.

These results complement the findings of a previous study on social differences in life expectancy and health expectancy (Brønnum-Hansen et al., 2004), in which lifetime expected to be spent with long-standing illness by educational level was estimated. In that study, however, long-standing illness was not limited to illness that restricted daily life or at work, and the impact of specific diseases was not analysed. In the present study we quantified social differences in the burden of illness by estimating the effect of eliminating specific diseases in groups at high, medium, and low educational levels using a composite measure on mortality and morbidity. Thus, (partial) life expectancy and health expectancy before and after hypothetical elimination of a specific disease were estimated based on educational level specific rates of total and cause specific deaths rates and disease prevalence. We assessed only diseases with a high prevalence or mortality in order to ensure a visible gain when averaged across (educational groups of) the population, because this increase would reflect a small or no gain for many and a large gain for few. Because disease prevalence was based on self-reported data, the study included not only diseases that would usually be diagnosed at a hospital (e. g. cancer and diseases of the circulatory system) but also diseases that seldom lead to hospital admission (e. g. musculoskeletal). This enabled us to evaluate the disease burden of both fatal diseases (implying hospital admission) and non-fatal diseases (not necessarily implying hospital admission).

Use of population and mortality data for all inhabitants of Denmark and data on educational level from national registers allowed calculation of sex- and age-specific death rates for persons at each educational level. Although Statistics Denmark has no data on the educational level of people over 75, we recently studied the impact of specific diseases on life expectancy and health expectancy among Danes aged 65 and older, with no classification by educational group (Brønnum-Hansen, Juel & Davidsen, 2006).

Although there is some dependence between causes of death, we assumed independence and used underlying cause of death in our calculations, because of insufficient data on multiple causes of death and lack of knowledge about the exact nature of dependence between causes. The bias introduced by this assumption might have affected our results in different directions, as mortality reduction by elimination of a specific disease might have been overestimated because of co-morbidity from diseases related to that eliminated or because contributory causes of death might lead to underestimation of any reduction in mortality.

If co-morbidity is more common among people with a low rather than a high educational level, the assumption of independence might have biased our results. For instance, diabetes, which is most prevalent among persons with a low education level, increases the risk for circulatory diseases. Therefore, we might expect that elimination of diabetes would reduce the death rates and prevalence of cardiovascular diseases to a greater degree among people with a low education level, but it is unclear by how much. If diabetes and diseases of the circulatory system were all eliminated, partial life expectancy would increase by 1.5 years and 0.7 years for 30-year-old men and women with a low educational level (data not shown). For men, the gain would be 2.4 more years without long-standing, limiting illness and 0.9 fewer years with long-standing illness, whereas women could expect 1.3 more years without and 0.6 fewer years with long-standing illness. For people with a high educational level, partial life expectancy would increase by 0.9 years for men and 0.3 years for women, and the gain would be 1.5 more years without illness and 0.6 fewer years with illness for men; the figures for women would be 1.0 and 0.7 years.

More knowledge about the health impacts of various diseases in specific subpopulations improves the possibilities for targeted health planning. The practical applications of the results of this study depend on the possibilities for eliminating specific diseases. Health policy in Denmark aims at social equity in access to health care services. Thus, no social inequality in medical attendance or hospital contacts would be expected. If treatment of fatal diseases succeeds in prolonging lifetime, social inequalities in health might increase if co-morbidity is more common among disadvantaged groups. Disease elimination, however, presupposes elimination of risk factors related to the disease. Several diseases are attributable to tobacco smoking, and recently we reported that smoking affects health regardless of educational level and that the social gradient in expected lifetime without long-standing illness cannot be explained by a reverse social gradient in smoking prevalence (Brønnum-Hansen & Juel, 2004c). Smoking even extends the expected lifetime with musculoskeletal diseases, irrespective of educational level (Brønnum-Hansen & Juel,

2004b). As many risk factors are more prevalent and tend to cluster among people with a low educational level, successful health promotion targeting high-risk subpopulations, including people with a low educational level, should involve simultaneous interventions against several risk factors and health determinants in order to reduce inequalities in health.

Conclusions

We found that persons with a low educational level are more likely to have long-standing, limiting illness than those with a high educational level. The gain in partial life expectancy that could be expected to derive from elimination of cancer decreases with educational level, but also added lifetime with long-standing illness decreases with educational level. A similar phenomenon was seen for cardiovascular diseases: if they were eliminated, women with a low educational level would gain lifetime years, but the reduction in lifetime with long-standing illness would be greatest for women with a high educational level. We found a social gradient in the burden of all major diseases with low fatality, except for diseases of the nervous system for women and chronic obstructive lung disease for men.

Acknowledgements

The study was funded by The Danish Ministry of Health grant for research and analysis.

Zusammenfassung

Fragestellung: Welchen Einfluss hatten Krankheiten auf die soziale Ungleichheit bezüglich der Lebenserwartung und der zu erwartenden in Krankheit verbrachter Lebensspanne in Dänemark in den Jahren 1995–1999?

Methoden: Berechnet wurde die Lebenserwartung mit und ohne chronische Krankheit von Personen mit einem niedrigen, mittleren oder hohen Bildungsgrad. Diese auf den beobachteten Sterblichkeitsraten und der Prävalenz von Krankheiten beruhenden Schätzwerte wurden verglichen mit Schätzwerten, von denen bestimmte Krankheiten ausgeschlossen wurden.

Ergebnisse: Die partielle Lebenserwartung (35–70 Jahre) würde sich um beinahe 1,5 Jahre erhöhen, wenn Krebs ausgeschlossen werden könnte. Die Lebenserwartung ohne langanhaltende Krankheit würde sich um ungefähr 1 Jahr erhöhen. Ohne kardiovaskuläre Erkrankungen würde sich die partielle Lebenserwartung vor allem bei Männern mit niedrigem Bildungsstand erhöhen. Wenn Erkrankungen des muskloskelettalen Systems eliminiert werden könnten, wäre der Nutzen dabei am grössten für Personen mit niedrigem Bildungsstand.

Schlussfolgerungen: Die zu erwartenden Steigerung der Lebenserwartung, die mit der Beseitigung ausgewählter Krankheiten einhergehen würde, nimmt mit dem Bildungsgrad ab. Die Beseitigung von Krebs würde die Lebenserwartung aller Personen sowohl mit als auch ohne andere Krankheiten unabhängig vom Bildungsgrad erhöhen.

Résumé

Inégalités sociales et impact des maladies chroniques sur l'espérance de vie au Danemark

Objectifs: Estimer l'impact de certaines maladies sur les inégalités sociales face à l'espérance de vie et à l'espérance de vie sans maladie (Danemark, 1995–1999).

Méthodes: L'espérance de vie avec et sans maladie chronique a été calculée pour des individus bénéficiant de niveaux d'éducation bas, moyens et hauts. Ces estimations basées sur les taux de mortalité obervés ainsi que sur la prévalence des maladies ont été comparées aux estimations basées sur des taux dont une maladie spécifique avait été éliminée.

Résultats: L'espérance de vie partielle (30–75 ans) augmenterait de 1.5 ans si les cancers étaient prévenus. Sans ces maladies, l'espérance de vie en bonne santé augmenterait d'environ 1 an. L'élimination des maladies cardiovasculaires augmenterait l'espérance de vie partielle, principalement chez les hommes ayant un bas niveau d'éducation. L'élimination des pathologies musculo-squelettiques serait particulièrement bénéfique aux personnes les moins formées.

Conclusions: L'allongement de l'espérance de vie attendu lors de l'élimination de certaines maladies diminue avec l'amélioration du niveau d'éducation. L'élimination du cancer allongerait la vie pour tous les niveaux d'éducation avec ou sans maladies.

References

Andersen O, Laursen L, Petersen JK (2001). Dødelighed og erhverv 1981–1995. (Mortality and occupation 1981–1995). Statistics Denmark, Copenhagen (in Danish).

Brønnum-Hansen H (2000). Socioeconomic differences in health expectancy in Denmark. Scand J Public Health *28*: 194–9.

Brønnum-Hansen H, Andersen O, Kjøller M, Rasmussen NK (2004). Social gradient in life expectancy and health expectancy in Denmark. Soz Praventiv Med *49*: 36–41.

Brønnum-Hansen H, Juel K (2004b). Smoking expands expected lifetime with musculoskeletal disease regardless of educational level. Eur J Epidemiol *19*: 195–6.

Brønnum-Hansen H, Juel K (2004c). Impact of smoking on the social gradient in health expectancy in Denmark. J Epidemiol Community Health *58*: 604–10.

Brønnum-Hansen H, Juel K, Davidsen M (2006). The burden of selected diseases among older people in Denmark. J Aging Health. In press.

Colvez A, Blanchet M (1983). Potential gains in life expectancy free of disability: a tool for health planning. Int J Epidemiol *12*: 224–9.

Davidsen M, Kjøller M (2002). The Danish health and morbidity survey – design and analysis. Statistics in Transition *5*: 927–42.

Manton KG, Stallard E (1991). Cross-sectional estimates of active life expectancy for the US elderly and oldest-old populations. J Gerontol *46*: 170–82.

Mathers CD (1999). Gains in health expectancy from elimination of diseases among older people. Disabil Rehabil *21*: 211–21.

National Institute of Public Health (2002). Sundhed & sygelighed i Danmark 2000 og udviklingen siden 1987. (The Danish Health Interview Survey 2000). National Institute of Public Health, Copenhagen (in Danish).

Nusselder WJ, van der Velden K, van Sonsbeek JL, Lenior ME, van den Bos GA (1996). The elimination of selected chronic diseases in a population: the compression and expansion of morbidity. Am J Public Health *86*: 187–94.

Preston SH, Heuveline P, Guillot M (2003). Demography. Measuring and modelling population processes. Oxford: Blackwell.

Sullivan DF (1971). A single index of mortality and morbidity. Health Services and Mental Health Administration (HSMHA). Health Report *86*: 347–54.

Address for correspondence
Henrik Brønnum-Hansen, MSc
National Institute of Public Health
Øster Farimagsgade 5
DK 1399 Copenhagen K
Denmark
Tel.: +45 39 20 77 77
Fax: +45 39 20 80 10
e-mail: hbh@niph.dk

Appendix

Social differences in the burden of long-standing illness in Denmark

Appendix 1

Construction of cause-deleted life tables

Let l(x) and e(x) signify the conventional period life table figures of survivors and life expectancy at age x. Then

d(x,n) = l(x) - l(x+n) = number of deaths between ages x and x+n

a(x,n), the mean number of person-years lived in the age interval x to x+n by those dying between ages x and x+n, is calculated as

$$\frac{1}{d(x,n)}\sum_{k=1}^{n} d(x-1+k, x+k)\cdot(k-0.5)$$

from life tables with age intervals of 1 year.

Furthermore,

L(x,n) = n·l(x+n)+a(x,n)·d(x,n) = number of person-years lived between age x and age x+n

$$e(x) = \frac{1}{l(x)}\sum_{y=x} L(y,n)$$

$e_{partial}(x) = e(x) - \frac{l(75)}{l(x)}\cdot e(75)$ = partial life expetancy, i.e. expected lifetime between age x and 75.

$m(x,n) = \frac{d(x,n)}{L(x,n)}$ = death rate in the age interval x to x+n

$$q(x,n) = \frac{d(x,n)}{l(x)} = \frac{n\cdot m(x,n)}{1+[n-a(x,n)]\cdot m(x,n)}$$

= probability of dying between age x and age x+n

p(x,n) = 1 – q(x,n) = probability of surviving between age x and age x+n.

Cause-deleted life tables are constructed by Chiang's method (1968), assuming proportionality within age intervals (x to x+n) of death intensity from cause i (μ^i) and from all causes combined (μ):

$\mu^i(y) = R^i(x)\cdot\mu(y)$, $x \le y \le x+n$

Thus, the probability of not dying from cause i between age x and age x+n is

$${}^*p^i(x,n) = p(x,n)^{R^i(x)}$$

Because of the proportionality assumption,

$R^i(x) = \frac{D^i(x,n)}{D(x,n)}$, where $D^i(x,n)$ and D(x,n) are the observed number of deaths from cause i and from all causes in the population between age x and age x+n, respectively.

A cause-deleted life table is a table from which death from cause i has been deleted. In this table, l(x) and e(x) are renamed $^*l^{-i}(x)$ and $^*e^{-i}(x)$, and we have:

$$R^{-i}(x) = \frac{D(x,n) - D^i(x,n)}{D(x,n)}$$

$${}^*p^{-i}(x,n) = p(x,n)^{R^{-i}(x)}$$

Thus,

$^*l^{-i}(x+n) = {}^*l^{-i}(x)\cdot{}^*p^{-i}(x,n)$

$^*d^{-i}(x,n) = {}^*l^{-i}(x) - {}^*l^{-i}(x,n)$

$^*L^{-i}(x,n) = n\cdot{}^*l^{-i}(x+n) + {}^*a^{-i}(x,n)\cdot{}^*d^{-i}(x,n)$

where, (as suggested by Keyfitz, 1966):

$${}^*a^{-i}(x,n) = \frac{-\frac{n}{24}\cdot{}^*d^{-i}(x-n,n) + \frac{n}{2}\cdot{}^*d^{-i}(x,n) + \frac{n}{24}\cdot{}^*d^{-i}(x+n,n)}{{}^*d^{-i}(x,n)}, \quad x < 75.$$

Life expectancy in the cause-deleted table is

$${}^*e^{-i}(x) = \frac{1}{{}^*l^{-i}(x)}\sum_{y=x} {}^*L^{-i}(y,n)$$

The abridged life tables are constructed for n = 5. Partial life expectancies (expected lifetime before age 75) are calculated assuming e(75) as well as $^*e^{-i}(75)$ to be equal for all educational groups, because education is not available for people over 75.

Chiang, C. L. (1968). Introduction to stochastic processes in biostatistics. New York: Wiley.

Keyfitz, N. (1966). A life table that agrees with data. Journal of the American Statistical Association *61*: 305–12.

Soz Praventiv Med 51 (2006) 221–231

Appendix 2

Calculation of health expectancy by the method of Sullivan

Below, l(x) and e(x) represent conventional life table figures for calculating observed health expectancy, and $*l^{-i}(x)$ and $*e^{-i}(x)$ (cf. Appendix 1) for constructing health expectancy after hypothetical disease elimination. Likewise, π in the formulae below signifies the observed as well as the hypothetical prevalence proportion.

If $\pi(x,n)$ is the proportion of persons between age x and x+n not suffering from any long-standing, limiting illness among N(x,n) responders to the survey, then the expected years of life without long-standing, limiting illness between age x and x+n among l(x) survivors is:

$H(x,n) = L(x,n) \cdot \pi(x,n)$,

where L(x,n) ($*L^{-i}(x,n)$ for the cause-deleted table) is defined in Appendix 1.

The expected lifetime without long-standing, limiting illness of a x_0-year-old person is:

$$HLE(x_0) = \frac{1}{l(x_0)} \sum_{x=x_0,x_0+n,\ldots} H(x,n)$$

The variance of $HLE(x_0)$ is approximated by:

$$Var(HLE(x_0)) = \frac{1}{l^2(x_0)} \sum_{x=x_0,x_0+n,\ldots} L^2(x,n) \cdot \frac{\pi(x,n) \cdot (1-\pi(x,n))}{N(x,n)}$$

Soz Praventiv Med 51 (2006) 221–231