

# Educational inequalities in mortality over four decades in Norway: prospective study of middle aged men and women followed for cause specific mortality, 1960-2000

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## ABSTRACT

**Objectives** To determine the extent to which educational inequalities in relation to mortality widened in Norway during 1960-2000 and which causes of death were the main drivers of this disparity.

**Design** Nationally representative prospective study.

**Setting** Four cohorts of the Norwegian population aged 45-64 years in 1960, 1970, 1980, and 1990 and followed up for mortality over 10 years.

**Participants** 359 547 deaths and 32 904 589 person years.

**Main outcome measures** All cause mortality and deaths due to cancer of lung, trachea, or bronchus; other cancer; cardiovascular diseases; suicide; external causes; chronic lower respiratory tract diseases; or other causes. Absolute and relative indices of inequality were used to present differences in mortality by educational level (basic, secondary, and tertiary).

**Results** Mortality fell from the 1960s to the 1990s in all educational groups. At the same time the proportion of adults in the basic education group, with the highest mortality, decreased substantially. As mortality dropped more among those with the highest level of education, inequalities widened. Absolute inequalities in mortality denoting deaths among the basic education groups minus deaths among the high education groups doubled in men and increased by a third in women. This is equivalent to an increase in the slope index of inequality of 105% in men and 32% in women. Inequalities on a relative scale widened more, from 1.33 to 2.24 among men (P=0.01) and from 1.52 to 2.19 among women (P=0.05). Among men, absolute inequalities mainly increased as a result of cardiovascular diseases, lung cancer, and chronic lower respiratory tract diseases. Among women this was mainly due to lung cancer and chronic lower respiratory tract diseases. Unlike the situation in men, absolute inequalities in deaths due to cardiovascular causes narrowed among women. Chronic lower respiratory tract diseases contributed more to the disparities in inequalities among women than among men.

**Conclusion** All educational groups showed a decline in mortality. Nevertheless, and despite the fact that the

Norwegian welfare model is based on an egalitarian ideology, educational inequalities in mortality among middle aged people in Norway are substantial and increased during 1960-2000.

## INTRODUCTION

Inequalities in mortality have been widening in Western populations in recent decades.<sup>1</sup> Some trend studies on inequalities in death cover the period from 1980,<sup>1-4</sup> but such studies on inequalities before that decade are scarce. Also, trend studies have tended to focus on relative inequalities rather than absolute measures.<sup>5</sup>

In the 1960s the Norwegian economy was transformed by the discovery of oil and gases, and currently Norway has one of the highest per capita incomes in the Western world.<sup>6</sup> During the same period the level of education in Norway increased; in 1960 only 5% of men and 2% of women had a university degree, whereas in 1990 these proportions had increased to 21% and 14%. The biggest shift in educational level was from the 1970s to 1980s. Materially, living standards have increased, and most children and young people today have never experienced a lack of basic needs or absolute poverty. Unemployment rates were in general low in the 1960s and 1970s, at around 1-2%. At the end of the 1980s and the beginning of the 1990s a financial crisis hit Norway and unemployment rates increased, peaking at 6% in 1993. Towards 2000, however, the rates had decreased to 3.4%.<sup>7</sup> The Norwegian healthcare system is built on the principle of equal access to services—that is, all inhabitants should have the same opportunities for health care, regardless of social or economic status.<sup>8</sup> Furthermore, the national insurance scheme was introduced in 1967, which is a public universal insurance scheme that assures everybody a minimum of social security, regardless of income. Compared with other Western countries, the inequality between incomes in Norway is at the lower end of the spectrum.

In the 1950s, 70% of Norwegian men and 20% of Norwegian women smoked.<sup>9</sup> Towards the 1970s smoking had declined in men, mostly in the higher

education groups, and in women the smoking epidemic followed the trends for men but with some time lag. Since the 1970s smoking and education have been inversely associated, and towards 2000 the inequalities between people who smoke has widened.<sup>10</sup> Today Norway is among the European countries with the highest absolute educational inequalities in smoking.<sup>9,11</sup> Educational inequalities have also been shown from the 1970s to the 1980s for body mass index, blood pressure, smoking, and cholesterol concentrations.<sup>12</sup>

We determined how much educational inequalities in mortality widened in Norway during 1960-2000 and which causes of death were the main drivers of this disparity.

## METHODS

We adhered to the strengthening of reporting of observational studies in epidemiology guidelines for cohort studies. Four cohorts were studied, one for each decennial census in 1960, 1970, 1980, and 1990. Each cohort included all Norwegian citizens aged 45-64 years at the time of the census and each was followed up for cause specific mortality over 10 years. Data were compiled by Statistics Norway and based on individual census records linked to the Norwegian causes of death register and to the national education database.<sup>13</sup> The database comprises data collected directly from schools in 1980 and 1990, and from the censuses in 1960 and 1970. Using the unique personal identification numbers of the Norwegian citizens, we linked death records with information on educational level for four time periods: 31 October 1960 to 30 October 1970, 31 October 1970 to 30 October 1980, 31 October 1980 to 30 October 1990, and 2 November 1990 to 1 November 2000.

In total we included 32.9 million person years and 359 547 deaths in the study. The death certificates were registered by Statistics Norway and there were no missing cases. The causes of death were coded according to the *International Classification of Diseases*, using the ninth revision until 1996 and the 10th revision thereafter. We categorised deaths into seven groups (ICD-10 codes): cancer of lung trachea, or bronchus (C32-C34) (defined here as lung cancer), other cancer (C00-C32, C35-C97), cardiovascular diseases (I00-I99), suicide (X60-X84), external causes (excluding suicide) (V01-Y89), chronic lower respiratory tract diseases (J40-J47), and other causes.

We grouped education into three levels: basic, secondary, and tertiary. In 1960 education was a four category variable, whereas from 1970 onwards it was categorised on a nine graded scale, allowing for more detailed information. Owing to changes in the education system during the 1960s, the coding of education was different then compared with 1970, 1980, and 1990.<sup>13</sup> In our analysis the basic education group in 1960 comprised those with seven years of schooling and those with no educational level. The secondary group comprised those with primary education and lower secondary education (8-12 years of schooling)

and the tertiary group comprised those with post-secondary education (13 years of schooling). For education in 1970, 1980, and 1990, the basic education group comprised those up to lower secondary education (0-9 years), the secondary group those with secondary and post-secondary education (10-12 years), and the tertiary group those with university or high school education ( $\geq 13$  years). Education was almost complete for all cohorts, only missing 0.5-2.8% of data.

An additional dataset from three regional Norwegian health examination surveys (1974-6, 1985-8, and 2000-3), with 17 351 respondents, provided educational inequalities in cholesterol and triglyceride concentrations, systolic blood pressure, body mass index, smoking, and inactivity (see web extra appendix A).

## Statistical analysis

We calculated age standardised mortality rates for educational groups separately for men and for women using the direct method with the European standard population.<sup>14</sup> Inequality measures were used to take into account the substantial changes in distribution of education from 1960 to 1990. The slope index of inequality, or difference index, and relative index of inequality, or ratio index, are epidemiological measures of inequality in health applicable to ordinal socioeconomic variables.<sup>15</sup> These measures have two ideal properties: firstly, they are regression based and therefore give an inequality measure across the full range of socioeconomic status (not just comparing the two most extreme groups), and secondly, they allow for differing group size of time or place. To calculate these indices we ordered the educational groups from highest to lowest and assigned each group a score on the basis of the cumulative percentage distribution of education. In 1960, for example, 5% of men attained a tertiary level of education and a score of 2.5 (that is,  $5/2$ ), 17% achieved secondary education and a score of 13.5 ( $(17/2)+5$ ), and 78% had basic education and a score of 61 ( $(78/2)+17+5$ ). Thus, as percentage distributions of change in education over time, the scores also change to maintain a ranking score on a cumulative percentage scale. We used Poisson regression models to estimate the indices, with confidence intervals, regressing mortality on the score variable for each educational group<sup>15</sup>:

$$\ln(\text{age adjusted mortality}) = a + b \times \text{score} + e$$

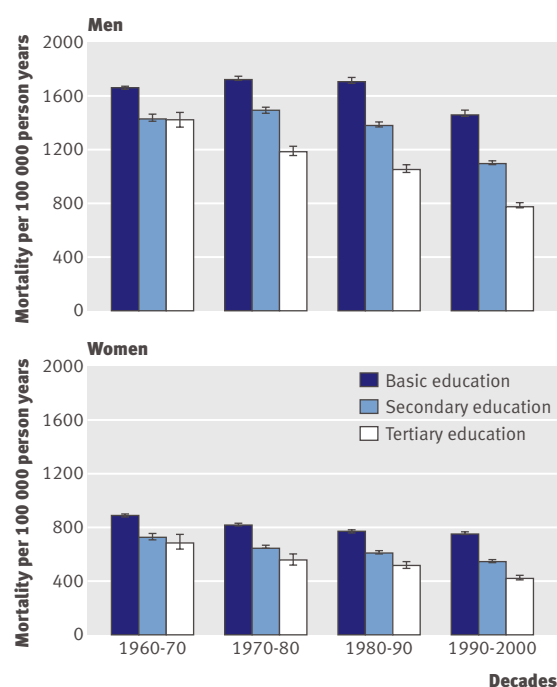
where  $a$  is the intercept,  $b$  is the slope, score is the ranking score, and  $e$  is the error term. The ratio index is simply  $\exp(b)$ , where  $\exp$  is the exponential. The difference index is calculated as  $100\,000 \times \exp((a+b)/a)$ . The difference index can be interpreted as the increased risk of dying—that is, the rate difference of death, for the hypothetical individual with the highest educational level minus the rate for the individual with the lowest level. Likewise, the ratio index is a rate ratio of death, for the individual with the highest educational level relative to the individual with the lowest level. Thus these difference and ratio measures of health inequality will always be larger than standard difference and ratio measures that implicitly compare

midpoints of the lowest and highest educational groups —not the estimated mortality for the 0th and 100th centile of the underlying rank distribution.

We used a weighted linear regression to calculate test for linear trend in the difference and ratio measures across cohorts, with the difference index as dependent variable and time as independent variable, using weights equal to the inverse variance of the difference index. The same procedure was used for  $\ln(\text{ratio index})$ .

## RESULTS

Both the size and the mortality of the education groups changed over time. In 1960 the mortality rate of basically educated men (78%) was 1658 per 100 000 person years, and by 1990 (34% of men) it was 12% lower, at 1466 per 100 000 person years (table 1, fig 1, and web extra table A2). In 1960 the mortality rate of tertiary educated men (5%) was 1425 per 100 000 person years, and by 1990 (21% of men) it was 45% lower, at 780 per 100 000 person years. A similar pattern was observed among women, with the basic education group decreasing in size from 81% to 17% over time and the mortality rate decreasing by 15%, from 893 to 760 per 100 000 person years. The tertiary educated group increased in size from 2% to 14% but had a larger 38% reduction in mortality, from 689 to 426 per 100 000 person years. The decrease for the secondary



**Fig 1** Age adjusted mortality per 100 000 person years by education in four cohorts of Norwegian men and women aged 45-64 in 1960-70, 1970-80, 1980-90, and 1990-2000

**Table 1** Person time and number of deaths\* by cause and educational level in four cohorts of Norwegian men and women aged 45-64 at start of follow-up during each decade during 1960-2000

Variables	Basic education				Secondary education				Tertiary education				Total			
	1960-70	1970-80	1980-90	1990-2000	1960-70	1970-80	1980-90	1990-2000	1960-70	1970-80	1980-90	1990-2000	1960-70	1970-80	1980-90	1990-2000
No of men	322 879	326 057	199 586	138 949	68 051	98 466	169 229	185 080	20 220	36 098	54 892	82 099	411 150	460 621	423 707	406 128
No of women	347 200	389 146	246 463	170 203	74 208	71 165	158 394	183 428	8901	14 265	32 070	56 451	430 309	474 576	436 927	410 082
Person years:																
Men	3 016 226	2 415 025	1 837 495	1 293 479	642 977	1 539 470	1 589 122	1 765 103	191 553	345 036	524 759	796 323	3 850 756	4 299 531	3 951 376	3 854 905
Women	3 341 197	2 995 385	2 372 387	1 639 911	720 217	1 452 383	1 540 137	1 791 536	86 591	139 736	313 627	554 915	4 148 005	4 587 504	4 226 151	3 986 362
% person years:																
Men	78	56	47	34	17	36	40	46	5	8	13	21	100	100	100	100
Women	81	65	56	41	17	32	36	45	2	3	7	14	100	100	100	100
Causes of death																
Men:																
Total No of deaths	50 001	43 515	31 453	18 965	9238	21 969	22 024	19 410	2730	4109	5537	6212	61 969	69 593	59 014	44 587
Lung cancer	2114	2394	2567	1998	357	1293	1616	1776	108	200	366	510	2579	3887	4549	4284
Other cancer	9148	7591	5851	4137	1765	4605	4774	5107	510	894	1417	1990	11 423	13 090	12 042	11 234
Cardiovascular	25 652	20 878	15 357	7761	4981	11 923	10 818	7535	1464	2118	2638	2229	32 097	34 919	28 813	17 525
External	2298	2031	1366	818	316	863	850	774	73	133	208	232	2687	3027	2424	1824
Suicide	671	662	688	402	105	355	442	402	47	78	145	147	823	1095	1275	951
Chronic lower respiratory tract disease	1224	1108	975	730	171	476	559	617	38	53	101	124	1433	1637	1635	1471
Other	8894	7004	4650	3119	1541	3487	2964	3199	491	632	662	980	10 926	11 123	8276	7298
Women:																
Total No of deaths	29 849	24 680	18 456	12 459	5290	9516	9495	9885	597	790	1643	2364	35 736	34 986	29 594	24 708
Lung cancer	341	519	895	1234	87	237	472	803	11	19	81	152	439	775	1448	2189
Other cancer	9448	8663	6776	4613	2007	4025	4173	4503	221	357	816	1280	11 676	13 045	11 765	10 396
Cardiovascular	13 075	9808	6611	3356	2002	3205	2699	2190	226	241	396	401	15 303	13 254	9706	5947
External	612	588	445	263	141	280	276	273	21	25	55	92	774	893	776	628
Suicide	220	251	269	154	56	157	233	179	11	15	61	64	287	423	563	397
Chronic lower respiratory tract disease	483	504	638	790	67	133	263	391	9	10	26	55	559	647	927	1236
Other	5670	4346	2822	2050	931	1481	1379	1546	97	123	208	320	6698	5950	4409	3916

\*Weighted for age in five year age groups by direct method using European standard population (weights: 45-49=0.28, 50-54=0.28, 55-59=0.24, 60-64=0.20). Some numbers by causes do not sum to total mortality numbers because of weighting.

**Table 2** Educational inequalities in mortality by cause of death in four cohorts of Norwegian men and women aged 45-64 in each decade from 1960-2000

Cause of death	Men		Women	
	Absolute inequality* (95% CI)	Relative inequality† (95% CI)	Absolute inequality* (95% CI)	Relative inequality† (95% CI)
<b>Total mortality:</b>				
1960-70	460 (396 to 524)	1.33 (1.28 to 1.38)	356 (307 to 405)	1.52 (1.43 to 1.60)
1970-80	625 (577 to 674)	1.48 (1.43 to 1.52)	377 (342 to 412)	1.66 (1.58 to 1.74)
1980-90	878 (830 to 925)	1.80 (1.74 to 1.86)	371 (339 to 403)	1.73 (1.65 to 1.81)
1990-2000	943 (901 to 985)	2.24 (2.16 to 2.32)	471 (442 to 501)	2.19 (2.08 to 2.30)
P value for trend	0.012	0.014	0.102	0.048
<b>Lung cancer:</b>				
1960-70	30 (17 to 44)	1.57 (1.28 to 1.91)	-4 (-9 to 1)	0.68 (0.43 to 1.08)
1970-80	45 (33 to 56)	1.64 (1.44 to 1.86)	3 (-2 to 8)	1.18 (0.87 to 1.61)
1980-90	98 (85 to 112)	2.35 (2.09 to 2.63)	17 (10 to 24)	1.65 (1.33 to 2.05)
1990-2000	129 (115 to 143)	3.13 (2.79 to 3.50)	69 (60 to 79)	3.74 (3.15 to 4.44)
P value for trend	0.015	0.031	0.131	0.010
<b>Other cancer:</b>				
1960-70	63 (36 to 90)	1.24 (1.13 to 1.35)	15 (-12 to 41)	1.05 (0.96 to 1.16)
1970-80	52 (31 to 72)	1.19 (1.11 to 1.27)	31 (10 to 52)	1.12 (1.03 to 1.20)
1980-90	58 (37 to 79)	1.21 (1.13 to 1.29)	35 (15 to 55)	1.13 (1.05 to 1.22)
1990-2000	92 (72 to 112)	1.37 (1.28 to 1.47)	70 (51 to 89)	1.31 (1.22 to 1.41)
P value for trend	0.270	0.289	0.036	0.051
<b>Cardiovascular disease:</b>				
1960-70	159 (114 to 204)	1.21 (1.15 to 1.28)	262 (228 to 297)	2.04 (1.86 to 2.24)
1970-80	267 (232 to 301)	1.39 (1.33 to 1.45)	243 (220 to 265)	2.38 (2.20 to 2.58)
1980-90	435 (402 to 469)	1.82 (1.74 to 1.90)	237 (218 to 256)	2.97 (2.72 to 3.25)
1990-2000	444 (417 to 471)	2.62 (2.48 to 2.77)	190 (175 to 205)	3.79 (3.41 to 4.20)
P value for trend	0.026	0.025	0.030	0.006
<b>External causes:</b>				
1960-70	70 (54 to 86)	2.70 (2.18 to 3.35)	-4 (-10 to 3)	0.83 (0.58 to 1.17)
1970-80	68 (57 to 79)	2.60 (2.24 to 3.03)	1 (-4 to 7)	1.06 (0.80 to 1.41)
1980-90	51 (41 to 61)	2.28 (1.95 to 2.67)	2 (-3 to 7)	1.11 (0.83 to 1.48)
1990-2000	48 (39 to 57)	2.71 (2.28 to 3.22)	0 (-5 to 5)	1.01 (0.75 to 1.35)
P value for trend	0.032	0.832	0.462	0.463
<b>Suicide:</b>				
1960-70	7 (0,15)	1.41 (1.00 to 2.00)	-3 (-7 to 1)	0.61 (0.35 to 1.06)
1970-80	9 (3 to 15)	1.41 (1.11 to 1.78)	-5 (-9 to -1)	0.61 (0.41 to 0.91)
1980-90	18 (11 to 25)	1.73 (1.40 to 2.14)	-10 (-15 to -5)	0.49 (0.35 to 0.68)
1990-2000	18 (12 to 24)	2.05 (1.62 to 2.60)	-2 (-6 to 1)	0.78 (0.54 to 1.13)
P value for trend	0.027	0.052	0.982	0.574
<b>Chronic lower respiratory tract diseases:</b>				
1960-70	37 (25 to 48)	2.66 (1.99 to 3.57)	12 (5 to 19)	2.41 (1.47 to 3.96)
1970-80	40 (32 to 49)	2.85 (2.32 to 3.50)	18 (12 to 23)	3.68 (2.50 to 5.40)
1980-90	48 (39 to 56)	3.17 (2.60 to 3.85)	25 (19 to 31)	3.40 (2.54 to 4.55)
1990-2000	58 (50 to 67)	4.43 (3.63 to 5.40)	59 (51 to 67)	7.51 (5.88 to 9.59)
P value for trend	0.026	0.059	0.119	0.048
<b>Other causes:</b>				
1960-70	105 (78 to 132)	1.45 (1.32 to 1.59)	95 (73 to 117)	1.80 (1.58 to 2.07)
1970-80	151 (131 to 171)	1.79 (1.66 to 1.93)	95 (81 to 110)	2.13 (1.89 to 2.40)
1980-90	176 (157 to 194)	2.31 (2.12 to 2.52)	72 (59 to 84)	2.05 (1.80 to 2.33)
1990-2000	161 (144 to 178)	2.32 (2.13 to 2.53)	93 (81 to 105)	2.66 (2.35 to 3.02)
P value for trend	0.262	0.045	0.803	0.053

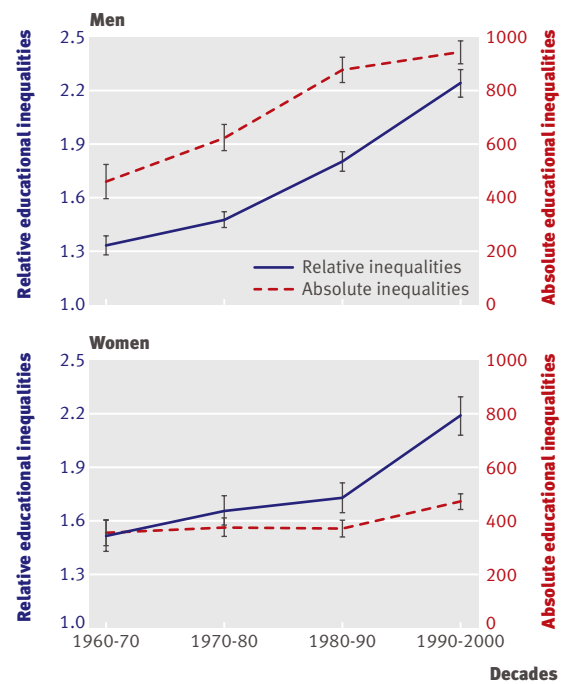
\*Slope index of inequality.  
†Relative index of inequality.

educated group was 23% among men (exclusively from the 1980s to 1990s) and 25% among women.

The diverging trends in mortality, even after allowing for changing group size over time, resulted in large changes in inequalities in mortality over time, on both absolute and relative scales. Among men, absolute educational inequalities in mortality, expressed by the difference index, doubled from 460 to 943 per 100 000 person years (overall P for trend 0.01), with the largest increase from 625 to 878 per 100 000 person years between the 1970s and 1980s and then a levelling out in the 1990s (fig 2 and table 2). The relative inequalities, expressed by the ratio index, increased more than three-fold, from 1.33 to 2.24 (P=0.01). In women, the absolute inequality was stable from the 1960s to the 1980s and thereafter increased steeply to the 1990s (P<0.01); a third increase from 356 to 471 per 100 000 person years across the full period. Relative inequalities more than doubled, from 1.52 to 2.19 (P=0.05), with the most notable increase after the 1980s.

**Cancer mortality**

Towards 1990 the death rate from lung cancer more than doubled among basically educated men, and among basically educated women increased sixfold from the 1960s to the 1990s (see web extra fig A1). Rates also increased in the other educational groups, but to a smaller extent. Thus educational inequalities in deaths from lung cancer increased substantially over time (table 2 and figs 3 and 4). For other cancers, inequalities increased among women in all decades and among men after the 1970s.



**Fig 2** Trends in relative and absolute inequalities in education in Norwegian men and women aged 45-64 at start of follow-up in each decade during 1960-2000. Whiskers are 95% confidence intervals

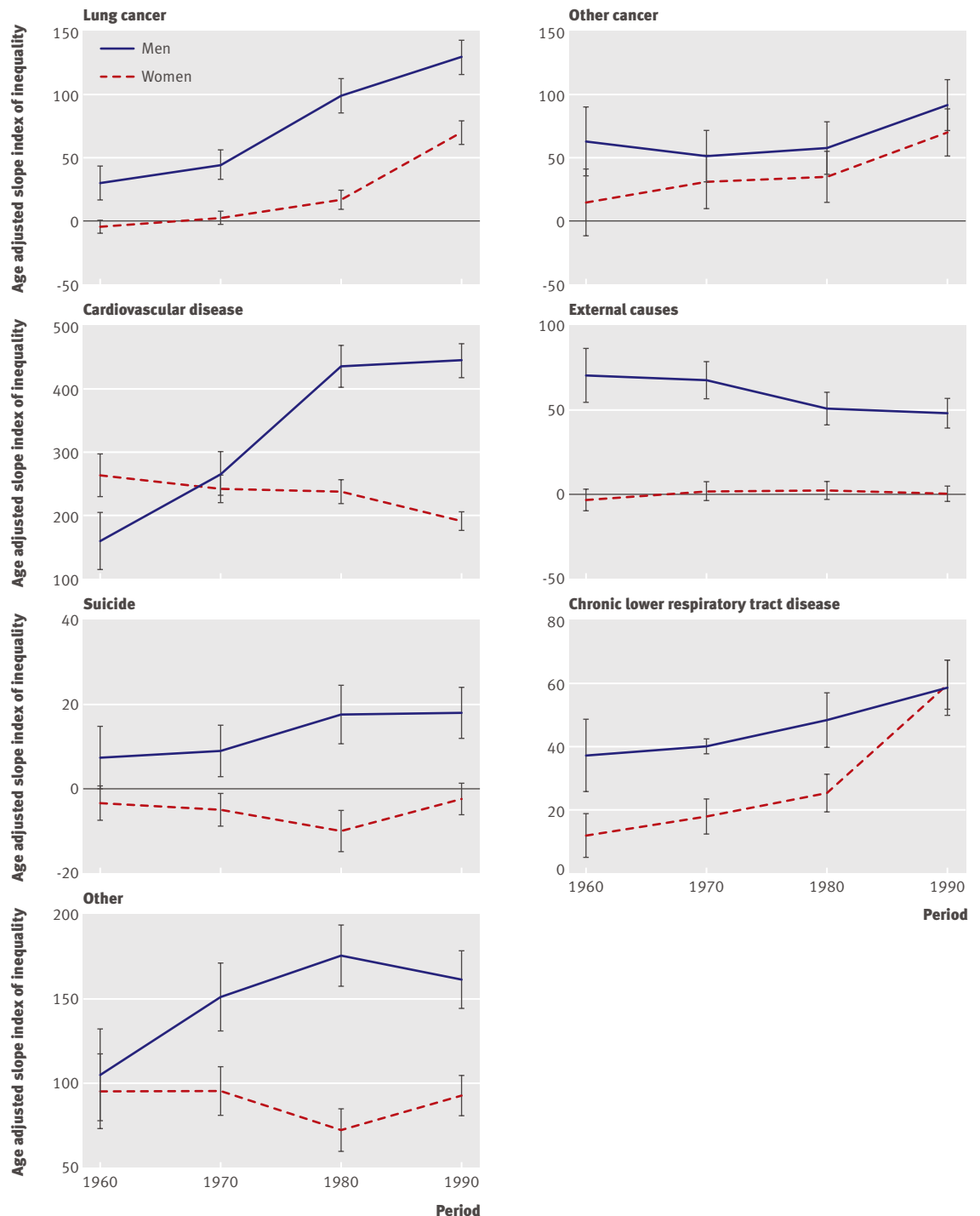
**Cardiovascular mortality**

Deaths from cardiovascular disease decreased substantially in all groups over the four decades, but more so in percentage terms in the groups at the extremes of educational attainment (63% among tertiary educated men and 29% among basically educated men; fig 2). The reductions were even larger among women (48% for basically educated *v* 72% for tertiary educated). Inequalities in deaths due to cardiovascular disease

increased in men, on both relative and absolute scales (P for trend <0.05; table 2 and figs 3 and 4). Among women, however, absolute inequalities fell and relative inequalities increased. The same pattern was seen for both ischaemic heart disease and stroke.

**External causes and suicide**

Death rates for external causes were stable for women over the four decades (fig 2), and no inequalities in



**Fig 3** | Trends in absolute inequalities in education in Norwegian men and women aged 45-64 at start of follow-up in each decade during 1960-2000. Whiskers are 95% confidence intervals

**Table 3** | Distribution of absolute inequality (slope index) among causes of death. Values are percentages unless stated otherwise

Cause of death	Men					Women				
	1960-70	1970-80	1980-90	1990-2000	Change (%) in contribution to absolute inequality*	1960-70	1970-80	1980-90	1990-2000	Change (%) in contribution to absolute inequality*
Lung cancer	6	7	11	14	8	-1	1	4	14	15
Other cancer	13	8	7	10	-3	4	8	9	15	11
Cardiovascular disease	34	42	49	47	13	70	63	63	40	-30
External	15	11	6	5	-10	-1	0	0	0	1
Suicide	2	1	2	2	0	-1	-1	-3	-1	0
Chronic lower respiratory tract diseases	8	6	5	6	-2	3	5	7	12	9
Other	22	24	20	17	-5	25	25	19	19	6
Total†	100	100	100	100		100	100	100	100	

\*Change (percentage points) in contribution to overall absolute inequality from 1960-70 to 1990-2000.

†Based on sum of cause specific absolute inequality, and does not exactly sum up to all cause mortality absolute inequality presented in table. This is due to separate regression models for each group of causes. The discrepancy is, however, small (1-3 for men, 2-5 for women).

education were seen (table 2 and figs 3 and 4). In men, however, a strong inverse gradient was observed across all decades. Absolute inequalities decreased significantly during 1960-2000, whereas relative inequalities were stable, at around 2.5. Unlike all other causes of death, suicide rates in women were higher in the higher educated groups (table 2 and figs 3 and 4). This tendency was evident in all periods but statistically significant only in the 1970s and 1980s, on both absolute and relative scales. Among men, inequalities were present and even increased over the four decades.

#### Chronic lower respiratory tract diseases

The trend for mortality from chronic lower respiratory tract diseases was almost identical to that for lung cancer; among basically educated women the rates more than tripled over the four decades, whereas among tertiary educated women the rates were stable (fig 2). Among basically educated men the rates increased by 39% and among tertiary educated men the rates decreased by 21% from the 1960s to the 1990s. Educational inequalities in chronic lower respiratory tract diseases increased from the 1960s, and the increase was especially large in the last decades in women.

#### What causes of death contribute most to the overall absolute inequality?

Cardiovascular mortality was the largest contributor to overall absolute inequality across all decades (table 3, and see web extra fig A2). Among men, the proportion of inequalities due to cardiovascular mortality increased from 34% to 47% from the first to last decade. Conversely, the proportion declined among women during the same period, from 70% to 40%. Lung cancer had a low contribution in the early decades, but increased in the 1980s and 1990s; among men from 6% to 14% and among women from -1% to 14%. Among women, a similar pattern was observed for chronic lower respiratory tract diseases (from 3% to 12%). Among men, external causes contributed 13-15% of deaths in the early periods, but in the 1980s

and 1990s the contribution dropped to 6% and 5%, respectively. Among women, deaths due to external causes did not contribute to the overall absolute inequality in any of the decades.

#### What causes of death drive the widening of absolute inequalities?

Among men, absolute inequalities (expressed by the difference index) increased by 483 deaths per 100 000 person years from the 1960s to the 1990s (table 2). Most of this increase (59%) was due to cardiovascular diseases—that is, (increase in absolute educational inequalities for cardiovascular disease)/(increase in sum of cause specific absolute educational inequalities)=285/479 (the sum 479 does not total 483 because separate regressions were run for each cause of death) and lung cancer (21%). The remaining increase was due to other cancers (6%), chronic lower respiratory tract diseases (4%), suicide (2%), and other causes (12%). Inequalities in deaths due to external causes narrowed and a negative offsetting contribution by 5%.

Among women the difference index for deaths from all causes increased by 115 deaths per 100 000 persons years from the 1960s to the 1990s (table 2). The increased inequalities were caused by cancer, especially lung cancer (69%), and chronic lower respiratory tract diseases (44%). However, inequalities in cardiovascular causes decreased by 72 deaths per 100 000 person years, a large offsetting negative contribution of 68%.

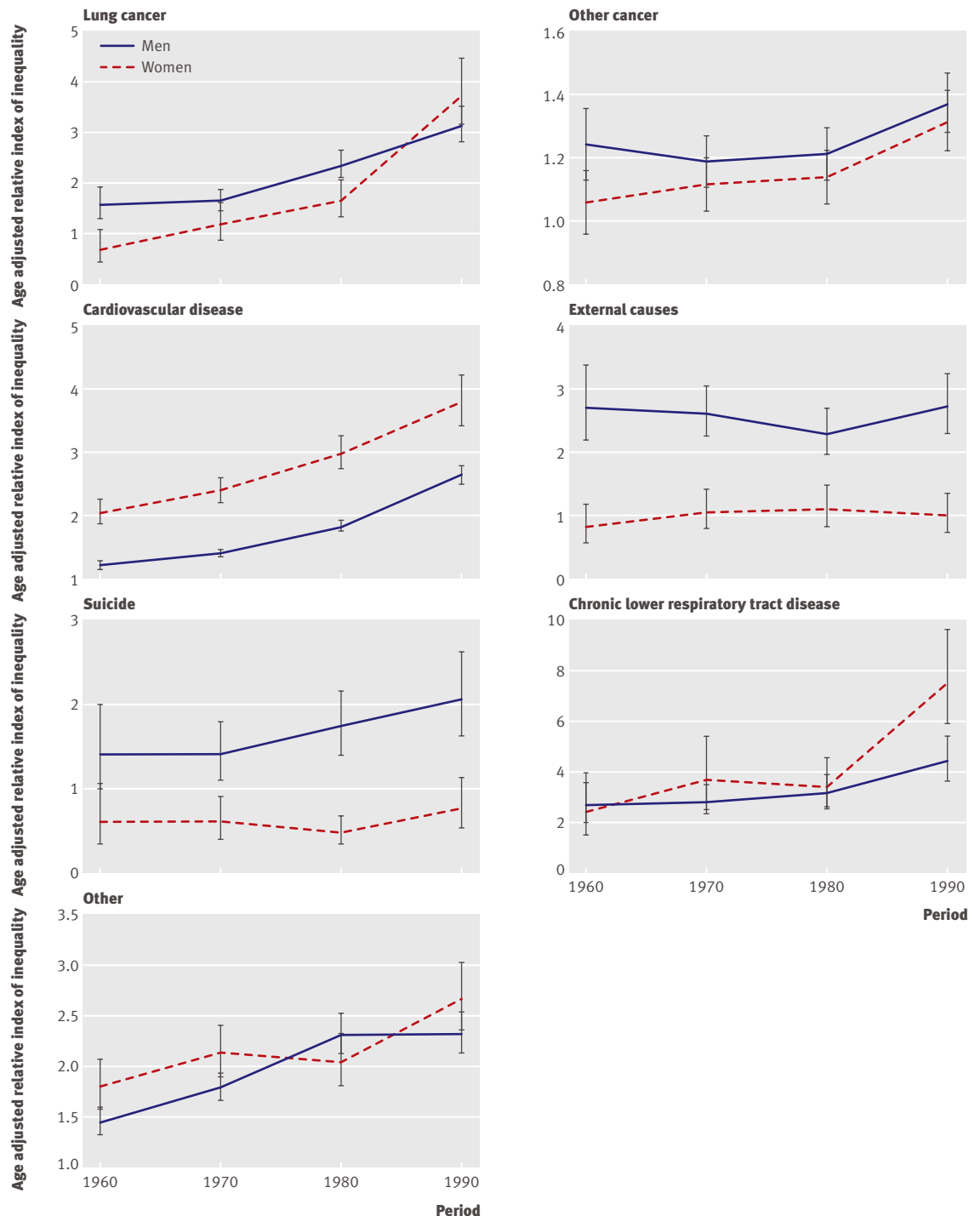
#### DISCUSSION

Mortality decreased in all educational groups in Norway over the four decades from 1960-90. In parallel, the proportion of people in the basic education group, with the highest mortality, decreased substantially. Nevertheless, taking into account this shift towards higher education, educational inequalities in mortality widened in both sexes, but especially among men. A doubling of absolute inequalities among men was mainly due to diseases related to smoking behaviour, such as cardiovascular diseases, lung cancer, and

chronic lower respiratory tract diseases. Among women, absolute inequalities increased, with lung cancer and chronic lower respiratory tract diseases being major drivers of this increase. However, large decreases in inequalities in cardiovascular disease among women meant that the widening of the total mortality inequality by a third was considerably less than the doubling among men.

**Strengths and limitations of the study**

This is one of the largest studies of its kind, is nationally representative, and has few missing observations. The originality and novel contributions of this study include covering cause specific mortality across four decades (1960-2000) of rapid expansion of a comprehensive welfare state in Norway, and the presentation of trends in both absolute and relative inequalities.



**Fig 4** | Trends in relative inequalities in education in Norwegian men and women aged 45-64 at start of follow-up in each decade during 1960-2000. Whiskers are 95% confidence intervals

Different coding practices at different time points could have biased our results. However, time related errors for deaths are not likely to be that important in our study as misclassification between broad groupings of deaths is unlikely. The coding of suicide, however, could be affected both by the social class of the decedents and by the general coding practices at that time. A new death certificate form in the 1980s and changes in the registration procedure are suggested to be partly responsible for the rise in the Norwegian suicide rates in the 1980s.<sup>16</sup>

We used a ratio index and a difference index to compensate for change in the size of groups over time. However, with only three groups, and the basic education group comprising over three quarters of the population in the 1960s, these measures may be unstable. It is possible that if our measure of education had a more even distribution across the population, that non-linear mortality gradients within the large basic education group might have been disclosed, altering the indices. However, it is unlikely that this reason alone would be sufficient to spuriously cause all of the large widening in inequalities observed.

As a simple check and sensitivity analysis against our use of the ratio and difference indices of inequality, among men in 1990 the size of basic and secondary education groups combined was similar to the size of the basic education group alone in 1960, and secondary plus tertiary education in 1960 was similar to the size of the tertiary group alone in 1990. Making such aggregations, the mortality would be 1434  $((1437 \times 17\% + 1425 \times 5\%) / 22\%)$  for the high education group in 1960, and 1256  $((1466 \times 34\% + 1100 \times 46\%) / 80\%)$  for the low education group in 1990. Thus, the difference in mortality between high and low education in 1960 was 224 (1658–1434) and in 1990 was 475 (1256–780). Consistent with the difference index analyses, a doubling of absolute inequalities was observed for men over time. Similar calculations for women showed 38% increased inequality, again similar to the difference index analyses. What is different for this alternative approach is that the crude rate differences between the high and low education groups are lower than the difference index values. This is mathematically guaranteed as the index essentially stretches out the rate difference to the 0th centile compared with 100th centile. The above aggregation approach, using 20% and 80% size groups, compares the midpoints (or the 10th centile with the 60th centile on a cumulative rank). That is half of the “distance” that the difference index covers, meaning the rate differences themselves about halve the size, but the percentage change in the rate differences over time is similar between methods. Because the inequality index method is regression based across what categories are available (three in our analyses), and allows for varying groups size over time and between comparison populations, it is preferred for main analyses. However, that it compared the 0th centile with the 100th centile (and therefore inequalities seem larger than with more basic group comparison methods) must be emphasised.

The accuracy of the education variable might have changed, as errors in measuring education may have been reduced over time, and this could be a partial reason for increasing inequalities. The accuracy probably changed most from 1970 to 1980 owing to the change from self report to collection of data directly from the schools. A quality control of the 1970 census showed under-reporting of basic level education and corresponding over-reporting of secondary and tertiary levels.<sup>13</sup> This would probably underestimate the inequalities in mortality before 1980, but it is unlikely that this would cause the large widening in inequalities observed.

The meaning of education has probably changed over time, although we compared groups that might differ not only in size but also in content. Especially for women, education reflects different aspects in 1960 compared with 1990. In the early cohorts most women had basic education and their socioeconomic status was probably more influenced by their husband's educational attainment. Analyses of inequalities in total mortality, however, showed similar results for mortality in relation to the woman's and husband's education (data not shown).

#### Comparison with previous studies

Relative educational inequalities in mortality increased for both men and women in New Zealand, Denmark, Finland, and Norway for 30–59 year olds during 1981–95.<sup>3</sup> The absolute inequalities increased among both men and women in Denmark and among women in Finland and Norway. A small increase was seen among Norwegian men. Our study found a similarly small, but statistically significant, increase in absolute inequality among men from the 1980s to the 1990s.

A study of educational inequalities in mortality across Europe during the 1990s showed that men and women aged 30–74 years with low education had higher mortality than those with higher education.<sup>11</sup> Norway was about mid-range in absolute inequalities compared with the other countries, but had larger inequalities than the other Scandinavian countries. The authors suggest that social security and universal public services, as exemplified in Scandinavia, are not sufficient for smaller inequalities in health, as educational inequalities in lifestyle related risk factors play an important opposing part.<sup>11</sup>

#### Explanation and interpretation of results

The fall in mortality across all educational groups probably reflects the transition of Norway, which implies access to better universal health care and better living conditions.<sup>6,8</sup>

Educational inequalities in mortality among middle aged people in New Zealand increased from the 1980s to 2000 although less so than in Norway, in both absolute and relative terms.<sup>17</sup> It might be expected that a sustained egalitarian policy in Norway might have prevented widening inequalities in mortality by education. The Norwegian economy has been stable since



**WHAT IS ALREADY KNOWN ON THIS TOPIC**

Inequalities in death by educational level are widening in Western populations  
 Reasons for this disparity, including why it exists in both egalitarian and non-egalitarian societies, are not well understood  
 Few studies have reported cause specific mortality over several decades

**WHAT THIS STUDY ADDS**

Cause specific mortality has fallen in all educational groups in Norway across four decades (1960-2000)  
 Inequalities in mortality by education noticeably widened, particularly for men  
 The main drivers for the widening inequalities were smoking related causes of death such as lung cancer and chronic lower respiratory tract diseases, as well as cardiovascular diseases for men

the 1970s,<sup>18</sup> and the unemployment rate has been low. Thus it is unlikely that unemployment could explain the widening inequalities in mortality seen in Norway. Another plausible explanation is the shift towards higher education during 1960-2000. Education could affect health directly or indirectly—for example, through improving health related knowledge or as an important determinant of occupation and income, favourable living conditions, and access to better health care.<sup>19,20</sup> It therefore could be argued that the importance of education is more than just a cross sectional truism at any point in time but also an increasing issue over the four decades covered in our study. Put another way, it is theoretically plausible that education has become a more important or more discriminating determinant of health over time in Norway, as the basic education group was a more marginalised group in the 1990s than in previous decades.<sup>21</sup> This is partially reflected in a study during 1991-2001, where it was reported that those with low education experienced more unemployment and that this effect became stronger in later years.<sup>22</sup>

Furthermore, if education has become a more important component over time, it is also possible that risk factors become more patterned by education. This is seen for smoking, as smokers are largely unevenly distributed across educational levels in Norway, and inequalities have widened.<sup>10</sup>

As is the situation in other Western countries, Norway has experienced a fall in cardiovascular mortality since the late 1970s.<sup>24</sup> This fall has been greater among those with tertiary education compared with people with lower education, and has been one of the main drivers of increasing educational inequalities in mortality.<sup>1</sup> This is in line with the findings in our study, at least in men. Hypothetically, if we removed educational inequalities in cardiovascular mortality, we would also remove about half of the inequalities in mortality among men and 40% among women.

It is difficult to understand why absolute inequalities in cardiovascular mortality increased among men and decreased among women. Possible explanations are, firstly, that the importance of cardiovascular risk factors could differ between the sexes and, secondly, that

the patterns for risk factors are different for men and women. Classic cardiovascular risk factors have been shown to explain 91% and 67% of the educational inequalities in mortality from ischaemic heart disease for men and women, respectively, in Norway.<sup>25</sup> We found that inequalities in cholesterol and triglyceride concentrations, systolic blood pressure, and body mass index narrowed significantly more among women than among men (see web extra table A1). This pattern could possibly explain some of the different cardiovascular mortality trends in men and women, but the results should be interpreted with caution as the time lag between risk factors and disease is likely to be complex for cardiovascular diseases.<sup>26-28</sup>

Studies in New Zealand, the United States, and the United Kingdom all point to about half of the reduction in cardiovascular mortality being due to improved treatments,<sup>29-32</sup> and a Swedish study indicated that 36% of the mortality decline until 2000 could be explained by treatments, including secondary prevention.<sup>33</sup> If access to and receipt of these treatments varies by educational level and varies in educational inequality over time, then this would also be an important explanation for the trends in Norway, although its contribution to divergent trends by sex is more difficult to envisage.

The opposite results in men and women for suicide are in line with results from a European comparative study,<sup>34</sup> but conflict with the results from a Norwegian study of young adults aged 25-35 years, with almost identical follow-up as the last period in our study.<sup>35</sup> This study reported excess suicide risk among both men and women from lower educational groups. The excess suicide, and also the excess deaths from external causes, among lower educated men observed in our study could possibly be explained by life threatening behaviours, such as alcohol or drug misuse. Also, common mental disorders are found to follow the same educational gradient and can possibly add to the explanation.<sup>36,37</sup>

**Conclusion**

Mortality rates have decreased in all educational groups, but inequalities in mortality by educational level in Norway have substantially widened in the last four decades. Smoking related causes of death such as lung cancer and chronic lower respiratory tract diseases, as well as cardiovascular diseases for men, were the main drivers. Our study adds further evidence to the contention that an egalitarian social policy is not sufficient to prevent widening educational inequalities in mortality and that presumably differential patterning of health behaviours by educational level does matter.

**Contributors:** BHS planned the study, analysed the data, discussed the results, and wrote the manuscript. E-KG and ØAS planned the study, discussed the results, and wrote the manuscript. TB discussed the results and wrote the manuscript. SG-I analysed the data, discussed the results, and wrote the manuscript. ØN planned the study, discussed the results, and wrote the manuscript. All authors saw and approved the final version. BHS, E-KG, ØAS, and ØN had full access to the individual specific mortality data used in the study, and can take responsibility for the integrity of the data and the accuracy of the data analysis. SG-I, BHS, and ØN had full access to the individual specific risk factor data used in the

additional analyses in the appendix, and can take responsibility for the integrity of the data and the accuracy of the data analysis. TB (and all authors) had access to the processed tables and figures.

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