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Changing socioeconomic inequalities in cancer incidence and mortality: Cohort study with 54 million person-years follow-up 1981–2011

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Cancer is increasingly responsible for the mortality gap between high and low socioeconomic position groups in high-income countries. This study investigates which cancers are contributing more to socioeconomic gaps in mortality and how this changes over time.

New Zealand census data from 1981, 1986, 1991, 1996, 2001 and 2006, were linked to three to five years of subsequent mortality and cancer registrations, resulting in 54 and 42 million years of follow-up cancer incidence and mortality, respectively. Age- and ethnicity-standardised cancer mortality rates and the slope index of inequality (SII) by income were calculated. The contribution of cancer to absolute inequalities (SII) in mortality increased from 16 to 27% for men and from 12 to 31% for women from 1981–84 to 2006–11, peaking in 1991–94 for men and in 1996–99 for women and then levelling off, parallel to peaks in lung cancer inequalities. Lung cancer was the largest driver of cancer inequality trends (49% of the cancer mortality gap in 1981–84 to 33% in 2006–11 for men and 32 to 33% for women) followed by colorectal cancer in men (2 to 11%) and breast cancer in women (declining from 44 to 13%). Women in the lowest income quintile experienced no decline in cancer mortality.

The contribution of cancer to income inequalities in all-cause mortality has expanded in this high-income country. Action to address socioeconomic inequalities should prioritise equitable tobacco control, obesity control and improved access to cancer screening, early diagnosis and high quality treatment for those with the lowest incomes.

Cancer mortality has been declining in high-income countries for several decades but not all groups have benefited equally. Individuals with lower socioeconomic position (SEP) experience greater cancer mortality and slower improvement in mortality rates. Absolute and relative socioeconomic inequalities in cancer mortality (particularly non-lung cancer) have increased over time in several populations[1–4] in contrast to falling mortality and inequalities from other diseases—most notably cardiovascular disease (CVD). Since the 1950s and 1960s inequalities in the US have reversed from greater cancer mortality in high-income groups to greater mortality in low-income groups.[5,6]

Trends in mortality, cancer incidence and by extension inequalities are modifiable. Cancer mortality rates have declined for populations within many countries, through changes in risk factors and improvements in detection and treatment, demonstrating the potential health gains for all groups.[7] Exploring trends for specific cancers and their inequalities can show the extent to which societal efforts to improve equity have been successful or not, and also they inform current and future policy priorities for addressing mortality and cancer incidence inequalities. For example, inequalities in the cancer burden are modifiable through the control of tobacco, alcohol, obesity and carcinogenic infections; and by survival improvements through access to screening and appropriate treatment including management of comorbidities.[8]

Several studies from the early 2000s have reported increasing relative inequalities in cancer mortality, but trends in absolute inequalities in cancer are more mixed.[6,9–11] In several European countries between the 1990s and 2000s, absolute cancer inequalities in mortality declined in men, consistent with declining lung cancer inequalities. This was less so among women for whom lung cancer mortality among the lower educated increased in many European countries.[12] Specifically, in France the cancer mortality SEP gap in women increased and the lowest educated women failed to experience the decline in cancer mortality experienced by the highest educated.[9]

The contribution of specific cancers to inequalities in mortality and incidence can vary substantially between jurisdictions and over time, highlighting the need for different policy priorities by country to tackle socioeconomic

Key words: income, disparity, lung cancer, colorectal cancer, breast cancer

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What's new?
In high-income countries, cancer is a major factor in the mortality gap between persons of low and high socioeconomic position. Few studies, however, have compared socioeconomic mortality gaps for specific cancers in the 2000s with previous decades. This analysis, using data from New Zealand, shows an increase in cancer mortality inequalities (by income) until the 1990s. Inequalities leveled off in the 2000s. Lung cancer accounted for a significant portion of the mortality gap, followed by colorectal cancer in men and breast cancer in women. Colorectal cancer mortality rates were highest in low-income groups, while breast cancer mortality declined across income groups.

inequalities. In Colombia (a middle-income country) the major contributors to socioeconomic inequalities in mortality were stomach cancer in men and cervical cancer in women, both related to carcinogenic infections.[10] In many high-income countries, smoking-related cancers, particularly lung cancer, have tended to dominate socioeconomic inequalities, but carcinogenic infections and obesity can also be important contributors. For example, in France lung, head and neck, oesophageal (men, smoking-related) and endometrial cancers (women, obesity-related) were the largest contributors to cancer inequalities[9] and in Korea it was lung (men), liver and stomach cancers (related to carcinogenic infection).[11]

Given this background, we examined cancer trends by household income from 1981–2011, and identified the specific cancers that made the largest contribution to absolute inequalities in cancer mortality and incidence, and the changes over time in their percentage contribution. Our analysis focussed on the absolute measure of inequality (SII) because it is less prone to be misleading for clinical practice and public policy,[13] and more pliable to decompose by cancer type. We used New Zealand as a case study given this country has detailed and high-quality data from three decades of census-linked national cancer records which incorporate a consistent measure of equivalised household income. Additionally, we report trends by education and neighbourhood deprivation over the same period in the Supporting Information. Our study updates previous cancer inequality studies in New Zealand that focused on cancer incidence[14] and more aggregated measures of cancer mortality.[15]

Material and Methods

Records from the New Zealand Mortality Dataset and the New Zealand Cancer Registry were probabilistically linked to records from the census, by matching on sex, date of birth, ethnicity, country of birth and geographical area, using record linkage software (QualityStage). Notification of malignant tumours to the Cancer Registry has been mandatory since 1994. Approximately 98% of links with the mortality record correctly linked to the previous census record.[16] Six cohorts were created from the usual resident population on census nights in 1981, 1986, 1991, 1996, 2001 and 2006. In the first four cohorts, three years of subsequent deaths were linked to the census records and in 2001 and 2006 five years of subsequent death records were linked. Five years of subsequent cancer incidence records were also linked to each census record for all cohorts with the exception of 2001 which had four years of cancer incidence records linked due to study timing. In the cancer incidence analysis, person-time was censored upon the occurrence of the first cancer but due to data limitations we could not censor for non-cancer mortality (other than in 2006–11) and leaving the country.

This provided 292,632 incident cancers arising from 54.0 million person-years of follow-up (1981–86 to 2006–11) and 86 268 cancer deaths from 42.0 million person-years of follow-up (1981–84 to 2006–11). The percentage of deaths linked to a census record ranged from 71% (1981 mortality linkage)[17] to 83% (2006 mortality linkage).[18] Therefore, linked census-cancer records were weighted up to be representative of all eligible cancers, using the inverse of the probability of being linked. This adjusts for underestimation of rates from the linkage, and corrects for any bias where the percentage of eligible cancer records linked varied by income. Further details are published elsewhere.[15,18–23]

Equivalised income

We converted categories of individual income collected from the census to equivalised household income using a New Zealand-specific index accounting for the number of children and adults in the household.[24] Missing individual income data on one or more adult household members generates a missing household income with the proportion excluded from the analysis ranging from 12.2% (1991 census) to 17.4% (2001 census) with no pattern of increase over time (13.5% 2006 census). The main findings by income were compared with results calculated by quintile of small area deprivation[25] and education (see Supporting Information Figures).

Selected cancers

The five most common cancer incidences in men and women from the 2006–11 and 1981–86 cohorts were selected from a wider list of 25 primary cancers coded to the International Classification of Disease (ICD 9 and 10); namely stomach (C16), colorectal (C18-20), lung (C34), melanoma (C43), breast (C50), cervical (C53), endometrial (C54), prostate (C61) and non-Hodgkin lymphoma (NHL; C82-85) cancers. Mortality was analysed for the same cancers; however, this was not possible for NHL, endometrial and cervical cancer mortalities because the numbers were small and therefore these cancers contributed to the "other cancer" mortality results.

Analysis

Direct age and ethnicity standardisation was applied using the WHO World Standard Population and the 2001 census distribution of ethnicity (Māori [Indigenous population], Pacific, Asian and European/Other). Ethnicity is a confounder of the association between income and cancer given its influence on SEP and independent association with the cancer burden. Standardised rates for 25–74 year olds were calculated for income quintiles.

The Slope Index of Inequality (SII) and Relative Index of Inequality (RII)[26] were calculated for equivalised income quintiles in each cohort using age- and ethnicity- standardised mortality rates, with quintile-cumulative rank midpoints pooled by sex. The SII estimates the difference in cancer rates between theoretical individuals with the extreme highest and lowest level of income, while taking into account the entire distribution of income and changing proportions of the population in each income group over time.[26,27] Statistical tests of increasing or decreasing linear trend over time were calculated on the log of the rates, SIIs and RIIs using these outcomes as the dependent variable and the midpoint of each cohort follow-up period as the explanatory variable in the model.

The analysis was repeated for education and small area deprivation quintiles as well as household income to explore potential reverse causation where cancer leads to lower income.

Results

Cancer mortality inequalities increased in absolute terms between 1981–84 and 2006–11, by 43% from a SII of 88 to 126 per 100,000 for men and two and a half-fold increase for women from 25 to 87 per 100,000 ($p = 0.044$). Looking more closely by time, it appeared that the maximum income gap in cancer mortality was reached in the late 1990s for women, and the gap increased for men during the 1980s followed by relatively "stable" absolute mortality inequalities since (Fig. 1). Reconceptualising the cancer contribution as a percentage of the all-cause mortality gap, this percentage increased by 12% points over time for men (from 16% in 1981–84 to its highest point at 27% in 2006–11) and by 20 percentage points for women (from 12% in 1981–84% to 31% in 1996–99 and in 2006–11; Fig. 2, Supporting Information Table S6). Relative inequalities in cancer mortality by income also increased over time and had a similar levelling off pattern in recent cohorts (Table 1). Cancer mortality rates declined in all income quintile groups except that there was virtually no reduction in cancer mortality in the lowest income women (196 to 194 per 100,000, $p = 0.784$).

The income gap in all-cause mortality in women increased initially (217 per 100,000 in 1981–84 to 281 per 100,000 in 2006–11, $p = 0.024$) but then has plateaued since 1996–99 (Fig. 2). However, for men in the last four cohorts all-cause mortality inequalities decreased faster (563 to 461 per 100,000) than cancer inequalities due to a reduction in cardiovascular mortality inequalities (Fig. 2). Cancer mortality has been falling at a slower rate than all-cause mortality in all income groups (Fig. 3).

The cancers contributing to the absolute cancer mortality gap were examined. For all the specific cancers examined in 2006–11, mortality was higher in the lowest income quintile (with the one exception of melanoma in men). The greatest contributors to the income-mortality gap in men were lung cancer (SII of 41 per 100,000, 33% of the total) and colorectal cancer (SII 14 per 100,000, 11%). In women it was lung cancer (SII 29 per 100,000, 33% of the total) and breast cancer (SII 11 per 100,000, 13%). For both men and women lung cancer made up one-third of the income inequalities in cancer mortality (SII 2006–11) and relative inequalities in lung cancer mortality rates by income were more than double (RII 2.8 in men and 2.5 in women).

In Figure 1, the net height (positive SII minus the negative portion of the SII) of the bars represents the difference in cancer mortality between the lowest and highest income individuals (SII) and specific cancer SIIs are represented by the stacked bars. Several of the specific cancer inequalities in mortality appeared to change from 1981–84 to 2006–11, however, the majority of changes were not statistically significant when we investigated a linear change across all six cohorts. The contribution of other cancer types to absolute inequalities (that are less common and are not disaggregated in this study) appeared to increase over time, particularly in men.

Lung cancer mortality rates decreased in all income quintiles for men (by 36% in low income $p = 0.002$, and 50% in high income $p = 0.029$) but increased in women (by 54% in low income $p = 0.028$, and 26% in high income $p = 0.063$; Fig. 4*a*). The income gap in lung cancer mortality for men peaked in 1991–94 followed by a decline (*e.g.*, the CI for 2006–11 did not overlap with the CIs in 1986–89 and 1991–94). For women the income-gap increased in the 1980s and 1990s and peaked in 1996–99 with an SII of 42(95%CI: 29–54) per 100,000 compared with 29 (95%CI: 21–37) per 100,000 in 2001–06 and 29 (CI 25–32) in 2006–11 (Supporting Information Table S4). Colorectal cancer mortality in women decreased for all income groups (by 32% in low income $p = 0.027$ and 46% in high income $p = 0.010$) and in men there was a similar trend in the latter four cohorts (Fig. 4*a*). There were no significant trends over time in absolute inequalities in colorectal cancer mortality and incidence for either men or women except for weak evidence ($p = 0.082$) of an increase in absolute colorectal mortality inequalities in women.

Mortality from breast cancer, prostate cancer and melanoma, was consistently greater for those with the lowest income whilst incidence was greater in those with the highest income (Fig. 4*b*). Breast, prostate cancer and melanoma mortality inequalities were similar over time. Incidence rates of breast cancer, prostate cancer and melanoma all increased. The highest income people experienced the greatest increases in cancer incidence and this widened cancer incidence inequalities.

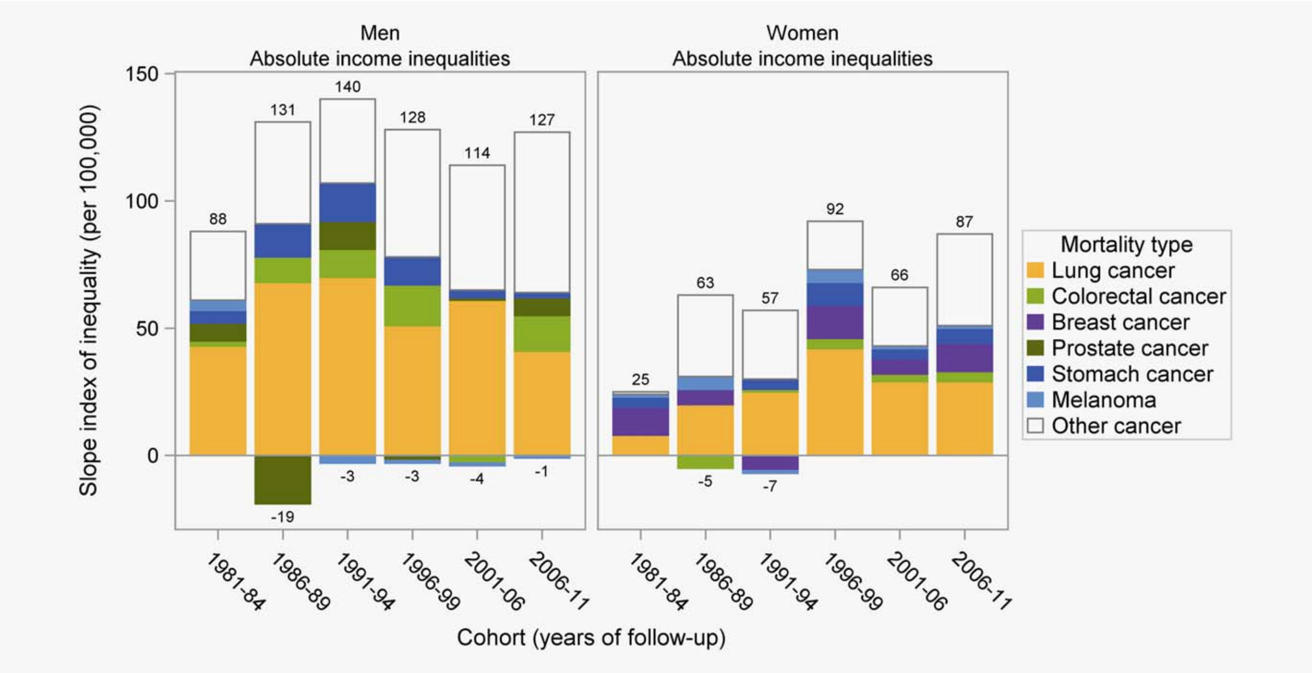

Figure 1. Decomposition of absolute income inequalities in cancer mortality by major contributing cancer types, men and women aged 25–74 years, New Zealand census-linked mortality study, adjusted for age and ethnicity. Note NHL, cervical and endometrial cancer types are not individually examined due to small numbers. The net height of the bars (positive height minus the absolute negative height) represents the overall SII for cancer mortality and specific cancer SIIs are represented in the corresponding section of the bar. Cancer mortalities above zero line are more common in low income groups and cancer mortalities below the zero line are more common in high income groups.

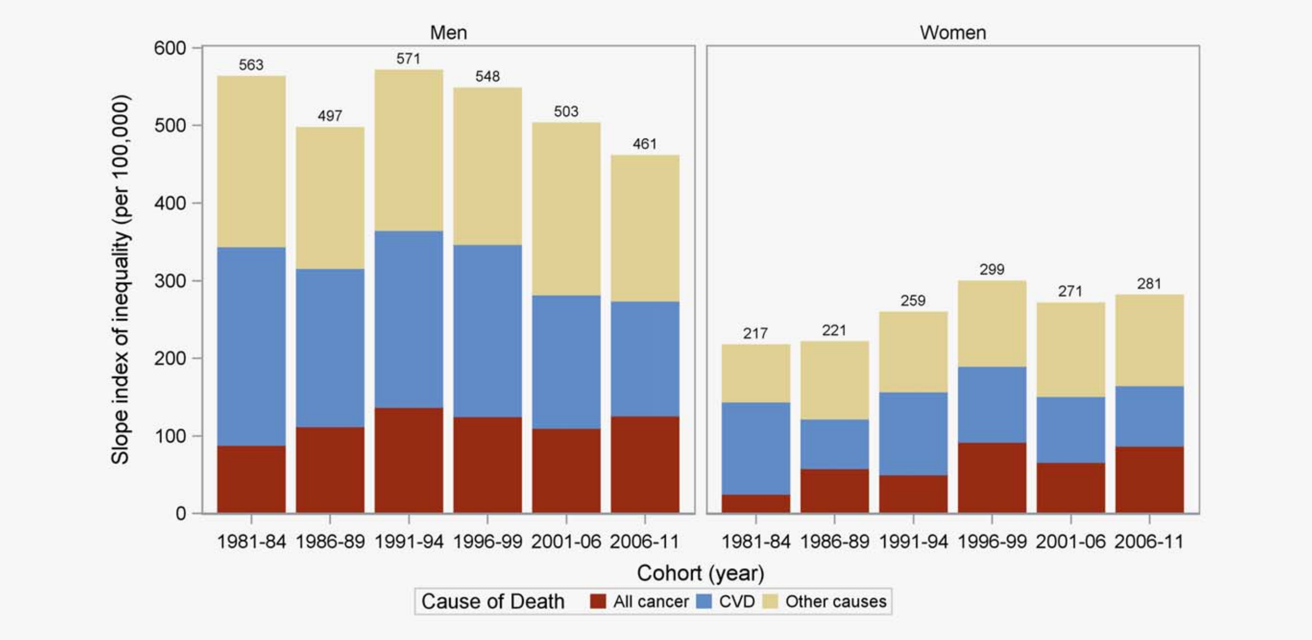

Figure 2. Contribution of cancer and cardiovascular disease (CVD) to absolute mortality inequalities by income (slope index of inequality, SII) over time in 25–74 year olds, New Zealand census-linked mortality data, adjusted for age and ethnicity. Note: The total height of the bar is the value of the SII for all-cause mortality per 100,000 person-years and the height of the cancer and CVD bars are the value of the SIIs for the corresponding causes of mortality.

In men, stomach cancer mortality and incidence rates decreased for all income groups with a similar but nonsignificant pattern apparent in women. The SII decreased for low income men from 5 to 2 per 100,000 ($p = 0.016$). The trends over time for stomach cancer incidence inequalities in women were more mixed (Table 2).

Table 1. Trends in the absolute and relative inequalities in cancer mortality (per 100,000 person-years) by income quintile using the slope index of inequality (SII) and the relative index of inequality (RII), men and women 25–74 years old, New Zealand census-linked mortality data [Color table can be viewed at wileyonlinelibrary.com]

		Highest income quintile		Lowest income quintile		Absolute and relative income inequalities in cancer mortality				
	Cohort (years)	Rate (per 100,000)	Linear trend *p* values	Rate (per 100,000)	Linear trend *p* values	Slope index of inequality (CI)	Prop. cf. all-cancer SII (%)	SII linear trend *p* values	Relative index of inequality (CI)	RII linear trend *p* values
Men										
Lung	1981–84	55.7		99.2		43 (25–61)	49		1.85 (1.28–2.67)	
	2006–11	27.9	0.029	63.5	0.002	41 (32–50)	33	0.330	2.75 (2.06–3.67)	0.377
Colorectal	1981–84	28.9		29.5		2 (−9–13)	2		1.07 (0.70–1.65)	
	2006–11	19.9	0.151	30.9	0.985	14 (10–19)	11	0.507	1.73 (1.33–2.24)	0.513
Prostate	1981–84	14.7		19.9		7 (−11–24)	8		1.65 (0.73–3.74)	
	2006–11	14.5	0.851	20.1	0.630	7 (4–10)	6	0.975	1.53 (1.05–2.21)	0.963
Stomach	1981–84	21.6		19.7		5 (−9–20)	6		1.29 (0.49–3.36)	
	2006–11	8.9	0.431	10.3	0.133	2 (−1–4)	2	0.016	1.21 (0.71–2.07)	0.298
Melanoma	1981–84	6.1		10.8		4 (0–7)	5		1.58 (0.76–3.32)	
	2006–11	9.3	0.029	8.4	0.456	−1 (−2–0)	−1	0.244	0.88 (0.60–1.30)	0.344
All-cancer mortality	*1981–84*	202.6		278.7		88 (80–97)	100		1.46 (1.20–1.79)	
	2006–11	141.6	0.059	244.6	0.081	126 (118–134)	100	0.014	1.99 (1.78–2.22)	0.095
Women										
Lung	1981–84	16.4		28.8		8 (−18–34)	32		1.33 (0.70–2.52)	
	2006–11	20.6	0.063	44.3	0.028	29 (25–32)	33	0.712	2.50 (1.87–3.35)	0.302
Colorectal	1981–84	30.7		28.2		0 (−17–16)	0		0.99 (0.69–1.43)	
	2006–11	16.7	0.010	19.1	0.027	4 (−2–10)	5	0.082	1.22 (0.93–1.59)	0.044
Breast	1981–84	33.6		41.4		11 (−4–26)	44		1.32 (0.93–1.85)	
	2006–11	26.4	0.139	36.4	0.472	11 (5–18)	13	0.619	1.43 (1.15–1.79)	0.439
Stomach	1981–84	2.3		8.7		4 (−11–19)	16		1.54 (0.46–5.09)	
	2006–11	3.1	0.661	6.4	0.950	6 (0–11)	7	0.221	3.41 (1.1–10.61)	0.139
Melanoma	1981–84	4.7		5.6		1 (−2–4)	4		1.28 (0.55–2.97)	
	2006–11	4.5	0.397	4.9	0.324	1 (−1–4)	1	0.941	1.34 (0.80–2.25)	0.956
All-cancer mortality	*1981–84*	173.2		196.1		25 (6–44)	100		1.14 (0.92–1.43)	
	2006–11	125.8	0.025	193.9	0.784	87 (75–98)	100	0.044	1.74 (1.56–1.94)	0.027

Notes: All rates are age- and ethnicity-standardised to the WHO World Standard Population. SIIs and RIIs are also adjusted for age and ethnicity. The five most common cancers were selected in men and women in 1981–84 and 2006–2011, however mortality data were not available for non-Hodgkin's lymphoma, cervical cancer and endometrial cancer due to small numbers. The *p* value is a test of linear trend over all six cohorts from 1981–84 to 2006–11.

Cervical cancer incidence among women decreased in all income groups, but there was no evidence of a change in income inequalities. Endometrial cancer increased in all groups of women particularly for the lowest income (20 to 27 per 100,000 $p = 0.059$, highest income 17 to 22 per 100,000 $p = 0.127$). There was a trend to increasing inequalities in endometrial cancer incidence on the absolute ($p = 0.200$) and relative scale ($p = 0.073$). NHL incidence increased over time in men and women, more than doubling in the highest and lowest income men, but there was no evidence of any increase in inequalities (Table 2).

The absolute inequalities in mortality (SIIs) were also analysed by level of education and neighbourhood deprivation (NZDep) (Supporting Information). A wider mortality gap (SII) was more frequently found when using the deprivation index than in the income analyses (*i.e.*, there was a wider gap using NZDep in 4 of the 6 cohorts for both men and women). For absolute inequalities in cancer incidence, the NZDep analyses resulted in a wider net SII for 2 in 6 cohorts for men and 1 in 6 for women in 2006–11 (Supporting Information Figures S2 and S3).

Discussion

Socioeconomic inequalities in cancer differ across populations and over time. This study examined cancer mortality and incidence trends over three decades in a high-income country (New Zealand), linking census and cancer mortality and

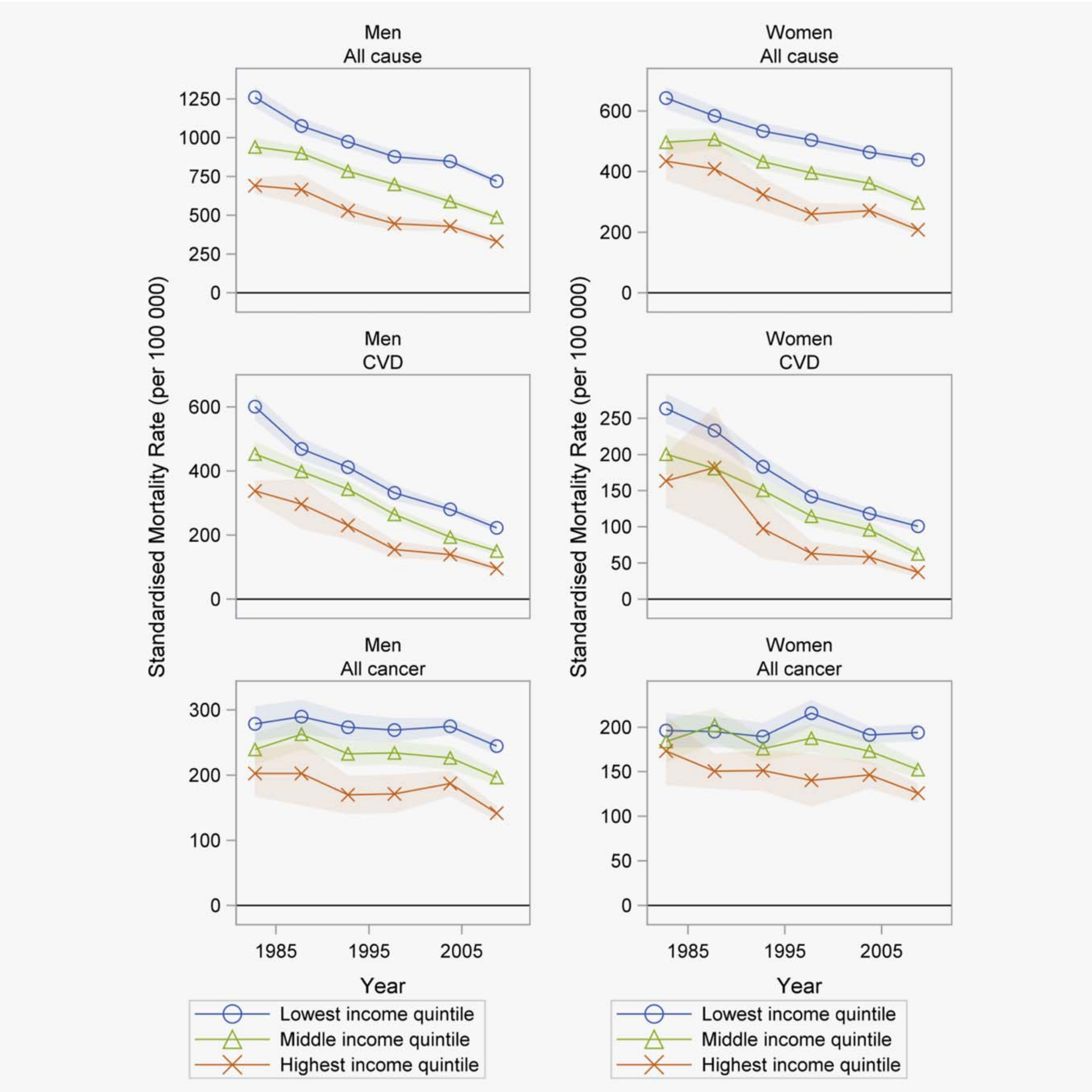

Figure 3. Age- and ethnicity-standardised mortality rates by lowest, middle and highest income quintile, New Zealand census-linked mortality data 1981–2011 for men and women 25–74 years old. [Color figure can be viewed at wileyonlinelibrary.com]

registration records for a whole population. Cancer mortality inequalities increased in absolute terms reaching a maximum income gap in cancer mortality in the late 1990s for women and early 1990s for men and then inequalities appeared to plateau (Fig. 1). The cancer contribution increased as a percentage of the male all-cause mortality gap by 12 percentage points from 1981–84 to 2006–11 and in women the percentage increased by 20 percentage points from 1981–84 to 1996–99 and stayed at this level in 2006–11.

The pattern of increasing absolute socioeconomic inequalities in cancer mortality has been found elsewhere including Norway,[1] Finland[28] and France (women only). In Norway the contribution of cancer to the education gap in mortality in men (measured by SII, as per in our study) was only 15% for men and 4% for women in the 1960s and between the 1980s and 2000s it increased in men from 17 to 25% and in women from 12 to 32%.[1] That was an increase of 8 percentage points for men and 20 percentage points for women, very similar to our findings for the same time period. More recently in France from 1990–1998 to 1999–2007 the cancer mortality gap in women (measured by standardised rate differences between highest and lowest education groups) increased by 11% (44 to

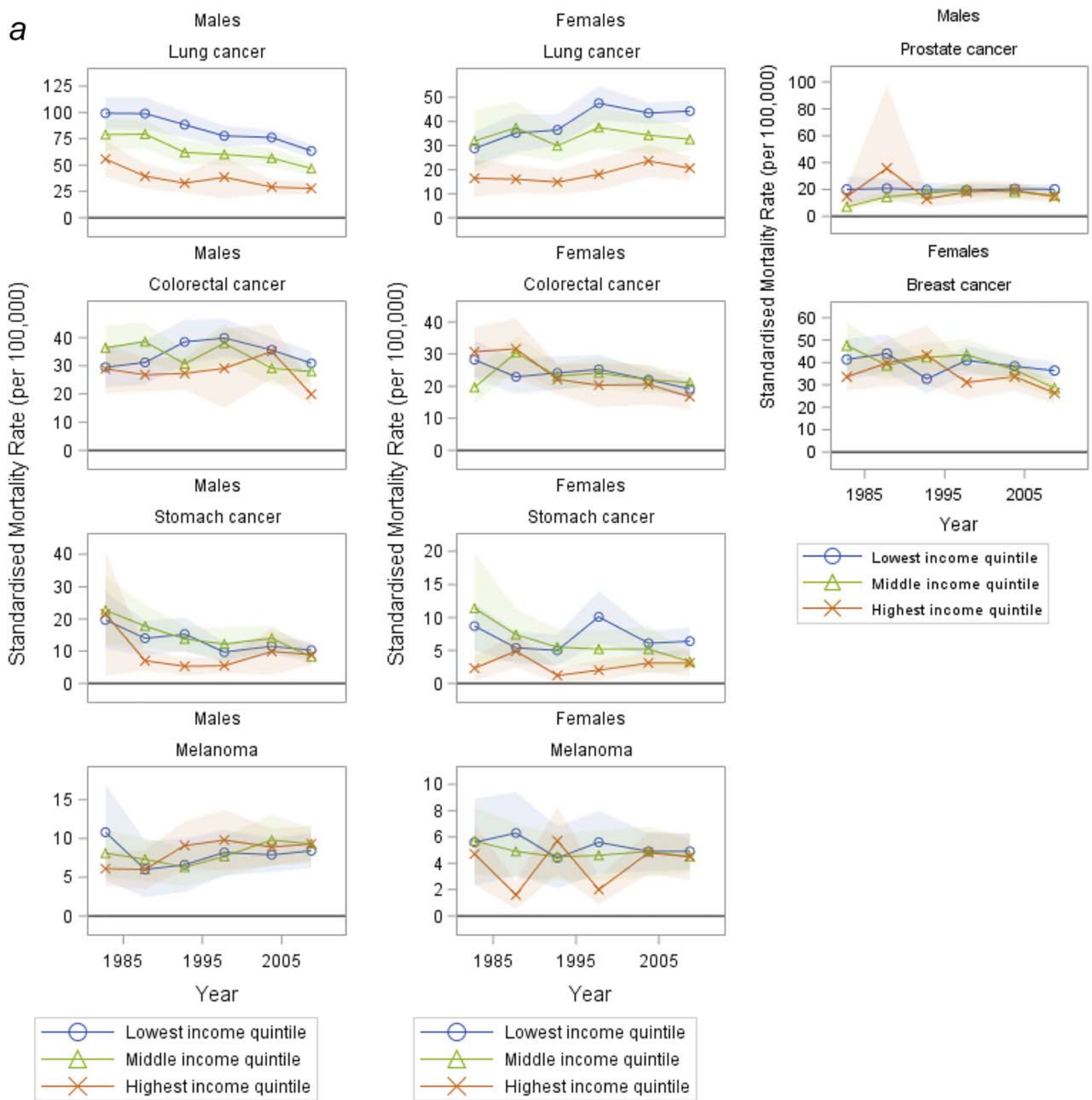

Figure 4. (*a*) Age- and ethnicity-standardised cancer mortality rates by income quintile, in men and women aged 25–74 years in New Zealand 1981–2011. (*b*) Age- and ethnicity-standardised cancer incidence rates by income quintile, men and women aged 25–74 years in New Zealand 1981–2011. Note: Non-Hodgkin's lymphoma incidence rates were lower among females and not able to be presented due to small numbers. [Color figure can be viewed at wileyonlinelibrary.com]

49 per 100,000) but in men it decreased by 9% (282 to 256 per 100,000)[9] – a similar pattern to our 1990s and 2000s findings, where inequality appeared to decrease for men.

Underlying these inequality trends were slower cancer mortality declines in the lowest income groups. For example, among women in the lowest income quintile there was no evidence of a cancer mortality decline over three decades. This was in contrast to declining cancer mortality in high-income groups and declining cardiovascular mortality in all income groups.

There was little evidence that specific cancer inequalities consistently increased or decreased over time, however the SII for stomach cancer mortality decreased in men (from 5 to 2 per 100,000, $p = 0.016$) and there was weak evidence that colorectal cancer inequalities increased in women (from 0 to 4 per 100,000, $p = 0.082$).

Lung cancer was the largest contributor to absolute inequalities in cancer mortality making up one-third of the gap in 2006–11, much lower than in Norway where the same figure was 55% of the total cancer mortality gap in the

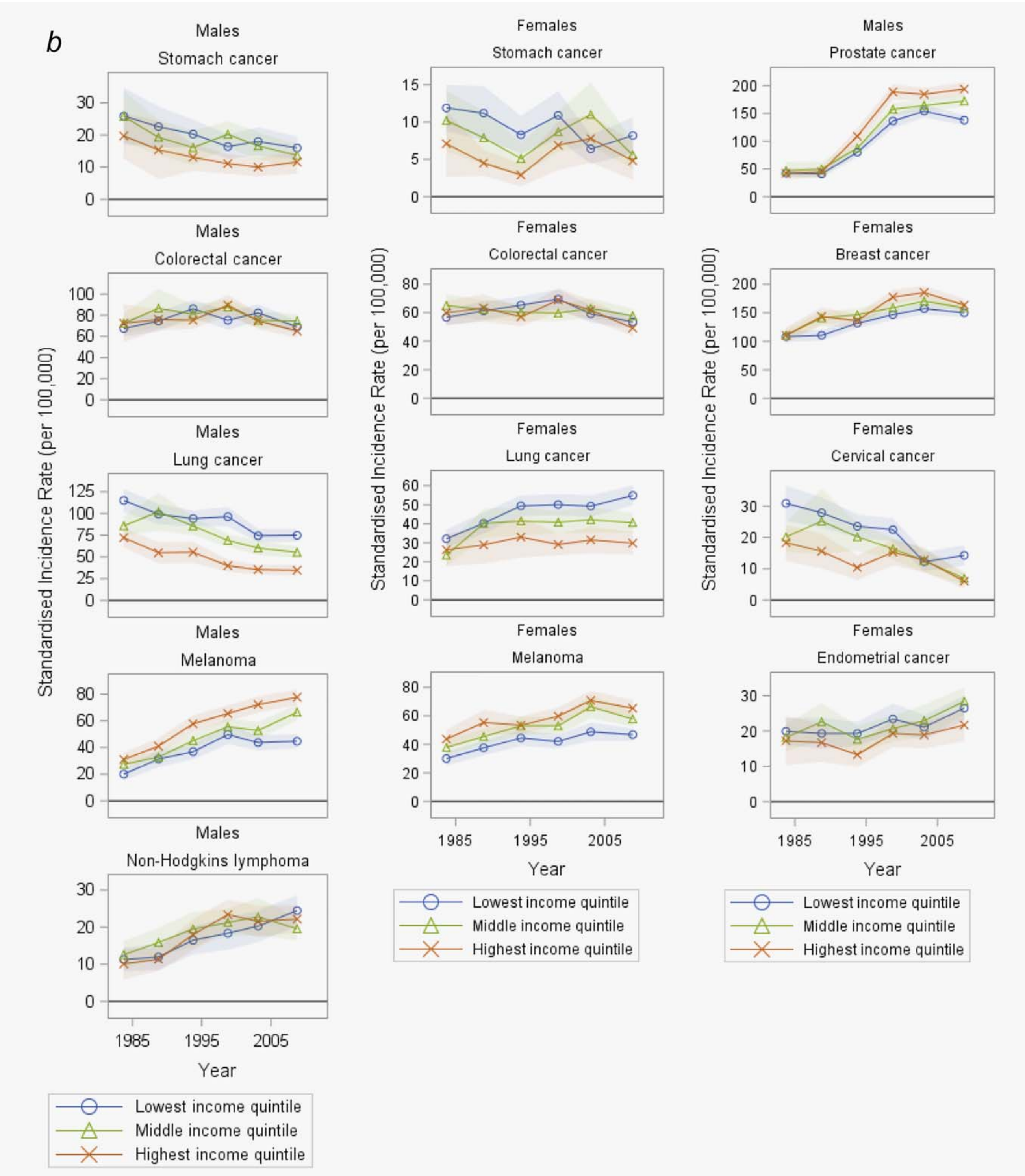

Figure 4. (continued)

2000s.[1] Lung cancer mortality increased in women in the 1980s and 1990s particularly for the lowest income, whereas it decreased for men throughout the study period in all income groups, similar to patterns elsewhere.[29] Absolute income inequalities in lung cancer appear to have peaked in New Zealand men and women. In France absolute education inequalities in lung cancer mortality declined for men from the 1990s to the 2000s but for women they increased,[9] similar to the majority of European countries.[12] Relative to European countries, our findings for women of decreasing absolute inequalities for lung cancer in the 2000s, were only replicated in England and Wales.[12] Sex-differences in the

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Table 2. Trends in the absolute and relative inequalities in cancer incidence in by income quintile using the slope index of inequality (SII) and the relative index of inequality (RII), men and women 25–74 years old, New Zealand census-linked mortality data [Color table can be viewed at wileyonlinelibrary.com]

		High income quintile		Low income quintile		Absolute and relative income inequalities in cancer incidence			
	Cohort (years)	Rate (per 100,000)	Linear trend *p* values	Rate (per 100,000)	Linear trend *p* values	Slope index of inequality (CI)	SII linear trend *p* values	Relative index of inequality (CI)	RII linear trend *p* values
Men									
Lung	1981–86	72.1		114.9		41 (11–71)		1.63 (1.30–2.04)	
	2006–11	34.6	0.007	74.9	0.007	48 (38–59)	0.651	2.72 (2.10–3.52)	0.047
Colorectal	1981–86	72.4		67.5		−7 (−15–0)		0.90 (0.70–1.16)	
	2006–11	65.2	0.305	69.0	0.958	12 (−6–29)	0.644	1.18 (1.02–1.37)	0.486
Prostate	1981–86	42.3		42.5		1 (−7–9)		1.03 (0.70–1.50)	
	2006–11	193.8	0.004	137.9	0.006	−67 (−80–54)	0.004	0.67 (0.61–0.74)	0.258
Stomach	1981–86	19.7		25.9		3 (−13–18)		1.13 (0.68–1.88)	
	2006–11	11.6	0.083	16.0	0.022	6 (3–10)	0.235	1.62 (1.03–2.56)	0.355
Melanoma	1981–86	31.1		20.1		−16 (−25–7)		0.56 (0.41–0.76)	
	2006–11	77.7	<0.001	44.7	0.015	−37 (−48–26)	0.012	0.55 (0.47–0.64)	0.229
NHL	1981–86	10.1		11.3		−2 (−10–6)		0.86 (0.50–1.48)	
	2006–11	22.2	0.015	24.5	<.001	0 (−8–8)	0.587	0.99 (0.76–1.29)	0.967
First cancer incidence	*1981–86*	397.2		446.4		36 (−22–94)		1.09 (0.99–1.20)	
	2006–11	602.9	0.016	589.5	0.029	−1 (−47–44)	0.181	1.00 (0.95–1.05)	0.118
Women									
Lung	1981–86	26.3		32.1		5 (−7–18)		1.23 (0.83–1.80)	
	2006–11	29.8	0.289	54.9	0.008	30 (25–35)	0.015	2.11 (1.66–2.67)	0.031
Colorectal	1981–86	59.9		56.7		−5 (−18–7)		0.91 (0.75–1.12)	
	2006–11	49.2	0.295	53.6	0.602	7 (−4–17)	0.477	1.14 (0.97–1.33)	0.432
Breast	1981–86	110.6		108.3		−3 (−5–1)		0.97 (0.83–1.14)	
	2006–11	163.4	0.062	149.8	0.009	−22 (−36–9)	0.024	0.87 (0.79–0.95)	0.828
Stomach	1981–86	7.1		11.9		6 (2–9)		1.75 (0.91–3.37)	
	2006–11	4.8	0.618	8.2	0.113	4 (1–6)	0.137	1.81 (1.00–3.29)	0.473
Melanoma	1981–86	43.7		30.0		−17 (−21–13)		0.64 (0.49–0.83)	
	2006–11	65.3	0.014	46.8	0.015	−19 (−32–6)	0.539	0.72 (0.62–0.83)	0.841
Cervical	1981–86	18.3		30.9		11 (−2–25)		1.60 (1.08–2.38)	
	2006–11	6.0	0.040	14.3	0.012	9 (3–15)	0.332	2.77 (1.57–4.89)	0.934
Endometrial	1981–86	17.2		19.9		−2 (−15–12)		0.93 (0.61–1.40)	
	2006–11	21.7	0.127	26.5	0.059	6 (−1–12)	0.200	1.25 (0.98–1.60)	0.073
First cancer incidence	*1981–86*	389.8		403.0		2 (−44–49)		1.01 (0.92–1.10)	
	2006–11	514.5	0.058	530.5	0.013	22 (7–37)	0.510	1.04 (0.99–1.10)	0.936

Notes: NHL incidence was not available for women due to small numbers.
All rates are age- and ethnicity-standardised to the WHO World Standard Population. SIIs and RIIs are also adjusted for age and ethnicity. The five most common cancers were selected in men and women in 1981–84 and 2006–2011. The *p* values are a test of linear trend over all six cohorts from 1981–84 to 2006–11.

lung cancer burden reflect the later peak in smoking prevalence in women and a higher peak in the lowest income. In New Zealand the steepest declines in smoking rates began in the 1980s. New Zealand made several progressive moves to address the tobacco epidemic in the 1980s including tobacco tax increases, mass media campaigns and legislation in 1990 to ban smoking in many workplaces. The steepest declines in smoking prevalence have been in the highest income group; substantially increasing the income disparities in tobacco exposure between 1981 and 2006 (see Supporting Information Table S5). Tobacco control to address smoking rates in the lowest income group remains a pressing priority and may require more targeted mass media campaigns and use of higher tobacco taxes[30] (given the likely higher price sensitivity of low-income smokers).

After lung cancer, the next largest contributors to absolute mortality inequalities in 2006–11 were colorectal cancer in men (11%) and breast cancer in women (13%).

Colorectal cancer mortality rates were highest in the lowest income group (a significant difference in men but not women). In women there was weak evidence for a trend of increasing absolute inequalities over time. Our results are consistent with the crossover of colorectal cancer rates in the US from being highest in high socioeconomic groups to highest in low socioeconomic groups[29,31] and in France (albeit borderline significance).[9] Trends in colorectal cancer mortality inequalities elsewhere have been linked to changing social distributions of obesity, and access to effective cancer screening and quality treatment.[9,31] Differential survival related to comorbidities and healthcare access[32] was considered the most likely explanation for the emerging socioeconomic gradient in colorectal cancer mortality in a previous New Zealand study.[33] However, there was no national colorectal cancer screening programme in New Zealand during the study period and differential survival cannot be the full picture because income inequalities in colorectal cancer incidence appear to be emerging. Obesity, physical activity and nutritional factors may therefore be important: obesity rates have increased in New Zealand since the 1990s and remain high and strongly socially patterned.[34] Addressing this would likely require action to address the obesogenic environment, with a focus on interventions that maximise health equity.

Breast cancer mortality in our study declined roughly in parallel for all income groups, with similar albeit unstable income mortality gaps over time. Trends in breast cancer mortality inequalities have been linked to: changes in reproductive patterns, obesity and physical inactivity reflecting changes in diet and lifestyle, alcohol consumption and the introduction of population-based screening and systemic use of adjuvant therapies.[7,35] Our finding of higher breast cancer mortality in lower income women in 2006–11 (and across the majority of cohorts), is consistent with deprivation inequalities (Supporting Information) but is in contrast to our findings for education inequalities (which were not significant) and inequalities in other countries. Higher educated women in many countries have the highest mortality, although in France and Finland in the 1990s the educational differences in breast cancer mortality disappeared.[9] Almost all income groups have benefited from decreased breast cancer mortality, likely through improved treatments.[36] In New Zealand, higher rates of breast cancer mortality in the lowest income groups is likely to be influenced by disparity in the rates of obesity,[37] a possible shift to an older age at first birth in low-income groups,[36] and inequity in access to improved treatments.

Excess mortality from "other cancers" (not studied here) appeared to increase over time and this may also relate to some of the risk factors discussed here. For example endometrial cancers in women are likely contributors to the excess mortality, given the greater incidence of this cancer in the lowest income quintile (Table 2, Supporting Information Table S3). Trends in endometrial cancer inequalities have been strongly linked to obesity, physical in activity and nutritional factors.[38]

Study strengths and limitations

This study benefited from a large number of person-years follow-up over three decades. Nevertheless, the statistical precision was often limited when studying trends by time-period, and we did not have data for cervical, endometrial and NHL mortalities. We also cannot rule out some influence of reverse causality on mortality results, where a cancer diagnosis leads to reductions in an individual's associated household income. This may overestimate mortality in the low-income group and the magnitude of inequalities demonstrated. However, it is not likely to be a substantial issue given the even greater inequalities demonstrated in the deprivation analysis, a more comprehensive measure of relative wealth and living standard (Supporting Information). Moreover, to bias trends by time the reverse causation would have to change over time. Reverse causality may have changed to a small degree over time if there was earlier diagnosis or greater use of treatments that disrupt working in the formal economy, but it seems unlikely to be that important. Inability to censor for non-cancer mortality is a limitation that may make our incidence measures of inequality marginally more conservative in the first five cohorts, but does not impact on mortality measures of inequality.

Selection bias is only possible if the true SIIs and RIIs comparing low and high income among the total population (with everyone's income recorded) were different from those in the 80% plus of the cohorts with complete data. This is unlikely. First, it would take quite markedly different income-mortality/cancer associations among the 12–17% census-respondents missing income to cause substantial selection bias. Second, our primary interest is in trends over time; thus there would have to be changing selection bias over time which seems unlikely. Third, we ascertained the deprivation-cancer gradients among those with complete income and they were not substantially different from the deprivation-cancer gradients among the total study population, suggesting selection bias is unlikely (Supporting Information Table S7).

Conclusions

Cancer is making an increasing contribution to the absolute inequalities in mortality both in New Zealand and elsewhere. There has been poor overall progress in addressing cancer inequalities, particularly for women. Lung cancer makes by far the largest contribution to the cancer mortality gap, underlining the importance of equitable tobacco control to reduce inequalities in smoking prevalence. Gaps in colorectal and breast cancer mortality may best be addressed by targeting the obesogenic environment and improving access to screening, early diagnosis and high quality treatment for low-income groups. The cancer burden should increasingly be a focus of efforts to reduce socioeconomic inequalities in mortality.

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