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Trends in mortality inequalities among the adult household population

by Emma Marshall-Catlin, Tracey Bushnik and Michael Tjepkema

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Trends in mortality inequalities among the adult household population

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Abstract

Background: The routine measurement of population health status indicators like mortality is important to assess progress in the reduction of inequalities. Previous studies of mortality inequalities have relied on area-based measures of socioeconomic indicators. A new series of census-mortality linked datasets has been created in Canada to quantify mortality inequalities based on individual-level data and examine whether these inequalities have changed over time.

Methods: This study used the 1991, 1996, 2001, 2006, and 2011 Canadian Census Health and Environment Cohorts (CanCHECs) with five years of mortality follow-up. It estimated age-standardized mortality rates by sex according to income quintile and highest level of educational attainment categories for the household population aged 25 or older. Absolute and relative measures of mortality inequality were also estimated.

Results: Men had a greater reduction in mortality rates over time compared with women, regardless of income or education level. Absolute income-related mortality inequality decreased for men but increased for women over time, while relative income-related inequality increased for both sexes. Education-related mortality inequality for women followed the same pattern as income, though the absolute mortality difference for men remained roughly unchanged over the period.

Interpretation: Mortality inequalities by income and education persist in Canada, and have increased for women. Further research to determine the mechanisms underlying these trends could help address the complex challenge of reducing health inequalities in Canada.

Keywords: socioeconomic factors, mortality, health equity, population health, census

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Health inequalities can be defined as avoidable differences in health status between population groups.¹ These differences have been attributed to personal, social, economic and environmental factors. For example, income has been tied to health outcomes in that people with low income may have less access to health services and higher-quality material resources (such as shelter and food), and the knowledge and skills obtained through formal education can influence the understanding of health messaging and the ability to effectively access health services.² The routine measurement of population health status indicators like mortality is important to assess progress in the reduction of inequalities and is a priority in Canada.³ Though mortality rates overall have been decreasing over time,⁴ inequalities remain. In the past, people in higher socioeconomic groups have experienced lower mortality rates than those with less income or lower educational attainment.⁵ Despite increasing attention and actions taken,³ regional studies suggest that mortality inequalities across socioeconomic groups may be increasing in Canada, especially for women.⁶⁻⁸

Many previous estimates of health inequalities have used area-based measures of socioeconomic indicators.^{9,10} However, area-based measures detect only a portion of social inequalities in health, and individual-level data are necessary to measure the association more precisely.¹¹ The Canadian Census Health Environment Cohorts (CanCHECs) now make this possible. The CanCHECs combine mortality data with sociodemographic information at an individual level for millions of records for each cohort year available (1991 to 2011), allowing for a robust

analysis of the relationship between socioeconomic status and mortality over time.

This study estimates mortality rates in 1991, 1996, 2001, 2006 and 2011 according to individual-level measures of income and education. The main objectives of the study are to quantify mortality inequalities across these measures among the adult household population in Canada, and to examine whether these inequalities have changed over time.

Data and methods

The CanCHECs are population-based linked datasets that follow the non-institutional (household) population at the time of the census for different health outcomes such as mortality, cancer and hospitalizations. The 2006 and 2011 CanCHECs were constructed using Statistics Canada's Social Data Linkage Environment (SDLE).¹² The SDLE helps create linked population data files for social analysis through linkage to the Derived Record Depository (DRD), a dynamic relational database containing only basic personal identifiers. Survey and administrative data are linked to the DRD using generalized record linkage software that supports deterministic and probabilistic linkage. The 1991, 1996 and 2001 CanCHECs were constructed before the creation of the DRD using the same standard generalized record linkage software.¹³⁻¹⁵ In recent months, the 1991, 1996 and 2001 CanCHECs were deterministically linked to the DRD using social insurance numbers in order to update and attach different health outcomes (mortality, cancer and hospitalizations)

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What is already known on this subject?

- Mortality rates have been decreasing over time in Canada, but mortality inequalities may be increasing.
- Mortality inequality research primarily uses area-based measures, which can introduce misclassification.

What does this study add?

- Large, nationally representative, census cohorts with individual-level income and education linked to administratively collected mortality data were used to examine mortality inequalities over a 20-year period.
- Although all-cause age-standardized mortality rates (ASMRs) for both sexes fell in absolute terms between 1991 and 2011 regardless of income or education, men had a greater reduction compared with women.
- Absolute income-related mortality inequality decreased for men but increased for women over time, while relative income-related inequality increased for both sexes.
- Education-related mortality inequality for women followed the same pattern as income, though the absolute mortality difference for men remained relatively unchanged over the period.

in a manner consistent with the 2006 and 2011 CanCHECs.

For the 1991, 1996, 2001 and 2006 censuses, a mandatory long-form census questionnaire was administered to the non-institutional population (about one in five households) including those in collectives (such as rooming houses and hotels) who usually live in Canada on Census Day. In 2011, the long-form census was replaced with the voluntary 2011 National Household Survey, which was administered to the non-institutional population living in private dwellings (about one in three households, excluding non-private dwellings such as rooming houses and hotels).

A cohort weight that adjusts for the census sampling design and non-linkage and bootstrap weights that allow for appropriate variance estimation were created for each CanCHEC. Applying the weights helps ensure that estimates are representative of the household population for the corresponding census year.

This study includes CanCHEC members who were aged 25 or older on Census Day and who did not live in a collective dwelling at the time of the census.

Mortality

Mortality data were based on the Canadian Vital Statistics Death Database, which was linked to the DRD. The linkage rate of deaths to the DRD exceeded 99% between 1991 and 2016.

Definitions

Income quintiles were derived by summing total pre-tax income from all sources for all economic family members or unattached individuals for the year prior to the census, and then calculating the ratio of this total income to the Statistics Canada low income cut-off for the applicable family size, community size group and year.¹⁶ Weighted quintiles were derived based on this ratio for each census metropolitan area, census agglomeration or provincial residual for each cohort.

Educational attainment was the highest level of education completed as of Census Day and was grouped into four different categories: less than secondary graduation, secondary graduation (or trades certificate), postsecondary certificate or diploma (excluding university degree), and university degree or equivalent.

Statistical analysis

The mortality follow-up period for each CanCHEC was restricted to five years after Census Day. A five-year follow-up period was chosen to ensure enough deaths to provide robust estimates of mortality and to minimize mortality overlap in follow-up periods across the different CanCHECs.

The number of deaths by sex, age group and population group during the

five-year follow-up period was calculated for each CanCHEC. In addition to the number of deaths, the number of people living during the follow-up periods (i.e., the at-risk population) by sex, age and population group was also calculated. Person-years at risk were calculated based on the date of the census and the date of death or the end of the follow-up period, as applicable, and then assigned to the appropriate age group. For example, since most individuals did not remain the same age for an entire follow-up year, someone who turned 65 exactly halfway through would contribute 0.5 person-years at risk to the 60-to-64 age group and 0.5 person-years at risk to the 65-to-69 age group for that year of follow-up.

Sex-specific all-cause age-standardized mortality rates (ASMRs) per 100,000 person-years at risk were calculated for each education and income category. The ASMRs were age standardized based on the 2011 Canadian standard population¹⁷ in five-year age groups. The age groups started at age 25 and ended at 85 or older, for a total of 13 age groups. The ASMR calculation was based on the number of deaths and person-years at risk in each age group. Trends over time in ASMRs were analyzed by calculating the average percentage change (APC) over the five time points.

Absolute rate differences (RDs) and relative rate ratios (RRs) comparing the lowest (first income quintile; less than secondary graduation) with the highest (fifth income quintile; university degree or equivalent) were calculated based on the ASMRs, with confidence limits computed using the ASMR standard errors.

All mortality estimates were weighted using the cohort weight and calculated using PROC RATIO in SUDAAN in SAS Enterprise Guide 5.1. Standard errors were estimated using the 500 bootstrap weights provided with each CanCHEC. APC over time was estimated using Joinpoint version 4.6.0.0. An APC was calculated for each income and education category by fitting a linear regression model assuming a constant rate of change in the logarithm of the weighted age-standardized rates from

Table 1
Percentage distribution across income quintiles and educational attainment categories, household population aged 25 or older, Canada, 1991 to 2011

	1991	1996	2001	2006	2011
Men					
	number				
Sample size	1,290,500	1,548,400	1,544,600	1,904,900	2,176,400
	weighted %				
Income quintile					
Q1 (lowest quintile)	16.9	17.6	17.0	17.7	18.0
Q2	19.9	19.5	19.5	19.5	19.4
Q3	20.7	20.5	20.6	20.5	20.4
Q4	21.2	21.0	21.2	21.0	20.9
Q5 (highest quintile)	21.3	21.4	21.6	21.4	21.3
Educational attainment					
Less than secondary graduation	35.7	32.1	28.7	19.9	17.1
Secondary graduation or trades certificate	37.2	36.6	36.9	37.9	38.1
Postsecondary diploma but not a university degree	12.1	14.8	15.8	21.0	21.5
University degree or equivalent	14.9	16.5	18.6	21.3	23.3
Women					
	number				
Sample size	1,312,300	1,655,300	1,648,500	2,046,400	2,349,900
	weighted %				
Income quintile					
Q1 (lowest quintile)	22.9	22.3	22.8	22.1	21.8
Q2	20.1	20.5	20.5	20.5	20.5
Q3	19.4	19.6	19.4	19.6	19.6
Q4	18.8	19.0	18.9	19.1	19.2
Q5 (highest quintile)	18.8	18.7	18.5	18.7	18.8
Educational attainment					
Less than secondary graduation	38.1	33.5	29.5	20.4	17.1
Secondary graduation or trades certificate	34.0	32.9	32.5	33.3	32.0
Postsecondary diploma but not a university degree	17.0	20.2	21.6	26.1	27.2
University degree or equivalent	10.9	13.4	16.4	20.1	23.7

Note: Sample sizes rounded to the nearest 100.

Source: Canadian Census Health and Environment Cohort, 1991 to 2011, Statistics Canada.

one cohort year to the next. The models incorporated the appropriate standard errors, the tests of significance used a Monte Carlo permutation method, and the estimated slope from each model was then transformed back to represent an APC.

Results

Table 1 presents the distribution of the cohort population of men and women according to income quintile and educational attainment. The proportion of the adult household population that did not graduate from secondary school decreased for both men and women between 1991 and 2011. The weighted proportion of women over the age of 25 with a university degree increased from 11% in 1991 to 24% in 2011. For men, it increased from 15% to 23%.

Mortality inequality by income quintile

ASMRs were highest among those in the lowest income quintile, for both men and women, across all time points (Table 2). Mortality rates decreased significantly for men in all income quintiles between 1991 and 2011 (the average change from one cohort year to the next ranged from -1.9 for Q1 to -2.7 for Q5, $p < 0.05$), and for women in all income quintiles except the lowest quintile (the average change ranged from -1.1 for Q2 to -2.0 for Q5, $p < 0.05$) (Figure 1). A gradient in the average percentage decrease over time was observed, with a larger average decline in ASMRs for men and women in the higher income quintiles compared with those in the lower income quintiles.

The difference in ASMRs in absolute terms between the highest and lowest income quintiles decreased significantly

over time for men, from a rate difference (RD) of 827 deaths (95% confidence interval [CI] 719; 935) per 100,000 person-years at risk in 1991 to an RD of 672 deaths (95% CI 637; 707) in 2011 (Table 3). For women, the trend was less clear given the wide confidence intervals around the estimate for 1991, though the results suggest an increase in absolute terms between 1996 and 2011. For both women and men, the difference in mortality rates in relative terms increased significantly between 1991 and 2011 (from a rate ratio [RR] of 1.4; 95% CI 1.3, 1.5 to an RR of 1.7; 95% CI 1.6, 1.7 for women, and from an RR of 1.7; 95% CI 1.6, 1.8 to an RR of 1.9; 95% CI 1.9, 2.0 for men) (Table 3).

Mortality inequality by educational attainment category

Women and men who had not graduated from secondary school had the highest ASMRs compared with those with higher educational attainment, and this difference persisted over time (Table 2). ASMRs for men at all education levels decreased over time (the average change between each time point ranged from -1.5 for no HS [less than secondary] to -2.4 for university, $p < 0.05$), whereas only women with a postsecondary diploma or higher had a statistically significant average decrease in their ASMRs between 1991 and 2011 (Figure 2).

The absolute difference in ASMRs between those who had not graduated from secondary school and those with a university degree or equivalent increased over time for women, from an RD of 261 deaths (95% CI 133; 389) per 100,000 person-years at risk in 1991 to an RD of 379 deaths (95% CI 354; 404) in 2011 (Table 3). For men, there was little change over time in absolute terms, but there was a significant increase in the relative difference, from an RR of 1.5 (95% CI 1.3; 1.7) in 1991 to an RR of 1.9 (95% CI 1.8; 1.9) in 2011. Women also saw an increase in their RR over time from 1.4 (95% CI 1.2; 1.7) to 1.8 (95% CI 1.7; 1.9).

Table 2

All-cause age-standardized mortality rates, by sex, income quintile and educational attainment categories, household population aged 25 or older, Canada, 1991 to 2011

	1991		1996		2001		2006		2011	
	ASMR	SE	ASMR	SE	ASMR	SE	ASMR	SE	ASMR	SE
Men										
Income quintile										
Q1 (lowest quintile)	2,030	30.9	1,874	16.7	1,682	13.8	1,526	10.6	1,397	15.0
Q2	1,615	31.5	1,501	10.6	1,330	10.7	1,203	7.7	1,089	10.1
Q3	1,463	42.9	1,348	13.3	1,172	11.6	1,055	8.8	938	10.0
Q4	1,345	53.1	1,254	15.2	1,062	11.2	943	8.6	826	9.8
Q5 (highest quintile)	1,203	45.7	1,089	15.0	955	12.1	807	9.0	725	10.0
Educational attainment										
Less than secondary graduation	1,707	20.8	1,603	8.4	1,454	8.8	1,372	8.0	1,289	12.4
Secondary graduation or trades certificate	1,434	33.9	1,354	11.4	1,199	10.5	1,133	6.6	1,037	8.6
Postsecondary diploma but not a university degree	1,246	80.1	1,164	20.1	1,023	19.2	963	10.1	855	10.1
University degree or equivalent	1,155	62.8	969	16.5	876	11.9	754	9.1	685	9.7
Women										
Income quintile										
Q1 (lowest quintile)	1,024	15.1	952	7.5	918	7.3	922	5.7	854	8.3
Q2	845	21.8	798	7.7	757	6.4	736	5.6	665	7.1
Q3	816	30.0	767	9.3	709	8.1	665	6.3	621	7.4
Q4	774	35.0	756	10.8	678	9.6	641	7.3	571	8.1
Q5 (highest quintile)	739	36.1	704	10.9	627	8.8	574	7.5	515	8.3
Educational attainment										
Less than secondary graduation	926	13.2	883	5.2	870	5.6	889	5.6	838	8.7
Secondary graduation or trades certificate	790	22.7	762	7.6	700	5.9	720	4.6	672	6.1
Postsecondary diploma but not a university degree	695	31.1	665	10.4	612	9.8	603	6.0	550	6.9
University degree or equivalent	665	64.0	587	16.4	559	12.9	532	8.7	459	9.1

ASMR = age-standardized mortality rate per 100,000 person-years

SE = standard error

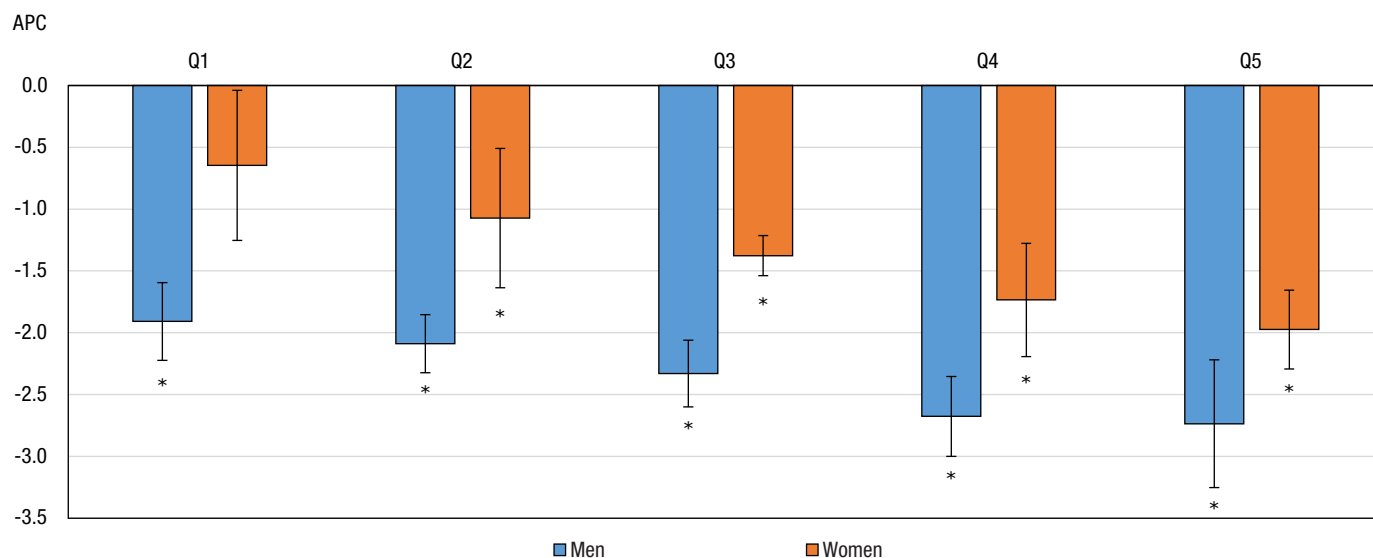
Source: Canadian Census Health and Environment Cohort, 1991 to 2011, Statistics Canada.

Discussion

Mortality rates have, in general, fallen over time in Canada.⁴ However, in the present study, this decline has not been shared equally across all income and education levels, nor have the changes over time been the same for men and women. Although all-cause age-standardized mortality rates (ASMRs) for both sexes fell in absolute terms between 1991 and 2011 regardless of income or education, men had a greater reduction compared with women. Regarding income-related mortality inequality, in absolute terms the difference in ASMRs for men in the lowest versus the highest income quintile decreased significantly between 1991 and 2011, while it increased for women from 1996 to 2011. In relative terms, the ratio of the ASMR in the lowest versus the highest income quintile increased for both sexes over time. Mortality inequality according to education category for women followed the same pattern as income, though the absolute rate difference between men with less than secondary graduation versus men with a university degree remained relatively unchanged over the period.

Figure 1

Average percentage change (APC) in all-cause age-standardized mortality rates by sex and income quintile, household population aged 25 or older, Canada, 1991 to 2011



* average percentage change significantly different from zero ($p < 0.05$)

Notes: error bars indicate 95% confidence interval; Q1 = first (lowest) income quintile; Q2 = second income quintile; Q3 = third income quintile; Q4 = fourth income quintile; Q5 = fifth (highest) income quintile.

Source: Canadian Census Health and Environment Cohort, 1991 to 2011, Statistics Canada.

Table 3
All-cause age-standardized rate differences and rate ratios, by sex, income quintile and educational attainment categories, household population aged 25 or older, Canada, 1991 to 2011

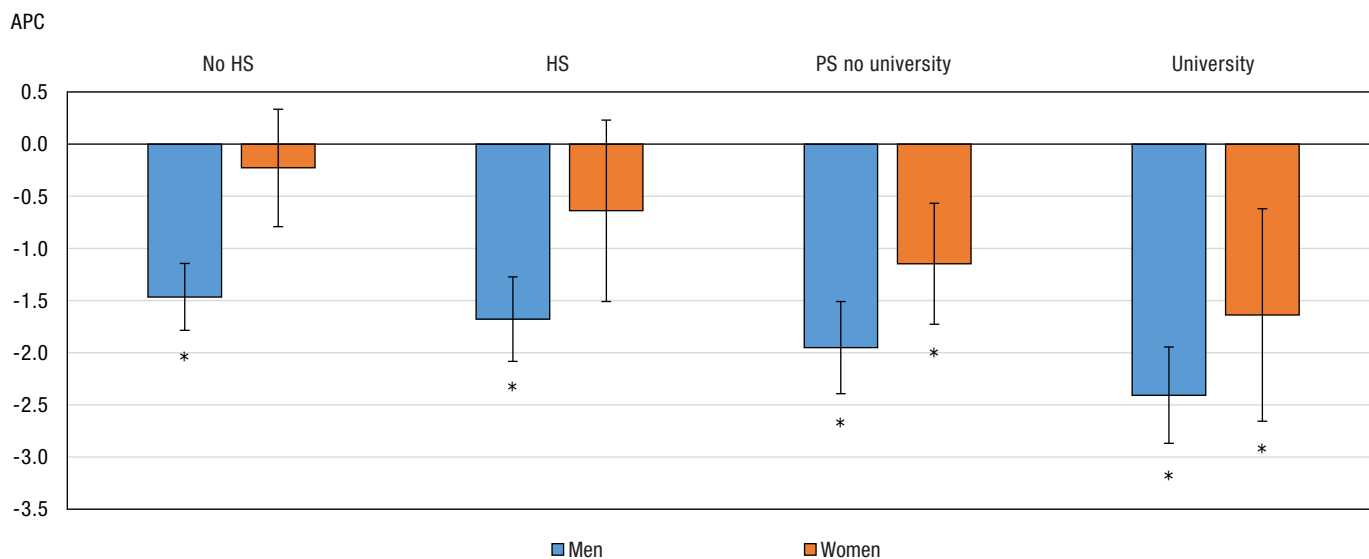
	1991			1996			2001			2006			2011		
	95% CI			95% CI			95% CI			95% CI			95% CI		
	RD/RR	from	to	RD/RR	from	to	RD/RR	from	to	RD/RR	from	to	RD/RR	from	to
Men															
Income quintile															
Rate difference (Q1 versus Q5)	827	719	935	785	741	829	727	691	763	719	692	746	672	637	707
Rate ratio (Q1 versus Q5)	1.7	1.6	1.8	1.7	1.7	1.8	1.8	1.7	1.8	1.9	1.8	1.9	1.9	1.9	2.0
Educational attainment															
Rate difference (less than secondary versus university)	552	422	682	634	598	670	578	549	607	618	595	642	604	573	635
Rate ratio (less than secondary versus university)	1.5	1.3	1.6	1.7	1.6	1.7	1.7	1.6	1.7	1.8	1.8	1.9	1.9	1.8	1.9
Women															
Income quintile															
Rate difference (Q1 versus Q5)	285	208	362	248	222	274	291	269	313	348	330	366	339	316	362
Rate ratio (Q1 versus Q5)	1.4	1.3	1.5	1.4	1.3	1.4	1.5	1.4	1.5	1.6	1.6	1.7	1.7	1.6	1.7
Educational attainment															
Rate difference (less than secondary versus university)	261	133	389	296	262	330	311	283	339	357	337	377	379	354	404
Rate ratio (less than secondary versus university)	1.4	1.2	1.7	1.5	1.4	1.6	1.6	1.5	1.6	1.7	1.6	1.7	1.8	1.7	1.9

RD/RR = rate difference or rate ratio

CI = confidence interval

Source: Canadian Census Health and Environment Cohort, 1991 to 2011, Statistics Canada.

Figure 2
Average percentage change (APC) in all-cause age-standardized mortality rates by sex and highest level of education, household population aged 25 or older, Canada, 1991 to 2011



* average percentage change significantly different from zero (p < 0.05)

Notes: error bars indicate 95% confidence interval; no HS = less than secondary graduation; HS = secondary graduation or trades certificate; PS no university = postsecondary diploma but not a university degree; University = university degree or equivalent.

Source: Canadian Census Health and Environment Cohort, 1991 to 2011, Statistics Canada.

Historically, men have had higher mortality rates than women, which has been explained by more risky behaviours, biology and health system use, among others.⁶ The present study found that the mortality gender gap narrowed because of a steeper decline in mortality rates for

men than women, regardless of income or education. These results are consistent with recent literature that has suggested that improvements in treatment for cardiovascular disease (CVD) coupled with an increased prevalence of CVD among women are contributing factors.⁴

The findings regarding income-related mortality inequality showed different patterns for men and women. Among men, larger absolute but smaller relative declines over time in the ASMR in the lowest income quintile compared with the highest income quintile led to a nar-

rowing of the absolute—but a widening of relative—mortality inequality. For women, those in the lowest income quintile had a smaller absolute and smaller relative decline in their ASMR compared with those in the highest income quintile, which led to a widening of absolute and relative inequalities in mortality over time. This trend of increasing inequality among women has been reported in Ontario using area-based measures^{6,8} and elsewhere in the world¹⁸ and may reflect various aspects of disadvantage. These could include the increased uptake among women of risky behaviours such as smoking⁴ coupled with the higher prevalence of this behaviour among lower income women in Canada,¹⁹ as well as growing inequalities in access to health care.²⁰

For women, mortality inequality according to education categories was similar to that of income in that there was a widening over time in both absolute and relative inequalities between those who did not graduate from secondary school and those with a university degree or equivalent. Among men, there was little change over time in the absolute difference between the ASMRs of those with less than secondary graduation compared with those who had a university degree or equivalent, though the relative difference between the two did increase over the period. As with low income, the mortality decline disadvantage of those with less education has been partly attributed to behavioural risk factors such as smoking and alcohol.²¹ Furthermore, the

population size of the low education category has declined significantly, and it may be increasingly composed of individuals who are more homogeneous in terms of characteristics that compound the risk of ill health.²² For example, it has been shown that, between 1998 and 2011, education-related inequalities in health status among women in Canada increased significantly.²³

Strengths and limitations

Absolute and relative measures of mortality inequality each have their uses in monitoring progress towards the reduction or elimination of health inequalities,^{16,24} and a strength of this study is that it presents both. Another strength is the use of the CanCHECs—large, nationally representative census cohorts with individual-level income and education linked to administratively collected mortality data. Although area-based measures contribute to the understanding of neighbourhood effects on health inequalities,²⁵ this study's use of individual-level data analysis allows for less misclassification of sociodemographic characteristics. Five cohorts permitted an analysis of trends over a 20-year period; however, two decades of data have raised concerns about comparability. Changes to question wording and collection mode from one census to the next over this period²⁶⁻²⁹ should be kept in mind when interpreting the results of this study. Notably, in 2006, there were substantive changes to questions on edu-

cational attainment, and, for the first time, census respondents could choose to allow linkage to their tax records rather than self-report their income data. The former change corrected the underreporting of secondary school completion in previous census years,³⁰ while the latter reduced clustering around round dollar amounts (such as \$30,000), thereby causing income distributions to be more variable than in previous censuses.³¹ The use of income quintiles for this analysis, however, helped to minimize the impact of increased variability in the income distribution from 2006 onward.

These results are limited to the household population aged 25 or older and therefore do not apply to the institutionalized population in Canada. Another limitation relates to potential inclusion bias associated with data linkage. Although the cohort weights were designed to help mitigate this bias, unknown bias might exist if people missing from the cohorts differed systematically from those who were included.

Conclusion

Although mortality rates have fallen significantly over the past 20 years, income- and education-related mortality inequalities persist for the adult household population in Canada, and have increased for women. Additional research to determine the reasons underlying these trends could help address the complex challenge of reducing health inequalities in Canada. ■

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