Population health impact of cancer in Canada, 2001

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Abstract

Summary measures of population health that incorporate morbidity provide a new perspective for health policy and priority setting. Health-adjusted life years (HALYs) lost to a disease combine the impact of years of life lost to premature mortality and morbidity, measured as year-equivalents lost to reduced functioning. HALYs for 25 cancers were estimated from mortality and incidence in 2001 in Canada; population-attributable fractions were estimated for major risk factors contributing to these cancers. Results from this analysis indicate that Canadians would lose an estimated 905,000 health-adjusted years of life to cancer for 2001, including 771,000 to premature mortality and 134,000 to morbidity from incident cases (years discounted at 3%). Most of the estimated premature mortality was due to lung cancer; morbidity was largely due to breast, prostate and colorectal cancers. An estimated one quarter of HALYs lost to cancer were attributable to smoking and almost one quarter were attributable to alcohol consumption, lack of fruit and vegetables, obesity and physical inactivity combined. These results are a significant advance in measuring the population health impact of cancer in Canada because they incorporate morbidity as well as mortality.

Key words: *burden of disease, cancer, DALY, HALY, health status indicators, population health, quality of life, summary measures*

Introduction

Cancer claimed the lives of over 65,000 Canadians in 2001 and it accounts for the most premature mortality among diseases in terms of potential years of life lost.[1] The impact of cancer morbidity is much harder to quantify, despite reliable and systematic reporting of cancer incidence in Canada.

Individuals living with cancer experience a range of physical, emotional and social limitations that affect their health-related quality of life. By measuring the severity of these limitations and incorporating them into summary measures that quantify both morbidity and mortality, we can gain a better picture of how cancer affects Canadians.

To date, some measures of population health, such as health-adjusted life expectancy, have incorporated morbidity using utility scores from national population health surveys.[2,3] Disability-adjusted life years lost to disease have been estimated for British Columbia[4] using Canadian mortality data as well as disability weights and epidemiologic data from an Australian burden of disease study.[5] The World Health Organization estimated morbidity in Canada for its Global Burden of Disease study[6] using disease patterns and disability weights not specifically developed for Canada.

The present study, the Population Health Impact of Disease in Canada (PHI),[7] builds on the methods used in the aforementioned burden of disease studies by its focus on estimating the combined impact of mortality and morbidity due to cancer in the Canadian context. Its main advancements over previous work are that it is based on a description of cancer progression and treatment consistent with patterns observed in Canada, uses extensive Canadian epidemiologic data, accounts for comorbidity at onset of cancer and, for the first time, uses preference scores elicited from lay Canadians to weight for the severity of various cancer-related health states.[8]

This article presents the first results of the PHI, providing estimates of health-adjusted life years (HALYs) lost to 25 cancers in Canada, as a sum of the years lost to premature mortality in 2001 and the lifetime morbidity due to cancer diagnosed in 2001. These burdens were allocated using population-attributable fractions to five risk factors: alcohol consumption, lack of fruit and vegetable consumption, obesity, physical inactivity and smoking.

Methods

This exercise was undertaken to estimate health-adjusted life years (HALYs) lost to cancer incidence and mortality in the year 2001. The impact of cancer mortality was measured in terms of the number of years of life lost due to premature death. Morbidity was estimated as the time lost to reduced functioning, weighted for severity, across cancer-related health states typical in the Canadian context.

The data to support these detailed estimates were obtained primarily from Canadian sources, supplemented with

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sources from the United States, from literature review and expert consultation (Table 1).[7,9-27]

TABLE 1
Data sources

Data	Source
Mortality counts	Statistics Canada, Vital Statistics: Death Database[9]
Population counts	Statistics Canada, Population estimates 0-90+ Canada – Provinces 1971-2001[10]
Life expectancies	Statistics Canada, Canadian Projected Cohort Lifetable, Lifepaths 41[11]
Year-equivalents lost to reduced functioning (YERF) estimates	
Preference scores	Population Health Impact of Disease in Canada program[7]
Starting health of population	National Population Health Survey, 1994-95 (Ages 5-14)[12]
	Canadian Community Health Survey, 2000-01 (Ages 15+)[13]
Diagnosis	Incidence: Canadian Cancer Registry (CCR)[14]
	Duration of diagnostic state: Simunovic M et al., 2001[15]
Staging	Surveillance, Epidemiology, and End Results (SEER) Program[16]
Treatment	Duration and distribution to treatments: Expert consultation[17]
Remission	Distribution to remission states: Expert consultation[17]
Case fatality	Surveillance, Epidemiology and End Results (SEER) Program[16]
Terminal and palliative	Duration: Expert consultation[17,18]
Survival	Surveillance, Epidemiology and End Results (SEER) Program[16]
Population-attributable fraction (PAF) estimates	
Risk factor exposure	All risk factors except smoking: Canadian Community Health Survey, 2000-01[13]
Relative risks	Smoking: Estimated using Peto-Lopez method[19] and lung cancer mortality from Canada[9,10] compared with American reference population (American Cancer Society CPS II[20] data from the Victorian Burden of Disease Study[4])
	Alcohol: All sites except breast cancer: English et al., 1995[21]; Breast cancer from Australian Institute of Health and Welfare, 2001[22]
	Lack of fruit and vegetables: New Zealand Ministry of Health, 1999[23]
	Obesity: All sites except rectal cancer: Mao Y et al., 2004[24]; Rectal cancer from Pan et al., 2002[25]
	Physical inactivity: Australian Institute of Health and Welfare, 1999[26]
	Smoking: Centers for Disease Control and Prevention, 2002[20]

Note: These data are documented in workbooks available online[7,27]

Calculating health-adjusted life years (HALYs) lost to cancer

Health-adjusted life years lost to each of 25 cancer sites (c) was calculated, by sex (s) and standard five-year age groups (a), as the sum of the years of life lost through premature mortality (YLLs) and year-equivalents lost to reduced functioning (YERFs). (YERFs are analogous to YLDs [years of life lived with disability] used by the World Health Organization in its burden of disease study. The change in terminology was modified to emphasize functional health rather than disability.)

$$HALY_{c,a,s} = YLL_{c,a,s} + YERF_{c,a,s}$$

Calculating years of life lost to cancer mortality (YLLs)

The mortality component of the calculation was measured as the years of life lost due to premature mortality. We calculated YLLs by sex (s) and age group (a) for each cancer site (c), as the number of deaths (M), multiplied by the remaining life expectancy at the average age of death (L):

$$YLL_{c,a,s} = M_{c,a,s} * L_{c,a,s}$$

Mortality rates were calculated using 1999 data,[9,10] the last year for which cause of death was classified using the *International Classification of Diseases 9th Revision* (ICD-9), and applied to the 2001 population to estimate the number of cancer deaths in 2001, by age group and sex. The remaining life expectancy associated with deaths in 2001 was based on Canadian projected cohort life tables.[11]

Calculating year-equivalents lost to reduced functioning (YERFs)

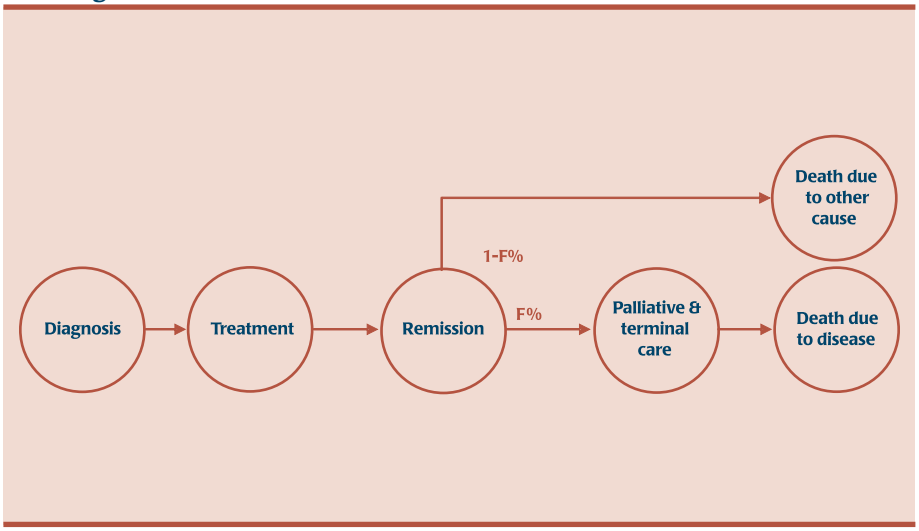
Morbidity was estimated as year-equivalents lost to reduced functioning (YERFs) due to cancer. In their simplest form, YERFs are calculated as the product of incidence and duration, weighted for severity of limitations. The course and treatment of cancer, however, is a rather complex series of health states: Cancer patients progress from diagnosis, through a treatment phase to a remission period, and possibly to a palliative and terminal care phase or to death from another cause (Figure 1). Although the experience of living with cancer may vary from patient to patient, for practical reasons, we limited our estimates to the health states along typical pathways that affect most patients.

In total, 21 health states related to cancer were identified and described using literature review and expert opinion.[28] These included several health states that describe quality of life at diagnosis of cancers with very good, fairly good or poor prognosis; nine treatment states, including surgery (in-patient, out-patient, bone marrow transplantation), radiotherapy (curative or palliative), chemotherapy (mild, moderate or severe effects) and hormonal therapy; four remission states that represent the long-term effects following surgery, chemotherapy, hormonal therapy or radiotherapy and include the residual effects of having cancer; and health states for palliative and terminal care.

More precisely then, YERFs were calculated as the product of incidence (I), duration in years (D) and weight of severity of limitations (W), for each combination of cancer site (c), stage at diagnosis (g), health state (e), sex (s) and age group (a):

$$YERF_{c,a,s} = \Sigma_g \Sigma_e [I_{c,a,s,g,e} * D_{c,a,s,g,e} * W_e]$$

FIGURE 1
Progression of health states related to course of cancer and its treatment



Notes:

1. Case fatality (F) is used to determine the proportion dying from cancer and from other causes. Distributions to treatment and subsequent health states are based on cancer site, stage, age group and sex.
2. Some individuals do not have treatment, so they proceed from diagnosis to a health state "no treatment" that lasts until palliative care begins. This health state is grouped with remission health states for practical purposes.

Incidence

Incidence counts of cancer, defined as cases of first primary malignant tumours, were obtained from the Canadian Cancer Registry.[14] Incidence rates were calculated using the three most recent years of complete data (1997-1999) and applied to the 2001 population to estimate the incidence of cancer in 2001, by cancer site, age group and sex.

Cases were distributed by stage at diagnosis because stage is a determinant of treatment and predictor of survival outcomes and was thus expected to lead to a more refined estimate of morbidity. Comprehensive Canadian staging data were not available, so we used data from the US Surveillance, Epidemiology and End Results (SEER) program.[16] Incident counts (SEER, 1998-2000) were distributed to localized, regional and distant stages by sex and age group (0-49, 50-74, 70+).

Expert consultation[17] was used to estimate the proportion of cases that would receive each type of treatment for the different cancers. Case fatality rates were used to determine the proportion of cases that would receive palliative and terminal care. To estimate the proportion of cases dying from each cancer, we generated cause-specific Kaplan-Meier survival curves for each cancer site by stage, using SEER*Stat 5.0 software and SEER follow-up data for the period 1975-2000.[16]

Duration

An initial health state at diagnosis was estimated to last 37 days on average.[15] The average durations of treatment, which vary by cancer site and stage at diagnosis, were obtained through expert consultation.[17] For those dying of cancer, duration of palliative care was assumed to last five months and terminal care one month.[17,18] The duration of remission was calculated as the average observed survival time less the time spent in the diagnostic, treatment and palliative/terminal health states.

Average observed piecewise survival times were estimated from SEER data (1975–2000) for each cancer site, by stage, sex and age group. Cause-specific survival duration was also estimated from SEER, using the methods described earlier for case fatality.

Weight for severity of limitations

In the YERF formula, preference scores are expressed as disutility weights (W) to weight health states according to the severity of reduced functioning. Preference scores are measures of utility that range from 0 (dead) to 1 (full health). The preference scores for the 21 cancer-related health states used in this analysis are shown in Table A of Appendix A.[1,7,8,28,29] They were derived by classifying the impact of the health state across eleven attributes (each with four to five levels) using the CLAssification and MEasurement System of Functional Health (CLAMES).[7,8,29] CLAMES is a generic tool used to measure health-related quality of life.

In certain situations, we combined the impact of two health states to represent the impact of having both at the same time: The impact at diagnosis of cancer was assumed to continue through the treatment phase; remission states were possible after various combinations of treatment; and the population was assumed to be in partial health prior to the onset of cancer in 2001. We assumed that the impact of these combined health states could be estimated as the product of the preference scores of each individual health state, as has been done elsewhere.[26]

The measure of partial health for the starting population was estimated by age group using Health Utilities Index Mark3 (HUI3)[30,31] from the Canadian Community Health Survey, 2000-01 (CCHS)[13] for ages 15 and over and from the National Population Health Survey, 1994–95 (NPHS)[12] for age groups 5-9 and 10-14, and we assumed full health for those under age five. We used the HUI3 as a proxy for preference scores since population preference scores measured by CLAMES were not available.

Attribution to risk factors

HALYs, YLLs, and YERFs lost to each cancer site were allocated to five risk factors (alcohol consumption, lack of fruit and vegetable consumption, obesity, physical inactivity and smoking) using population-attributable fractions (PAFs). The population-attributable fraction represents the proportion of disease in the population attributable to a particular risk factor[32] and can be used to estimate the impact at the population level if that risk factor were removed. The risk categories were based on relative risk data from the literature, with a priority on the most recent Canadian sources (Appendix B, Tables B1–B5).[20-26]

Prevalence of exposure by risk factor category was obtained from CCHS 2000-01[13] for all risk factors except smoking. The effect of smoking on cancer involves a lag between exposure and disease initiation, as well as changing exposure over time. We used the Peto-Lopez method[19] to estimate the cumulative exposure to smoking, based on a comparison of lung cancer mortality in Canada in 2001[9,10] and lung cancer mortality in smokers and non-smokers in an American reference population.[20]

Discounting

Discounting is a method that gives more preference to the present than the future. Discounting future years at a specific rate (r), the YLL and YERF formulae described earlier become:

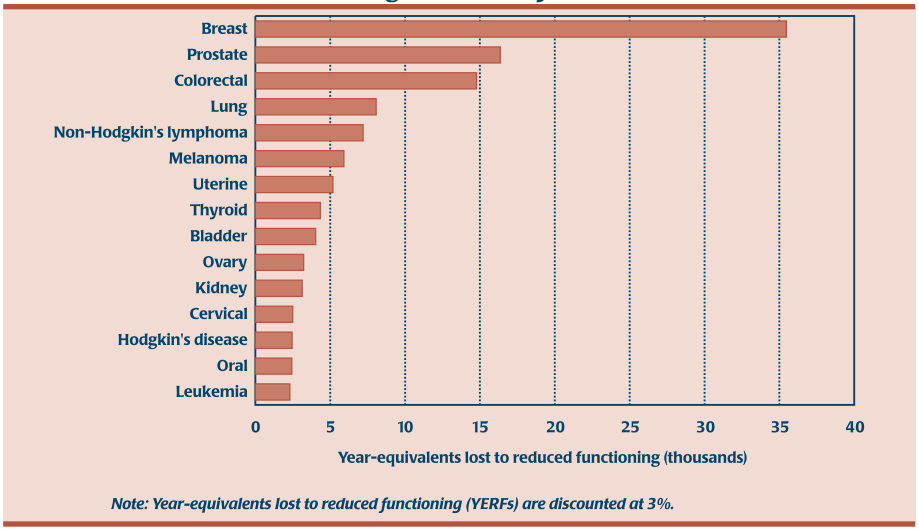
$$YLL_{c,a,s} = M_{c,a,s} * (1-e^{-rLc,a,s}) / r$$

$$YERF_{c,a,s} = \Sigma_g \Sigma_e [I_{c,a,s,g,e} * (1-e^{-rDc,a,s,g,e}) * e^{rTc,a,s,g,e}]/r * W_e]$$

The time from diagnosis to the beginning of the health state (T) is required to discount the health state at the appropriate time in the future. (We use the time of patient registration in the Canadian Cancer Registry as a proxy for the time of diagnosis.)

The results presented here are discounted at 3% according to Canadian guidelines for economic evaluation.[33] Age weighting was not used in these estimates since it raises controversial issues.[34,35]

FIGURE 2
Cancers with largest morbidity, Canada, 2001



Note: Year-equivalents lost to reduced functioning (YERFs) are discounted at 3%.

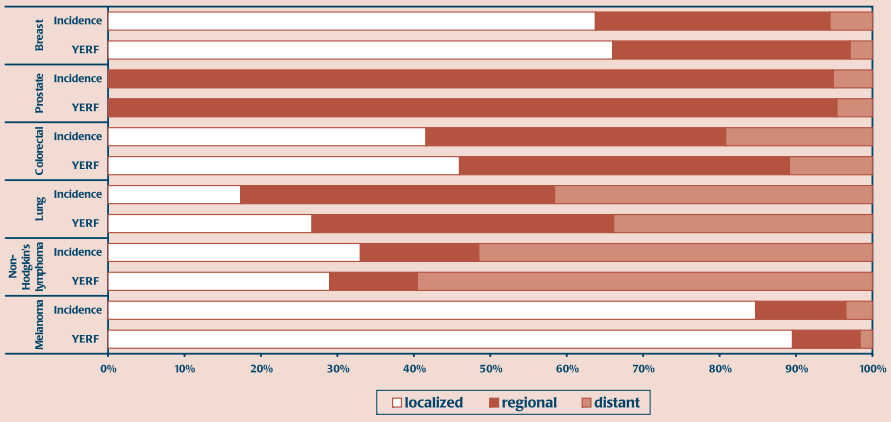
Results

Morbidity and mortality differences by cancer site

An estimated 905,000 health-adjusted life years (HALYs) would be lost to cancer in Canada from incidence and mortality in 2001 (Table 2). (Estimates for HALYs, YLLs and YERFs have been rounded to the nearest 1,000 here.) Lung cancer accounted for 221,000 years or almost one quarter of the years lost, followed by breast and colorectal cancers. Premature mortality accounted for 85% (771,000) of HALYs lost to cancer, including 213,000 years of life lost to premature mortality from lung cancer alone.

The remaining 15% of HALYs lost to cancer (134,000) were lost to morbidity. As shown in Figure 2, breast cancer accounted for 35,000 year-equivalents of reduced functioning, more than four times as many as lung cancer. The overall incidence of breast cancer was roughly the same as lung cancer; the difference in morbidity is mainly because breast cancer is diagnosed at an earlier stage than lung cancer and has much longer survival times (Table 3). The impact of morbidity was greater for

FIGURE 3
Distribution of incidence and morbidity by stage at diagnosis for the six cancers with the largest morbidity, Canada, 2001



Note: For prostate cancer, localized and regional diagnoses are combined.

TABLE 2
Estimated health-adjusted life years (HALYs) lost to cancer and proportion that is morbidity, by sex and cancer site, Canada, 2001

		HALY			YERF as proportion of HALY		
ICD-9 code	Cancer site	Total	Male	Female	Total (%)	Male (%)	Female (%)
140-149	Oral	15,896	10,892	5,004	15	15	17
150	Esophageal	17,088	12,473	4,615	3	3	3
151	Stomach	25,458	14,955	10,503	6	7	6
153-154, 159.0	Colorectal	105,217	54,107	51,111	14	14	14
155	Liver	16,816	10,651	6,164	3	3	3
156	Gall bladder	6,125	2,375	3,750	6	6	6
157	Pancreatic	37,700	18,746	18,953	3	3	3
161	Laryngeal	6,958	5,499	1,459	14	14	12
162	Lung	220,745	126,380	94,365	4	3	4
170-171	Bone and connective tissue	10,473	5,322	5,150	15	15	14
172	Melanoma	16,560	9,011	7,549	36	30	43
173	Non-melanoma skin*	2,525	1,604	920	16	10	27
174	Breast	105,896	–	105,896	33	–	33
180	Cervical	9,814	–	9,814	25	–	25
182, 179	Uterine	13,218	–	13,218	39	–	39
183	Ovarian	23,285	–	23,285	14	–	14
185	Prostate	46,950	46,950	–	35	35	–
188	Bladder	18,692	13,065	5,627	22	22	20
189	Kidney	19,443	11,820	7,623	16	16	17
191-192	Brain	27,399	15,132	12,266	8	8	8
193	Thyroid	6,002	1,553	4,449	72	60	77
200, 202	Non-Hodgkin's lymphoma	38,608	21,008	17,600	19	17	20
201	Hodgkin's disease	4,917	2,809	2,107	50	48	53
203	Multiple myeloma	14,221	6,962	7,259	10	11	9
204-208	Leukemia	29,416	16,414	13,003	8	8	8
All sites 140 to 208 not listed above	All other cancers	65,647	33,923	31,724	10	13	7
140-208	**TOTAL**	**905,067**	**441,652**	**463,415**	**15**	**12**	**17**

Notes:

All estimates are discounted at 3%.

– not applicable

*Data for non-melanoma skin cancers are underestimated due to reporting problems.

HALY is sum of years of life lost due to premature mortality (YLL) and year-equivalents lost to reduced functioning (YERF).

both colorectal and prostate cancers than for lung cancer.

The six cancers shown in Figure 3 accounted for 65% of morbidity due to cancer. Melanoma had the sixth largest impact in terms of morbidity, even though its impact was not large in terms of mortality (ranking 15th). For sites such as breast, prostate, and colorectal cancers, localized and regional diagnoses accounted for the majority of morbidity due to cancer, partly because survival is longer, but also because of the larger proportion diagnosed at these stages.

For lung cancer, however, regional and distant diagnoses accounted for 39% and 34% of morbidity, respectively, even though survival for localized diagnoses is almost 14 times as long as for distant diagnoses and almost three times as long as for regional diagnoses (Table 3). This is mainly because regional and distant diagnoses each account for more than twice as many cases as localized diagnoses. Palliative and terminal care together accounted for about 45% and 63% of morbidity associated with regional and distant diagnoses, respectively, due to severity of functional limitations and the larger proportion of individuals who die from later-stage disease.

Table 3 shows, too, that the duration of the remission period is also a major contributor to morbidity. For cancers with long remission periods, such as localized breast cancer, remission contributed 96% of the

TABLE 3
Estimated morbidity due to cancer, by health state and stage at diagnosis, for selected cancer sites, Canada, 2001 *(continued)*

		Localized		Regional		Distant	
Cause-specific survival (mean years)		*22.4*		*16.9*		*5.0*	
	Health state	# of cases	YERFs	# of cases	YERFs	# of cases	YERFs
BREAST CANCER							
At diagnosis		11,966	107	5,764	53	1,039	48
Treatment	surgery inpatient	3,087	67	5,073	113	364	16
	surgery outpatient	7,204	109	0	0	0	0
	chemo mild toxicity	0	0	0	0	0	0
	chemo moderate toxicity	2,872	394	3,689	515	478	131
	chemo severe toxicity	0	0	0	0	0	0
	radio curative	5,145	73	2,536	36	0	0
	radio palliative	0	0	0	0	270	10
Remission	surgery alone	3,829	4,656	1,153	1,116	114	27
	chemo alone	0	0	0	0	166	27
	radio alone	0	0	0	0	104	25
	surgery and chemo	1,316	2,598	1,383	2,174	146	55
	surgery and radio	3,590	8,361	231	428	0	0
	chemo and radio	0	0	0	0	62	24
	surgery and chemo and radio	1,556	4,674	2,306	5,516	104	60
	no treatment*	1,675	2,103	692	691	343	422
Palliative care		2,241	204	2,701	294	937	144
Terminal care		2,241	64	2,701	93	937	45
TOTAL			**23,411**		**11,029**		**1,032**

		Localized		Regional		Distant	
Cause-specific survival (mean years)		*21.1*		*15.2*		*2.9*	
	Health state	# of cases	YERFs	# of cases	YERFs	# of cases	YERFs
COLORECTAL CANCER							
At diagnosis		6,976	80	6,581	76	3,221	143
Treatment	surgery inpatient	6,558	148	6,450	146	2,287	94
	surgery outpatient	0	0	0	0	0	0
	chemo mild toxicity	628	88	3,488	488	0	0
	chemo moderate toxicity	0	0	0	0	1,417	374
	chemo severe toxicity	0	0	0	0	0	0
	radio curative	0	0	197	3	0	0
	radio palliative	0	0	0	0	0	0
Remission	surgery alone	5,930	4,961	2,962	1,727	1,127	63
	chemo alone	0	0	0	0	258	10
	radio alone	0	0	0	0	0	0
	surgery and chemo	628	853	3,291	3,115	1,160	105
	surgery and radio	0	0	0	0	0	0
	chemo and radio	0	0	0	0	0	0
	surgery and chemo and radio	0	0	197	284	0	0
	no treatment*	419	485	132	106	676	200
Palliative care		1,487	135	3,072	332	2,978	469
Terminal care		1,487	43	3,072	105	2,978	148
TOTAL			**6,793**		**6,381**		**1,605**

TABLE 3 *(continued)*
Estimated morbidity due to cancer, by health state and stage at diagnosis, for selected cancer sites, Canada, 2001

		Localized		Regional		Distant	
Cause-specific survival (mean years)		*11.0*		*3.9*		*0.8*	
Health state		# of cases	YERFs	# of cases	YERFs	# of cases	YERFs
LUNG CANCER							
At diagnosis		3,222	49	7,623	117	7,720	351
Treatment	surgery inpatient	2,095	52	1,220	31	0	0
	surgery outpatient	0	0	0	0	0	0
	chemo mild toxicity	0	0	0	0	0	0
	chemo moderate toxicity	258	20	4,269	340	3,783	514
	chemo severe toxicity	0	0	0	0	0	0
	radio curative	741	21	4,498	127	0	0
	radio palliative	0	0	0	0	3,629	131
Remission	surgery alone	1,869	751	534	55	0	0
	chemo alone	0	0	1,067	77	1,776	1
	radio alone	322	133	1,067	112	1,621	1
	surgery and chemo	0	0	0	0	0	0
	surgery and radio	161	124	229	45	0	0
	chemo and radio	193	128	2,744	465	2,007	3
	surgery and chemo and radio	64	64	457	116	0	0
	no treatment*	612	444	1,525	283	2,316	10
Palliative care		2,235	279	6,966	1,079	7,623	1,310
Terminal care		2,235	88	6,966	341	7,623	414
TOTAL			**2,154**		**3,187**		**2,734**

Notes:
YERF estimates are discounted at 3%
*included with remission health states, although not strictly speaking a remission period
Morbidity is quantified by year-equivalents lost to reduced functioning (YERFs).

morbidity, while treatment contributed 3%. By contrast, the remission period for distant-staged lung cancer, which is generally ongoing care, is very short and contributed less than 1% towards morbidity. The morbidity associated with treatment of these cases was relatively small (24%) because treatment options are limited for advanced lung cancer. The longer remission period associated with distant-staged colorectal cancer accounted for an estimated 24% of morbidity, while treatment accounted for 29%, and palliative and terminal care 38%.

Attribution to risk factors

Based on the relative risk data used, an estimated 25% of HALYs lost to cancer were attributable to smoking; 11% were attributable to lack of fruit and vegetable consumption, 6% to physical inactivity, 5% to obesity and 2% to alcohol (Table 4). The total HALYs attributable to these five risk factors could be as much as 49%. Smoking accounted for 14,000 lung cancer deaths and 188,000 health-adjusted life years lost to lung cancer. Because most of the HALYs lost to each cancer site were due to mortality, the attribution of YLLs to these risk factors was similar (data not shown).

A somewhat different picture emerged for morbidity. Smoking contributed 87% of morbidity due to lung cancer, but only 9% of morbidity due to cancer overall. Of the overall morbidity due to cancer, 12% was attributable to lack of fruit and vegetable consumption, which was assumed to have an impact across all sites. Physical inactivity accounted for an estimated 31% and 23%, respectively, of morbidity due to colorectal and breast cancers.

Discussion

This analysis indicates that Canadians would lose an estimated 905,000 health-adjusted life years from mortality and incidence of cancers in 2001—771,000 through years of life lost to premature mortality (YLLs) and 134,000 through morbidity, measured by year-equivalents lost to reduced functioning (YERFs). Lung cancer had the largest impact due to the large number of years lost to premature mortality, followed by breast, colorectal and prostate cancers. Breast cancer was the leading cause of morbidity, with levels higher than the morbidity of prostate and colorectal cancers combined. Although morbidity accounted for about 15% of total impact of cancer as measured by HALYs, it represents a substantial impact on quality of life. About one quarter of HALYs lost to cancer overall was attribut-

TABLE 4
Attribution of deaths, health-adjusted life years (HALYs) and morbidity to five risk factors (*percentages*) for selected cancer sites, Canada, 2001

	All cancers	Breast	Colorectal	Lung	Prostate
Total deaths	**64,825**	**5,002**	**8,242**	**17,504**	**3,849**
Smoking	*27*	*0*	*0*	*82*	*0*
Lack of fruit and vegetables	*9*	*9*	*8*	*10*	*6*
Physical inactivity	*5*	*20*	*26*	*0*	*0*
Obesity	*4*	*8*	*10*	*0*	*2*
Alcohol	*2*	*4*	*0*	*0*	*0*
Total HALYs	**905,067**	**105,896**	**105,217**	**220,745**	**46,950**
Smoking	*25*	*0*	*0*	*85*	*0*
Lack of fruit and vegetables	*11*	*12*	*11*	*12*	*10*
Physical inactivity	*6*	*22*	*29*	*0*	*0*
Obesity	*5*	*8*	*12*	*0*	*4*
Alcohol	*2*	*5*	*0*	*0*	*0*
Total morbidity	**134,280**	**35,471**	**14,779**	**8,075**	**16,362**
Smoking	*9*	*0*	*0*	*87*	*0*
Lack of fruit and vegetables	*12*	*13*	*12*	*12*	*12*
Physical activity	*9*	*23*	*31*	*0*	*0*
Obesity	*6*	*7*	*13*	*0*	*4*
Alcohol	*2*	*5*	*0*	*0*	*0*

Notes: HALY and morbidity estimates are discounted at 3%.

Morbidity is quantified by year-equivalents lost to reduced functioning (YERFs).

able to smoking; almost one quarter was attributable to the other risk factors combined. For overall morbidity due to cancer, however, a larger portion was attributable to lack of fruit and vegetable consumption than to smoking. These results are a significant advance in measuring the population health impact of cancer in Canada because they incorporate morbidity as well as mortality.

Our work uses preference scores elicited from the Canadian lay population, based on specific health state descriptions. Canadian preference scores for 21 health states related to cancer indicate the severity of functional limitations at diagnosis, during treatment, remission and palliative/terminal care. These allow for the change in severity of limitations across various treatments and subsequent health states and were applied to the effects of 25 cancer sites diagnosed at three different stages. Previous work in the Netherlands[36] and Australia[26] based disability weights on health states for diagnosis and treatment for some cancer sites. Our Canadian estimates go further by incorporating distributions and durations for a wider range of health states by age group, sex, and stage at diagnosis.

In addition, this work is novel in that the weights for severity of health states were calculated relative to the average health status for that age group, to take into account the reality that Canadians, especially as they age, are not usually in full health. Thus, individuals diagnosed with cancer are not, on average, in full health before developing cancer and they would not be expected to return to full health even if the effects of disease were completely removed. If we had assumed the population was in full health prior to the incidence of cancer in 2001, the estimated YERF would have been 159,000 (data not shown). This was 19% more than our estimate of 134,000, based on an assumption of partial health, highlighting the importance of accounting for comorbidity.

Several limitations of these estimates remain. Although Canadian incidence data for cancer were readily available, they were not available by stage. These estimates thus rely on American data for stage distribution and survival by stage. Comparison of these American data with Canadian data for several cancer sites indicated that they could provide interim data pending the availability of Canadian data. Average survival times by cancer site calculated from SEER and from the Canadian Cancer Registry[14], using similar years of data, were comparable.

Another data gap highlighted by this study is the proportion of patients receiving various types of treatments and the duration of those treatments. While the quality of life associated with treatment was significantly diminished, the relatively short durations of treatment in cancers with very good prognosis and the low proportions receiving treatment in cancers with poor prognosis resulted in low contributions towards the total estimate of morbidity. Sensitivity analyses around these data elements would provide a range of morbidity outcomes to help determine if this is a significant limitation.

A second general limitation resulted from the need to limit the number of health states feasible for such estimates. While every effort was made to establish the main pathways through the course of cancer and its treatment, some oversimplification was inevitable. For example, the health states for remission are not specific to stage at diagnosis or prognostic category. Our estimates thus assume that after treatment all individuals return to a similar level of functional limitation regardless of the extent of disease at diagnosis. In addition, we limited our estimates to first primary cancers, so recurrences are not explicitly included, overlooking any reduction of health status during subsequent diagnostic and treatment phases. These both would tend to underestimate morbidity.

A third limitation is that the classification tool we used to obtain preference scores, CLAMES, has not been validated as a tool

for measuring health-related quality of life. As a new tool, CLAMES has not been adapted for a population survey, so comparability studies of CLAMES and HUI3 (which has been measured on the CCHS and NPHS) have not yet been conducted. However, CLAMES and HUI3 are both utility-based multi-attribute instruments and have seven attributes in common.

Three other limitations inherent in this approach have been widely discussed elsewhere. First, population-attributable fractions by nature overestimate the total attribution to risk factors because they do not account for overlap of the impact of risk factors that often occur together. The relative risks that contribute to these population-attributable fractions do not likely account for all confounding and interactions of risk factors.[32] Moreover, risk factor prevalence was based on self-reported survey data, which may underestimate levels of obesity and smoking and overestimate the amount of physical activity and fruit and vegetable consumption.

Second, while the relative risks used were selected from recent high quality epidemiological studies, they are subject to some uncertainty due to sample size and possible measurement error. Some researchers have questioned the benefit of fruit and vegetable consumption to reduce the risk of cancer.[37] The attributable fractions should be interpreted with some caution.

Third, the cell-based approach to calculating summary measures oversimplifies the course of disease and its treatment and does not readily accommodate consideration of comorbidity from additional diseases. This is a particular concern among the older population groups because a larger proportion have more than one disease or health condition.

A microsimulation model for cancer now being developed as part of the PHI research program takes a more dynamic approach, incorporating comorbid conditions and considering previous and subsequent disease events and changes in risk factors over time.[7] This approach will allow us to perform, much more realistically and directly, "what-if" scenarios about potential interventions such as "How would different smoking rates affect cancers over the next ten years?"

Policy perspective

The estimates provided here are for cancer, a disease affecting many Canadians. Although the morbidity is not high for cancer compared with mortality, it has a substantial impact in terms of quality of life. The methods used here will be particularly useful in providing comparable estimates for other diseases such as arthritis, which have high morbidity. These methods contribute to a broad framework to measure and compare the relative impact of the major diseases and risk factors that affect Canadians, allowing standardized and comparable measures of both mortality and morbidity across diseases. This is particularly important when assessing the overall effect of risk factors across disease groupings.

Most of the mortality and morbidity related to lung cancer was attributable to smoking. However, for other cancers (e.g., breast and colorectal) both mortality and morbidity were primarily attributable to other risk factors such as physical inactivity, inadequate fruit and vegetable consumption, and obesity. While sensitive to the assumptions of relative risk, comparing the impact of risk factors on cancers and other diseases at the population level may help focus prevention strategies.

These estimates allow a closer look at the potential factors contributing to morbidity across the stages at diagnosis and throughout the course of treatment, remission and palliative care. This provides an additional perspective on interventions. Cancers that are mostly diagnosed early (e.g., breast) contribute a substantial amount of morbidity from long periods of remission. However, cancers diagnosed at a later stage (e.g., lung) contribute, in addition to mortality, substantial morbidity because the severity of limitation is far greater for advanced disease.

Interventions that promote early diagnosis and treatment, such as screening, can reduce mortality and, to some extent, morbidity due to cancer. However, a lengthy remission phase may still contribute substantially to morbidity. On the other hand, interventions that prevent cancer, such as diet and physical activity, have the potential to reduce morbidity even further.

Upstream risk factors, such as income level, may play a significant role in the distribution of the prevalence of the stated cancer risk factors, and may thereby indirectly affect mortality and morbidity. This could potentially be evaluated as a "what-if" scenario using this study's underlying cell-based model.[27] For instance, the prevalence of the cancer risk factors could be estimated for the poorest and richest quartiles of the population; the difference of HALYs attributed to each risk factor could be an indication of the impact of income distribution.

Conclusions

These results are a significant advance in measuring the population health impact of cancer in Canada because they incorporate morbidity as well as mortality. These estimates of HALYs lost to cancer among Canadians demonstrate how morbidity measures can inform health policy and priority setting. The morbidity associated with living with cancer is a substantial component of the total HALYs lost to cancers, even though it is not as large as the impact of mortality. The methods used here will be useful in examining the impact of other diseases for which morbidity is even larger. The methods presented here also provide new insights about the potential impact of specific risk factors such as diet and physical activity. The combined impact across all cancers and all diseases may be substantial. Moreover, diet and physical activity are integral to healthy living in general, and provide an opportunity to increase both quantity and quality of life.

APPENDIX A

TABLE A
Preference scores* for 21 cancer-related health states

At diagnosis	
Very good prognosis	0.891
Fairly good prognosis	0.853
Poor prognosis	0.809
Metastatic disease	0.439
Childhood acute lymphoblastic leukemia	0.732
Chronic lymphocytic leukemia	0.940
Treatment	
Surgery in-patient	0.732
Surgery out-patient	0.853
Radiotherapy curative	0.781
Radiotherapy palliative	0.507
Chemotherapy mild toxicity	0.750
Chemotherapy moderate toxicity	0.742
Chemotherapy severe toxicity	0.706
Hormonal therapy	0.896
Bone marrow transplantation	0.864
Remission	
After surgery	0.894
After radiotherapy	0.891
After chemotherapy	0.926
After hormonal therapy	0.912
Palliative care	0.484
Terminal care	0.179

Source: Population Health Impact of Disease in Canada program[7,8,29]

* Preference scores measure the relative preference for a health state on an interal scale between 0 (dead) and 1 (full health)

Note: Cancers were classified into the prognostic categories based on the death-to-incidence ratio and using Canadian Cancer Statistics.[1] This is described elsewhere.[28]

APPENDIX B

Population-attributable fractions were estimated for each risk factor by cancer site (c), age group (a) and sex (s):

$$PAF_{c,a,s} = \Sigma_i [Pe_{c,a,s,i} * (RR_{c,a,s,i} -1) / (1 + Pe_{a,s,i} * (RR_{c,a,s,i} -1))]$$

where Pe is the proportion of the population exposed to the risk factor, RR is the relative risk of developing or dying of cancer due to the exposure (shown in Tables B1 to B5) and index i represents the risk category.

TABLE B-1
Alcohol consumption

	Low	Hazardous	Harmful
Definition (drinks/day):			
Male	0.26 - 4.0	4.01 - 6.00	> 6
Female	0.26 - 2.0	2.01 - 4.00	> 4
Relative risks:			
Oral cancer	1.45	1.85	5.39
Esophageal cancer	1.80	2.37	4.26
Liver cancer	1.45	3.03	3.60
Laryngeal cancer	1.83	3.90	4.93
Breast cancer (female only)	1.14	1.41	1.59

Note: Reference category is 0-0.25 drinks per day.

Source: All sites except breast cancer: English et al., 1995[21]
Breast cancer: AIHW, 2001[22]

TABLE B-2
Lack of fruit and vegetable consumption

Definition: at risk if less than five servings per day, according to age				
Relative risks:				
Age	< 45	45 - 64	65 - 74	75 +
Relative risk for all cancers	1.40	1.30	1.20	1.10

Note: Reference category is five or more servings per day, all ages.

Source: New Zealand Ministry of Health, 1999[23], cited in Mathers et al., 1999[26]

TABLE B-3
Obesity

Defintion: body mass index ≥ 30 kg/m²

Relative risks:

	Males	Females
Stomach cancer	1.36	0.92
Colon cancer*	2.16	1.77
Rectal cancer*	1.78	1.44
Pancreatic cancer	1.43	1.63
Breast cancer		
pre-menopausal**	na	1.13
post-menopausal**	na	1.66
Prostate cancer	1.27	na
Ovarian cancer	na	1.95
Bladder cancer	1.35	1.15
Kidney cancer	3.15	2.42
Non-Hodgkin's lymphoma	1.42	1.54
Multiple myeloma	2.16	1.92
Leukemia	1.41	2.01

*relative risks combined for colorectal cancer, assuming two thirds colon and one third rectal cancer

**used age 50 as proxy for menopause

Note: Reference category is body mass index < 30 kg/m² (i.e., not obese).

Source: All sites except rectal cancer: Mao et al., 2003[24]
Rectal cancer: Pan et al., 2004[25]

TABLE B-4
Physical inactivity

Relative risks:

	Inactive	Moderately active
Colorectal cancer	1.70	1.21
Breast cancer (female only)	1.40	1.27

Note: Reference category is "active".

Source: Mathers et al., 1999[26]

TABLE B-5
Smoking

Relative risks:

	Males		Females	
	Current smoker	Former smoker	Current smoker	Former smoker
Oral cancer	10.89	3.40	5.08	2.29
Esophageal cancer	6.76	4.46	7.75	2.79
Pancreatic cancer	2.31	1.15	2.25	1.55
Laryngeal cancer	14.60	6.34	13.02	5.16
Lung cancer	23.26	8.70	12.69	4.53
Cervical cancer	n/a	n/a	1.59	1.14
Bladder cancer	3.27	2.09	2.22	1.89
Kidney cancer	2.72	1.73	1.29	1.05

Note: Reference category is "never smoked".

Source: National Center for Chronic Disease Prevention and Health Promotion, 2002[20]

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