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The economic burden of cancers attributable to tobacco smoking, excess weight, alcohol use, and physical inactivity in Canada

H. Krueger PhD,*† E.N. Andres MPH,† J.M. Koot BSc,*† and B.D. Reilly MSc†

ABSTRACT

Objectives The purpose of the present study was to calculate the proportion of cancers in Canada attributable to tobacco smoking (TS), alcohol use (AU), excess weight (EW), and physical inactivity (PIA); to explore variation in the proportions of those risk factors (RFS) over time by sex and province; to estimate the economic burden of cancer attributable to the 4 RFS; and to calculate the potential reduction in cancers and economic burden if all provinces achieved RF prevalence rates equivalent to the best in Canada.

Methods We used a previously developed approach based on population-attributable fractions (PAFS) to estimate the cancer-related economic burden associated with the four RFS. Sex-specific relative risk and age- and sex-specific prevalence data were used in the modelling. The economic burden was adjusted for potential double counting of cases and costs.

Results In Canada, 27.7% of incident cancer cases [95% confidence interval (CI): 22.6% to 32.9%] in 2013 [47,000 of 170,000 (95% CI:38,400–55,900)] were attributable to the four RFS: TS, 15.2% (95% CI: 13.7% to 16.9%); EW, 5.1% (95% CI: 3.8% to 6.4%); AU, 3.9% (95% CI: 2.4% to 5.3%); and PIA, 3.5% (95% CI: 2.7% to 4.3%). The annual economic burden attributable to the 47,000 total cancers was $9.6 billion (95% CI: $7.8 billion to $11.3 billion): consisting of $1.7 billion in direct and $8.0 billion in indirect costs. Applying the lowest RF rates to each province would result in an annual reduction of 6204 cancers (13.2% of the potentially avoidable cancers) and a reduction in economic burden of $1.2 billion.

Conclusions Despite substantial reductions in the prevalence and intensity of TS, TS remains the dominant risk factor from the perspective of cancer prevention in Canada, although EW and AU are becoming increasingly important RFS.

Key Words Economic burden of disease, risk factors, smoking, alcohol use, obesity, overweight, physical inactivity

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INTRODUCTION

Assessing the economics of cancers and their management has a long history in Canada. In the early 1990s, Statistics Canada developed the Population Health Model to "assist in the evaluation of cancer control interventions and policy decision-making"[1], with a focus on lung[2,3], breast[4–6], and colorectal cancers[7]. More recently, the Canadian Partnership Against Cancer developed the Cancer Risk Management Model to "gain insight into the cost/benefit of cancer control strategies to help guide and strengthen decision-making"[8], with a focus on lung[9] and colorectal cancers[10]. Other Canadian researchers have focused on prostate cancer[11,12] or the 21 most common cancers (brain, female breast, cervix, colorectal, corpus uteri, esophagus, gastric, head-and-neck, leukemia, liver, lung, lymphoma, melanoma, multiple myeloma, ovary, pancreas, prostate, renal, testis, thyroid, and urinary bladder)[13,14]. To our knowledge, however, no Canadian research on the economic relationship between cancers and modifiable risk factors (RFS) exists.

A considerable proportion of cancers are attributable to modifiable RFS and are therefore potentially preventable. Early work by Doll and Peto suggested that most cancers in the United States might be attributable to modifiable RFS such as tobacco smoking and diet[15]. Subsequent analyses have fine-tuned that estimate. Danaei *et al.* estimated that 37% of cancers in high-income countries are attributable

Correspondence to: Hans Krueger, H. Krueger and Associates Inc., 4554 48B Street, Delta, British Columbia V4K 2R8.
E-mail: hans@krueger.ca **DOI:** http://dx.doi.org/10.3747/co.23.2952

to smoking, alcohol use, overweight and obesity, physical inactivity, low fruit and vegetable intake, urban air pollution, unsafe sex, contaminated injections in health-care settings, and indoor smoke from household use of solid fuels[16]. Parkin and colleagues found that 14 RFS are responsible for 42.7% of cancers in the United Kingdom[17]. Of those 14 RFS, 4 (smoking, excess weight, alcohol use, and physical inactivity) cause 70% of preventable cancers.

The purpose of the present study was fourfold:

- to identify the proportion of cancers in Canada that are attributable to the RFS of tobacco smoking, excess weight, alcohol use, and physical inactivity;
- to determine whether the proportion varies by sex or province, or over time;
- to estimate the cancer-related economic burden attributable to the 4 RFS; and
- to determine the potential reduction in cancer cases and economic burden if all provinces achieved prevalence rates equivalent to the best in Canada for the 4 RFS.

METHODS

Our approach was based on population-attributable fractions (PAFS) and utilized our previously published model[18–20] to estimate the cancer-related economic burden associated with the 4 RFS.

Relative Risk

Sources and values for the relative risks (RRS) associated with tobacco smoking[21], excess weight[22], and physical inactivity[23] remain the same as in our previously published model. For the RR values associated with alcohol use, we utilized the meta-analyses by Bagnari *et al.*[24,25] [cancers of the lip, oral cavity, and pharynx (*International Statistical Classification of Diseases and Related Health Problems*, 10th revision, codes C00–14); the nasal cavity, middle ear, accessory sinuses, and larynx (C30–32); the stomach (C16); the liver (C22); the female breast (C50); the ovary (C56); and the prostate (C61)], the meta-analysis by Islami *et al.*[26] [cancers of the esophagus (C15)], the meta-analysis by Fedirko *et al.*[27] [cancers of the colorectum (C18–20)], and the meta-analysis by Tramacere *et al.*[28] [cancers of the pancreas (C25)].

RF Exposure

The analysis of Canada's population exposure to tobacco smoking, alcohol use, overweight or obesity, and physical inactivity used data from the Canadian Community Health Survey (CCHS) in 2000–2001 and 2011–2012[a,b]. The territories were not included in the provincial-level analysis, but were included in the analysis of Canada as a whole. Individuals were considered overweight if their body mass index was between 25 kg/m^2 and 29.99 kg/m^2 and obese if their body mass index was 30 kg/m^2 or greater, calculated based on self-reported height and weight. For youth 12–17 years of age, the Cole system of body mass index was used to determine rates of overweight and obesity[29]. Tobacco smokers were grouped into light (<10 cigarettes daily or occasional, non-daily smoking), moderate (10–19 cigarettes daily), or heavy (≥20 cigarettes daily) categories. Physical inactivity rates were based on categorization of individuals in the CCHS as "inactive" based on average daily leisure energy expenditure over the preceding 3 months. Respondents were classified as physically inactive if their daily leisure energy expenditure was less than 1.5 kcal/kg (1.5 metabolic equivalents).

We made one adjustment to the base CCHS data: specifically, we estimated the rates of overweight, obesity, and physical inactivity for children less than 12 years of age based on the sex-specific rates for 12- to 14-year-olds in the CCHS. We assumed that children under the age of 12 did not smoke.

Levels of alcohol exposure used in our model were the drinking categories defined by Taylor and colleagues[30]. For men, those categories are abstainer or very light (0–0.24 g daily), category I ("low," 0.25–39.9 g daily), category II ("hazardous," 40.0–59.9 g daily), and category III ("harmful," ≥60.0 g daily). For women, the categories were abstainer or very light (0–0.24 g daily), category I ("low," 0.25–19.9 g daily), category II ("hazardous," 20.0–39.9 g daily), and category III ("harmful," ≥40.0 g daily).

In 2000–2001 and 2011–2012, the CCHS did not gather data on average daily alcohol consumption; we therefore used data on average daily consumption and frequency of drinking occasions from the 2005 iteration of the CCHS[c], combined with frequency of drinking occasions from the 2000–2001 and 2011–2012 iterations of the CCHS to extrapolate the necessary data.

The prevalence of alcohol use was calculated for all individuals 15 years of age and older, and we assumed that no individuals younger than 15 consumed alcohol. For consistency with age groups used in the literature, age categories for alcohol use were also adjusted from those used with the other RFS. The resulting age groups were 15–29, 30–44, 45–59, 60–69, 70–79, and 80 years and up.

The 2005 iteration of the CCHS asked respondents to state the number of drinks (defined as 1 bottle or can of beer, 1 glass of draft, 1 glass of wine or a wine cooler, or 1 cocktail with 45 mL liquor) that they had consumed on each of the past 7 days. Using those responses, each individual's average daily consumption was calculated, based on the assumption that a standard drink contains 13.6 g ethanol[31].

The 2000–2001, 2005, and 2011–2012 iterations of the CCHS all collected data on the frequency of drinking occasions in the preceding 12 months. Those data were used to group respondents into categories of drinking frequency:

[a] Canadian Community Health Survey 2000–2001 public use microdata file (catalogue number 82M0013X2001000). All computations, use, and interpretation of the data are entirely those of H. Krueger and Associates Inc.

[b] Canadian Community Health Survey 2011–2012 public use microdata file (catalogue number 82M0013X2013001). All computations, use, and interpretation of the data are entirely those of H. Krueger and Associates Inc.

[c] Canadian Community Health Survey 2005 public use microdata file (catalogue number 82M0013X2006000). All computations, use, and interpretation of the data are entirely those of H. Krueger and Associates Inc.

less than once monthly, once monthly, 2–3 times monthly, once weekly, 2–3 times weekly, 4–6 times weekly, or every day. Using only the 2005 CCHS, we determined the weighted proportion of individuals reporting a particular average daily consumption, given their drinking frequency in the preceding 12 months. By applying those proportions to the weighted number of individuals reporting a given drinking frequency in 2000–2001 or 2011–2012, we were able to estimate the distribution of average daily consumption by individuals in those years. Average daily consumption was then used to classify all drinkers into the average daily consumption categories (that is, abstainer or very light, or category I, II, or III).

However, self-reported alcohol use tends to be underestimated. Individuals either report fewer drinks than were actually consumed or are unaware of the amount of alcohol present in their drinks[31–33]. Over-pouring is also a common occurrence, particularly among college-aged adults[34]. As a result, respondents tend either to underreport the number of "standard drinks" or to report their "standard drinks" using a much higher estimate of grams of ethanol than researchers assume.

To account for underestimation, it was necessary to adjust the usage values based on CCHS data to more accurately reflect the number of drinks that individuals were consuming. To estimate the degree to which results were underreported, we compared the CCHS results in 2005 to those of Taylor *et al.*[30], which were taken from the 2003–2004 Canadian Addiction Survey and adjusted for underreporting. We assumed that the number of individuals in the abstainer or very light category would not be susceptible to underreporting (that is, underreporting because of inaccurate estimation of drink size would be negligible if only 0 or 1 drinks were consumed monthly). Those values were therefore kept the same. However, category II and category III largely underrepresent the true proportions; we therefore scaled up the proportion of individuals in categories II and III to match those of Taylor *et al.*, and proportionally scaled down the number of individuals in category I. The sex- and age-specific adjustments that scaled our 2005 category II and III values to match Taylor *et al.* were then also applied to data obtained from the 2000–2001 and 2011–2012 CCHS.

Multiple Exposure Levels

The most basic PAF calculation, derived from a single RF prevalence and disease-related RR, uses the formula

$$\text{PAF} = [E(\text{RR} - 1)] \;/\; [E(\text{RR} - 1) + 1], \qquad \text{[Equation 1]}$$

where E is the proportion of the population exposed to the RF of interest (the prevalence), and RR is the relative risk of disease developing in the exposed group. Equation 1 was then used to calculate the PAF of physical inactivity.

However, more sophisticated approaches are required to calculate the PAF when a polytomous RF is involved, as is the case for excess weight, tobacco smoking, and alcohol use. Overweight and obesity should be regarded as a trichotomous exposure to excess body weight because 3 categories of exposure are involved: no excess weight, intermediate excess [overweight (E_{OW})], and more extreme excess [obesity (E_{OB})]. The resulting PAF calculation is

$$\text{PAF} = [E_{\text{OW}}(\text{RR}_{\text{OW}} - 1) + E_{\text{OB}}(\text{RR}_{\text{OB}} - 1)] \;/\; [E_{\text{OW}}(\text{RR}_{\text{OW}} - 1) + E_{\text{OB}}(\text{RR}_{\text{OB}} - 1) + 1]. \qquad \text{[Equation 2]}$$

Tobacco smoking, on the other hand, should be regarded as a tetrachotomous exposure because 4 categories of exposure are involved: non-smoker, light smoker (E_{TSL}), moderate smoker (E_{TSM}), and heavy smoker (E_{TSH}). The resulting PAF calculation is

$$\text{PAF} = [E_{\text{TSL}}(\text{RR}_{\text{TSL}} - 1) + E_{\text{TSM}}(\text{RR}_{\text{TSM}} - 1) + E_{\text{TSH}}(\text{RR}_{\text{TSH}} - 1)] \;/\; [E_{\text{TSL}}(\text{RR}_{\text{TSL}} - 1) + E_{\text{TSM}}(\text{RR}_{\text{TSM}} - 1) + E_{\text{TSH}}(\text{RR}_{\text{TSH}} - 1) + 1]. \qquad \text{[Equation 3]}$$

Alcohol use is also a tetrachotomous exposure with 4 categories of exposure: abstainer, category I [low (E_{AUI})], category II [hazardous (E_{AUII})], and category III [harmful (E_{AUIII}). The resulting PAF calculation is

$$\text{PAF} = [E_{\text{AUI}}(\text{RR}_{\text{AUI}} - 1) + E_{\text{AUII}}(\text{RR}_{\text{AUII}} - 1) + E_{\text{AUIII}}(\text{RR}_{\text{AUIII}} - 1)] \;/\; [E_{\text{AUI}}(\text{RR}_{\text{AUI}} - 1) + E_{\text{AUII}}(\text{RR}_{\text{AUII}} - 1) + E_{\text{AUIII}}(\text{RR}_{\text{AUIII}} - 1) + 1]. \qquad \text{[Equation 4]}$$

Annual Cancer Incidence

Data about the annual incidence of cancers by type and sex in Canada in 2000 and 2010 (the most recent year with data available), together with provincial-level data for 2010, were taken from Statistics Canada's CANSIM table 103-0550[35].

Calculating and Adjusting Costs

We used a prevalence-based cost-of-illness approach to estimate the economic burden (direct and indirect costs) associated with the RFs. The cost estimates are expressed in 2013 Canadian dollars.

Direct costs, including hospital care, physician services, other health care professionals (excluding dental services), drugs, health research, and "other" health care expenditures, were extracted from the National Health Expenditure Database[36]. Hospital care, physician care, and drug costs were allocated to each comorbidity, stratified by sex, based on 2008 data from the Economic Burden of Illness in Canada online tool[37].

The 2008 Economic Burden of Illness in Canada tool does not allocate costs for other health care professionals (excluding dental services), health research, or "other" health care expenditures. Those expenditures were therefore estimated by allocating costs using a proportional distribution the same as that for hospital, physician, and drug costs.

All direct care costs were multiplied by the calculated RF-, sex-, and comorbidity-specific PAFs to calculate the direct care costs attributable to a given RF. By completing the analysis at that level of detail, results were able to be segmented from a number of perspectives, including an assessment of direct care costs by cost category, sex, level of RF exposure, and specific diseases.

Adjusting Direct Costs in a Multifactorial System

To adjust for double counting, we used the following formula to calculate the combined PAF in a multifactorial system[18]:

$$\text{Combined PAF} = 1 - [(1 - \text{PAF}_{TS})(1 - \text{PAF}_{EW})(1 - \text{PAF}_{PIA})(1 - \text{PAF}_{AU})], \qquad \text{[Equation 5]}$$

where PAF_{TS} is the crude PAF for cost of tobacco smoking, PAF_{EW} is the crude PAF for cost of excess weight, PAF_{PIA} is the crude PAF for cost of physical inactivity, and PAF_{AU} is the crude PAF for cost of alcohol use.

A disaggregation step was applied at the end of the direct costing process to assign an economic burden to each RF. In that step, the crude cost for each RF was divided by the sum of the costs for all RFs (that is, the crude total cost for the combined system), thereby generating a ratio that was then applied to the adjusted total cost.

Indirect Costs

We applied the method used in the 1998 Economic Burden of Illness in Canada (a modified human capital approach) to calculate indirect costs (premature mortality, short- and long-term disability)[38]. To make that calculation, we determined the ratio of direct to indirect costs for each diagnostic category within the 1998 Economic Burden of Illness in Canada, stratified by the specific category of indirect cost (that is, short-term disability, long-term disability, and premature mortality)[38]. To generate the equivalent indirect cost data, the pertinent ratios (by diagnostic category and specific indirect cost category) were applied to the previously identified direct costs within each diagnostic category attributable to individual RFs.

Provincial-Level Analysis

After calculating the adjusted economic burden attributable to the 4 RFs in each province, we took the sex- and age-specific prevalence rates for each RF from the province with the lowest overall prevalence rate per RF and applied those to the populations of each remaining province. Thus, the differences in annual incident cancers and in the related economic burden were calculated for each province based on actual prevalence rates and the rates from the comparator province.

Sensitivity Analysis

The point estimates for RR were used in the base model. As reflected by the 95% confidence intervals (CIs), some degree of uncertainty is attached to the point estimates. To assess the effect of that uncertainty on the results, we used the lower and upper bounds of the 95% CI for the RR associated with each RF and disease in a sensitivity analysis.

RESULTS

In Canada in 2013, 27.7% of incident cancer cases (95% CI: 22.6% to 32.9%) were attributable to the RFs of tobacco smoking (15.2%; 95% CI: 13.7% to 16.9%), excess weight (5.1%; 95% CI: 3.8% to 6.4%), alcohol use (3.9%; 95% CI: 2.4% to 5.3%), and physical inactivity (3.5%; 95% CI: 2.7% to 4.3%; Table I). The proportion and the effect of each RF varied by sex, with 25.6% of cancers in women (95% CI: 21.1% to 30.2%) and 29.8% of cancers in men (95% CI: 24.0% to 35.6%) being attributable to the 4 RFs. The effects of smoking and alcohol use are higher in men than in women, and the effects of excess weight and physical inactivity are higher in women (Table I).

The proportion of the cancers attributable to the four RFs declined to 27.7% in 2013 (95% CI: 22.6% to 32.9%) from 30.1% in 2000 (95% CI: 24.8% to 35.4%; Table I). The largest proportion of that decline is connected to tobacco smoking [to 15.2% in 2013 (95% CI: 13.7% to 16.9%) from 17.9% in 2000 (95% CI: 16.1% to 19.8%)]. Despite that decline, the proportion of cancers attributable to tobacco smoking continues to be higher than those for the other 3 RFs combined. The overall decline was not observed for all RFs. The proportion of cancers attributable to excess weight and alcohol use increased from 2000 to 2013. The changes in proportions over time are mirrored in the prevalence of the RFs. The prevalence of tobacco smoking in Canada has declined to 17.5% in 2013 from 21.6% in 2000; at the same time, the prevalence of physical inactivity declined to 43.6% from 49.0%. On the other hand, the prevalence of obesity increased to 15.4% from 12.6%, and the prevalence of hazardous or harmful alcohol use increased to 9.9% from 7.5%.

The proportion of incident cancer cases attributable to the 4 RFs also varies substantially by province, from a low of 23.7% in British Columbia (95% CI: 19.0% to 28.5%) to a high of 32.3% in Quebec (95% CI: 26.7% to 37.9%; Table II).

Of the approximately 170,000 new cancers diagnosed in Canada each year, 47,000 (95% CI: 38,400 to 55,900) are potentially preventable if the RFs of tobacco smoking, excess weight, alcohol use, and physical inactivity were to be removed from the population (Table III). The preventable diagnoses include 17,900 lung cancers (95% CI: 17,700 to 18,100), 10,600 colorectal cancers (95% CI: 7,500 to 13,800), 4900 breast cancers (95% CI: 3300 to 6500), and 3900 cancers of the head and neck (95% CI: 3300 to 4400).

The economic burden attributable to those 47,000 cancers in 2013 was estimated to be $9.6 billion (95% CI: $7.8 billion to $11.3 billion; Table IV). Of that total, $1.7 billion (95% CI: $1.3 billion to $2.0 billion), 17.3%, represented direct costs, and $8.0 billion (95% CI: $6.4 billion to $9.4 billion), 82.7%, represented indirect costs, primarily the indirect costs associated with premature mortality [$7.2 billion (95% CI: $5.8 billion to $8.5 billion)].

British Columbia had the lowest prevalence of tobacco smoking, excess weight, and physical inactivity in Canada[20]; Prince Edward Island had the lowest prevalence of hazardous and harmful alcohol use. Because of the relatively small population sample from Prince Edward Island, we combined its age- and sex-specific prevalence rates with those for New Brunswick, the province with the second-lowest proportion of cancers attributable to alcohol (Table II).

Applying the sex- and age-specific prevalence rates for tobacco smoking, excess weight, and physical inactivity from British Columbia and for alcohol use from Prince Edward Island and New Brunswick to the populations of all other provinces would result in a reduction of 6204 (13.2%) potentially avoidable cancers and a reduction of $1.2 billion in economic burden annually (Table V). The proportion of cancers attributable to the 4 RFs that could potentially be avoided range from 1.1% (57 of 4992) in British Columbia to 21.4% (203 of 945) in Newfoundland and Labrador.

DISCUSSION

Approximately 47,000 of 170,000 new cancers diagnosed in Canada each year (27.7%) are caused by tobacco smoking, excess weight, alcohol use, and physical inactivity—a proportion that has declined from 30.1% in 2000. The greatest proportion of the decline is attributable to a reduction in the prevalence and intensity of tobacco smoking and, to a lesser degree, to improvements in physical activity. However, those improvements are offset to some degree by increases in the prevalence of excess weight and hazardous

TABLE I Proportion of cancers attributable to tobacco smoking, excess weight, alcohol use, and physical inactivity, Canada, 2000 and 2013

Risk factor, by sex	2000		2013		Variance	Percentage variance
	Value	95% CI	Value	95% CI		
Women (%)						
Tobacco smoking	14.5	12.9 to 16.2	12.4	11.2 to 13.7	–2.1	–14.2
Excess weight	5.1	3.8 to 6.4	5.7	4.4 to 7.0	0.6	11.8
Alcohol use	1.8	1.1 to 2.6	2.2	1.4 to 3.0	0.4	20.7
Physical inactivity	6.3	4.9 to 7.6	5.3	4.1 to 6.4	–1.0	–16.2
SUBTOTAL	27.7	22.7 to 32.7	25.6	21.1 to 30.2	–2.1	–7.6
Men (%)						
Tobacco smoking	21.1	19.1 to 23.2	17.9	16.0 to 20.0	–3.2	–15.1
Excess weight	4.1	3.0 to 5.3	4.5	3.3 to 5.8	0.4	9.4
Alcohol use	5.0	3.0 to 6.8	5.5	3.3 to 7.5	0.5	9.1
Physical inactivity	2.1	1.6 to 2.6	1.9	1.5 to 2.3	–0.2	–10.3
SUBTOTAL	32.4	26.7 to 38.0	29.8	24.0 to 35.6	–2.6	–7.9
Overall (%)						
Tobacco smoking	17.9	16.1 to 19.8	15.2	13.7 to 16.9	–2.7	–15.1
Excess weight	4.6	3.4 to 5.8	5.1	3.8 to 6.4	0.5	10.9
Alcohol use	3.5	2.1 to 4.8	3.9	2.4 to 5.3	0.4	11.0
Physical inactivity	4.1	3.2 to 5.0	3.5	2.7 to 4.3	–0.6	–13.8
TOTAL	30.1	24.8 to 35.4	27.7	22.6 to 32.9	–2.4	–7.9

TABLE II Proportion of cancers attributable to tobacco smoking, excess weight, alcohol use, and physical inactivity, Canada and provinces, 2013

Risk factor, by sex	Canada	BC	AB	SK	MB	ON	QC	NB	PE	NS	NL
Women (%)											
Tobacco smoking	12.4	10.8	11.9	14.3	13.8	10.8	15.0	14.3	12.9	15.1	12.6
Excess weight	5.7	4.7	5.6	6.8	6.2	5.7	5.4	7.6	7.2	7.4	8.8
Alcohol use	2.2	2.4	2.1	2.1	2.1	2.1	2.6	2.0	2.4	2.0	1.9
Physical inactivity	5.3	4.7	5.3	5.5	5.1	5.2	5.6	5.4	6.0	5.4	6.1
SUBTOTAL	25.6	22.6	24.9	28.6	27.3	23.7	28.6	29.4	28.5	29.9	29.5
Men (%)											
Tobacco smoking	17.9	13.8	16.6	16.6	16.5	15.9	23.2	20.8	19.9	20.0	19.5
Excess weight	4.5	4.0	4.4	6.0	5.6	4.2	4.6	5.6	5.2	5.9	6.8
Alcohol use	5.5	5.4	5.5	5.5	5.7	5.3	5.9	4.6	3.8	5.1	5.5
Physical inactivity	1.9	1.6	1.9	2.1	2.2	1.7	2.2	2.0	1.7	2.2	2.6
SUBTOTAL	29.8	24.7	28.5	30.1	29.9	27.1	35.9	33.0	30.6	33.1	34.3
Overall (%)											
Tobacco smoking	15.2	12.4	14.4	15.5	15.1	13.4	19.1	17.9	16.6	17.6	16.5
Excess weight	5.1	4.3	5.0	6.4	5.9	4.9	5.0	6.5	6.2	6.6	7.7
Alcohol use	3.9	4.0	3.9	3.7	3.9	3.7	4.3	3.4	3.1	3.6	3.9
Physical inactivity	3.5	3.1	3.5	3.8	3.6	3.4	3.9	3.5	3.7	3.8	4.1
TOTAL	27.7	23.7	26.8	29.4	28.6	25.4	32.3	31.3	29.6	31.6	32.2

TABLE III Cancers attributable to tobacco smoking, excess weight, alcohol use, and physical inactivity, Canada, 2013

Cancer type	ICD-10 code	Women			Men			Overall		
		Attributable (*n*)	Total (*n*)	Attributable proportion (%)	Attributable (*n*)	Total (*n*)	Attributable proportion (%)	Attributable (*n*)	Total (*n*)	Attributable proportion (%)
Lip, oral cavity, pharynx, larynx	C00–14, 30–32	692	1,550	44.6	3,145	3,795	82.9	3,837	5,345	71.8
Esophagus	C15	122	420	29.1	930	1,345	69.2	1,053	1,765	59.6
Stomach	C16	140	1,075	13.0	415	1,870	22.2	555	2,945	18.8
Colorectal	C18–20	3,953	9,625	41.1	6,641	11,330	58.6	10,594	20,955	50.6
Liver	C22	66	400	16.6	320	1,230	26.0	387	1,630	23.7
Pancreas	C25	291	1,885	15.4	738	1,880	39.3	1,029	3,765	27.3
Trachea, bronchus, lung	C33–34	7,939	10,850	73.2	9,965	12,325	80.9	17,904	23,175	77.3
Breast	C50	4,942	22,625	21.8				4,942	22,625	21.8
Corpus uteri[a]	C54–55	1,631	5,190	31.4				1,631	5,190	31.4
Ovary	C56	219	2,465	8.9				219	2,465	8.9
Prostate	C61				868	21,930	4.0	868	21,930	4.0
Kidney	C64	788	1,850	42.6	1,197	3,070	39.0	1,985	4,920	40.3
Urinary bladder	C67	422	1,750	24.1	1,631	5,445	29.9	2,052	7,195	28.5
SUBTOTAL		21,205	59,685	35.5	25,850	64,220	40.3	47,055	123,905	38.0
Overall			82,885	25.6		86,695	29.8		169,580	27.7

[a] Including endometrium.

and harmful alcohol use. The estimated annual economic burden attributable to those 47,000 cancers is $9.6 billion.

The proportion of cancers attributable to the 4 RFS varies by sex (25.6% for women vs. 29.8% for men). The effects of smoking and alcohol use are higher in men than in women, and the effects of excess weight and physical inactivity are higher in women. A higher proportion of Canadian men tend to be heavy smokers (6.4% vs. 2.8% of women) and heavy or harmful users of alcohol (6.0% vs. 2.3% of women). In women, the risk of breast, uterine, and ovarian cancers attributable to excess weight accounts for the difference between women and men. The risk of breast cancer also accounts for the difference between women and men with respect to physical inactivity.

The estimated proportion of cancers attributable to the 4 RFS also varies by province: from 23.7% in British Columbia to 32.2% in Newfoundland and Labrador. Variation between the provinces tends to reflect differences in the prevalence of the RFS between provinces[20]. Among the provinces, Quebec has the highest prevalence of smoking, contributing substantially to a higher observed proportion of cancers. British Columbia has the lowest rates of smoking, excess weight, and physical inactivity, leading to its lower observed proportion of cancers. However, the prevalence of hazardous or harmful alcohol use in British Columbia, at 9.9% of the population, is the second-highest in the country (range: 7.3% in Prince Edward Island to 11.9% in Quebec). Only in Quebec is the proportion of cancers attributable to alcohol use higher than it is in British Columbia (4.4% vs. 4.0% respectively; Table II).

If age- and sex-specific prevalence rates from the provinces with the lowest prevalences of the 4 RFS were to be applied to populations living in the other provinces, the result would be an annual reduction of 6204 (13.2%) potentially avoidable cancers and a reduction of $1.2 billion in economic burden annually.

Despite substantial reductions in the prevalence and intensity of tobacco smoking in Canada, tobacco smoking remains the dominant RF from the perspective of cancer prevention[20]. Between 2000 and 2013, the prevalence of tobacco smoking in Canada declined to 17.5% from 21.6%. Just as importantly, the prevalence of heavy smoking declined to 4.5% from 7.6%. Nevertheless, of the cancers caused by the 4 RFS, almost 55% are still caused by tobacco smoking. Although excess weight and alcohol use have a lesser effect on cancers than does tobacco smoking, the proportion of the cancers caused by the 4 RFS that is attributable to the former 2 RFS is increasing: in the case of excess weight, to 18.4% in 2013 from 15.3% in 2000; and in the case of alcohol use, to 14.1% from 11.6%.

In the United Kingdom in 2010, 19.4% of cancers were attributable to tobacco smoking, 5.5% to excess weight, 4.0% to alcohol use, and 1.0% to physical inactivity[17]. The equivalent proportions in the current study are 15.2%, 5.1%, 3.9%, and 3.5% respectively. The higher proportion of cancers attributable to tobacco smoking in the United Kingdom is likely linked to a higher prevalence of tobacco smoking in that country, where 22% of men and 19% of women 16 years of age and older were *current* tobacco smokers[39] in 2012 (compared with 18.8% and 13.4% respectively in Canada).

The U.K. study also estimated that just 1.0% of cancers are attributable to physical inactivity, compared with Canada's 3.5%. The U.K. study calculated change in risk per metabolic equivalent below the optimal physical activity

TABLE IV Annual economic burden of cancers attributable to tobacco smoking, excess weight, alcohol use, and physical inactivity, Canada, 2013 ($ millions)

Risk factor, by sex	Direct		Indirect								Total economic burden	
			Premature mortality		Long-term disability		Short-term disability		SUBTOTAL			
	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI	Cost	95% CI
Women												
Tobacco smoking	318	286 to 351	1,370	1,232 to 1,514	124	112 to 137	22	20 to 25	1,516	1,363 to 1,676	1,834	1,649 to 2,027
Excess weight	172	132 to 212	742	568 to 915	67	51 to 83	12	9 to 15	822	628 to 1,013	994	760 to 1,225
Alcohol use	71	46 to 95	308	201 to 408	28	18 to 37	5	3 to 7	341	222 to 452	412	268 to 546
Physical inactivity	161	129 to 190	696	554 to 819	63	50 to 74	11	9 to 13	771	614 to 907	932	742 to 1,097
SUBTOTAL	722	592 to 848	3,116	2,554 to 3,656	282	231 to 331	51	42 to 60	3,449	2,828 to 4,047	4,172	3,420 to 4,895
Men												
Tobacco smoking	476	423 to 529	2,053	1,825 to 2,281	186	165 to 207	34	30 to 37	2,273	2,020 to 2,525	2,749	2,443 to 3,054
Excess weight	169	125 to 211	727	537 to 909	66	49 to 82	12	9 to 15	805	595 to 1,060	973	719 to 1,216
Alcohol use	221	148 to 285	955	638 to 1,229	87	58 to 111	16	10 to 20	1,058	707 to 1,360	1,279	855 to 1,645
Physical inactivity	77	62 to 93	332	268 to 401	30	24 to 36	5	4 to 7	368	296 to 444	445	358 to 537
SUBTOTAL	943	758 to 1,117	4,068	3,268 to 4,820	369	296 to 437	66	53 to 79	4,503	3,618 to 5,335	5,446	4,376 to 6,453
Overall												
Tobacco smoking	794	709 to 880	3,423	3,057 to 3,795	310	277 to 344	56	50 to 62	3,789	3,383 to 4,201	4,583	4,092 to 5,081
Excess weight	341	256 to 423	1,469	1,105 to 1,824	133	100 to 165	24	18 to 30	1,626	1,223 to 2,019	1,967	1,479 to 2,441
Alcohol use	293	194 to 379	1,263	839 to 1,637	114	76 to 148	21	14 to 27	1,398	929 to 1,812	1,691	1,123 to 2,191
Physical inactivity	238	191 to 283	1,029	822 to 1,220	93	74 to 111	17	13 to 20	1,139	910 to 1,351	1,377	1,101 to 1,634
TOTAL	1,665	1,350 to 1,965	7,184	5,823 to 8,476	651	528 to 768	117	95 to 139	7,953	6,446 to 9,383	9,618	7,795 to 11,348

level. By comparison, we used an inactive or active dichotomy of more or less than 1.5 metabolic equivalents. The RR used in calculating the PAF was also much lower in the U.K. study than in the present study (for example, 1.09 for colon cancer vs. 1.41 for colorectal cancer). As a result, 3.4% of postmenopausal breast cancers, 3.8% of endometrial cancers, and 5.3% of colon cancers were found to be attributable to inadequate physical exercise in the United Kingdom[40]. By comparison, we estimated that 12.6% of breast cancers and 15.1% of colorectal cancers are attributable to physical inactivity in Canada.

Our study has a number of limitations. First, calculating the prevalence of alcohol use by sex, age, and consumption category is particularly challenging given current data availability and issues of underreporting. Despite our best efforts to adjust for underreporting, the actual prevalence of alcohol use could vary from our estimates. Second, the method of scaling up from direct to indirect costs depends on the assumption that the ratios of costs have not changed over time. Third, in generating disease-specific RRs, the sources for the RRs associated with smoking and physical inactivity adjust for known confounding factors. However, the meta-analyses for the RRs associated with overweight and obesity did not include physical inactivity as a potentially confounding RF, which might lead to an overestimate of the economic burden attributable to excess weight. Finally, the inclusion of indirect costs in any economic analysis is controversial, given that the various available approaches generate very different results. We used a modified human capital approach because that approach places an economic value on time lost because of disability and premature mortality. Using the friction cost method,

TABLE V Potentially avoidable cancer and economic burden attributable to tobacco smoking, excess weight, alcohol use, and physical inactivity, Canada and provinces, 2013[a]

Variable	Canada	BC	AB	SK	MB	ON	QC	NB	PE	NS	NL
Total cancers (*n*)	169,580	21,050	14,645	4,930	6,065	64,930	44,005	4,290	795	5,630	2,935
Attributable cancers (*n*)	47,055	4,992	3,922	1,447	1,733	16,524	14,216	1,344	235	1,776	945
Percentage attributable cancers (%)	27.7	23.7	26.8	29.4	28.6	25.4	32.3	31.3	29.6	31.6	32.2
Attributable cancer–related economic burden ($ millions)											
Direct	1,665	136	164	46	53	570	519	42	7	52	30
Indirect	7,953	639	781	220	255	2,722	2,478	202	35	246	141
Total	9,618	775	945	266	309	3,292	2,997	245	43	297	171
Economic burden per incident attributable cancer ($)											
Direct	35,393	27,210	41,717	31,768	30,835	34,499	36,507	31,527	31,446	28,999	31,324
Indirect	169,004	128,044	199,197	151,694	147,237	164,735	174,321	150,541	150,154	138,470	149,571
Total	204,398	155,254	240,914	183,462	178,072	199,234	210,828	182,067	181,600	167,468	180,894
Attributable cancers[b] potentially avoided (*n*)	6,204	57	558	217	220	1,835	2,517	257	38	302	203
Percentage attributable cancers potentially avoided (%)	13.2	1.1	14.2	15.0	12.7	11.1	17.7	19.1	16.2	17.0	21.4
Economic burden associated with attributable cancers potentially avoided ($ millions)											
Direct	201	2	22	6	6	62	82	7	1	8	6
Indirect	958	1	104	31	31	297	392	33	5	37	28
Total	1,159	3	125	37	37	360	475	39	6	45	33
Percentage of economic burden potentially avoidable (%)	12.0	0.4	13.3	14.0	12.1	10.9	15.8	16.1	14.6	15.2	19.6

[a] Based on lowest provincial prevalence rates and considering all 4 risk factors.

with its narrow focus on production losses, could reduce the indirect costs from $8.0 billion (95% CI: $6.4 billion to $9.4 billion) to just $204 million (95% CI: $166 million to $240 million][20].

CONCLUSIONS

An estimated 27.7% of new cancers diagnosed in Canada each year (95% CI: 22.6% to 32.9%) are caused by tobacco smoking, excess weight, alcohol use, and physical inactivity. The economic burden attributable to those 47,000 cancers (95% CI: 38,400 to 55,900) in 2013 is estimated at $9.6 billion (95% CI: $7.8 billion to $11.3 billion). Despite significant reductions in the prevalence and intensity of tobacco smoking in Canada, tobacco smoking remains the dominant RF from the perspective of cancer prevention in the country. Of the estimated annual economic burden of $9.6 billion, $4.6 billion (95% CI: $4.1 billion to $5.1 billion)—that is, 47.7%—is attributable to tobacco smoking.

CONFLICT OF INTEREST DISCLOSURES

We have read and understood *Current Oncology*'s policy on disclosing conflicts of interest, and we declare that we have none.

AUTHOR AFFILIATIONS

*School of Population and Public Health, University of British Columbia, Vancouver, BC; †H. Krueger and Associates Inc., Delta, BC.

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