Preventing alcohol-related cancer: what if everyone drank within the guidelines?

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Abstract

Objectives The purpose of this study was to estimate the proportion and number of cancer cases diagnosed in Ontario in 2012 that are attributable to alcohol consumption and to compare the impact of drinking within two sets of guidelines on alcohol-attributable cancer incidence.

Methods We estimated the proportion of cancers in Ontario attributable to alcohol consumption by calculating population-attributable fractions (PAFs) for six cancer types using drinking prevalence from the 2000/2001 Canadian Community Health Survey and relative risks from a meta-analysis. Each PAF was multiplied by the number of incident cancers in 2012, allowing for a 12-year latency period, to calculate the number of alcohol-attributable cases. We also estimated the number of alcohol-attributable cases under two scenarios: (1) assuming consumption had not exceeded the levels recommended by the Low-Risk Alcohol Drinking Guidelines (LRADG) and (2) assuming consumption had not exceeded the recommended levels by the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) guidelines.

Results One thousand two hundred ninety-five (95% confidence interval 1093–1499) new cases of cancer diagnosed in Ontario during 2012 are estimated to be attributed to alcohol consumption, representing approximately 1.7% (1.4–1.9%) of all new cancer cases. If no Ontario adults had exceeded the LRADG, an estimated 321 fewer cancer cases could have been diagnosed in 2012, whereas an estimated 482 fewer cancer cases could have been diagnosed if no Ontario adults had exceeded the stricter WCRF/AICR guidelines.

Conclusion Strategies to limit alcohol consumption to the levels recommended by drinking guidelines could potentially reduce the cancer burden in Ontario.

Keywords Neoplasms · Alcoholic beverages · Alcohol drinking

Introduction

The International Agency for Research on Cancer (IARC) has classified alcohol consumption as carcinogenic to humans, citing sufficient evidence that it causes cancers of the oral cavity, pharynx, larynx, esophagus, colorectum, liver, and female breast (International Agency for Research on Cancer 2012). In addition to cancer, alcohol is causally associated

with other chronic diseases and acute conditions (Rehm et al. 2010). There is evidence of both detrimental and protective effects of alcohol consumption on hypertension and cardiovascular diseases (Shield et al. 2013).

Guidelines have been developed in many countries to help individuals reduce their alcohol-related harm (Kalinowski and Humphreys 2016). In Canada, two sets of guidelines are commonly promoted. The Low-Risk Alcohol Drinking Guidelines (LRADG), published by the Canadian Centre on Substance Abuse in 2011, state that to reduce long-term health risks, men should drink no more than 15 drinks per week, with no more than three drinks per day on most days, while women should drink no more than 10 drinks per week, with no more than two drinks per day on most days (Canadian Centre on Substance Abuse 2016). A cancer-specific set of guidelines, developed in 2007 by the World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR), state that if

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alcoholic beverages are consumed, consumption should be limited to no more than two drinks per day for men and one drink per day for women, which translates to 14 drinks per week for men and seven for women (World Cancer Research Fund/American Institute for Cancer Research 2007).

The WCRF/AICR guidelines have been adopted, with somewhat different wording, by several cancer-related organizations in Canada, including Cancer Care Ontario and the Canadian Cancer Society (Cancer Care Ontario 2014; Canadian Cancer Society 2016). While the alcohol amounts specified in the WCRF/AICR guidelines are lower than those in the LRADG, the WCRF/AICR acknowledges that there is no “safe limit” of alcohol consumption to prevent increased cancer risk (World Cancer Research Fund/American Institute for Cancer Research 2007). Both sets of guidelines consider multiple harms and potential benefits, but the weighting of each is different.

Recent studies conducted in Canada and other countries have estimated the cancer incidence attributable to alcohol consumption (Grundy et al. 2016; Parkin 2011; Pandeya et al. 2015; Schutze et al. 2011; Praud et al. 2016). These studies provide estimates of the alcohol-attributable burden of cancer that could be prevented assuming exposure to alcohol in the population was reduced to zero. However, total abstinence from alcohol at the population level is likely not feasible. Therefore, we sought to calculate a more realistic estimate of the number of cancers that could potentially be prevented by estimating the alcohol-attributable burden of cancer under the assumption that alcohol consumption was reduced to levels recommended by the drinking guidelines promoted in Canada. Additionally, we sought to compare the potential impact of adhering to the LRADG with the WCRF/AICR guidelines because both are commonly promoted in Canada.

The first objective of this study is to estimate the proportion and number of cancers diagnosed in Ontario in 2012 attributable to alcohol consumption. The second objective is to compare the potential impact of drinking within the LRADG and the WCRF/AICR guidelines on the alcohol-attributable cancer burden in Ontario.

Methods

Exposure prevalence estimates

We estimated alcohol consumption prevalence in Ontario using cycle 1.1 (2000/2001) of the Canadian Community Health Survey (CCHS) by applying methods that we developed previously (Cancer Care Ontario 2014; Cancer Care Ontario 2016). A methodological overview of the CCHS has been described elsewhere (Beland 2002). We derived 15 consumption categories based on the following questions:

1. Thinking back over the past week, did you have a drink of beer, wine, liquor, or any other alcoholic beverage? If yes, how many drinks did you have on each day?
2. During the past 12 months, how often did you drink alcoholic beverages?
3. Have you ever had a drink? If yes, did you ever regularly drink more than 12 drinks a week? (Respondents were only asked this question if they reported not drinking during the past 12 months.)

We estimated the proportion of the population within each consumption category by sex and age group (Table 1). The age groups used (19–29, 30–44, 45–64, and 65+) were consistent with the sampling strategy of the CCHS.

For each sex, age group, and consumption category combination, we estimated the quantity of alcohol consumed by assigning each category combination a specific number of drinks per day using methods that we developed previously (Table 2) and multiplying this by 13.6 g, the amount of alcohol in one standard drink in Canada (Cancer Care Ontario 2014; Cancer Care Ontario 2016). Briefly, we assigned consumption categories 1 through 5 the median number of drinks per day consumed in each category, categories 6 through 12 the quantity consumed by similar respondents who reported drinking during the past week, and categories 13 and 14 a quantity based on their estimated level of consumption before the past year. We multiplied the number of drinks by 13.6 to obtain the quantity of alcohol consumed in grams per day.

Relative risk estimates

We examined six cancer types for which there was either sufficient evidence of an association between alcohol consumption and increased cancer risk according to the IARC or convincing evidence of an association according to the WCRF: oral cavity and pharynx (ICD-O-3 site codes C00–C14), esophagus (squamous cell carcinoma; C15, histology codes 8050–8078, 8083–8084), colon and rectum (C18–C19 and C26.0), liver (C22), larynx (C32), and female breast (C50). Relative risk estimates were obtained from a recent meta-analysis by Bagnardi and colleagues (Bagnardi et al. 2015). The increase in risk per gram of alcohol intake per day was 0.0273 for cancer of the oral cavity and pharynx, 0.0267 for squamous cell carcinoma of the esophagus, 0.0061 for cancer of the colon and rectum, 0.0121 for cancer of the liver, 0.0162 for cancer of the larynx, and 0.0079 for cancer of the female breast.

Cancer incidence attributable to alcohol consumption

We calculated the population-attributable fraction (PAF) for each cancer type, sex, and age group combination using

Table 1 Estimated proportion of the population (%) aged 19+ in alcohol consumption categories, by sex and age group, Ontario, 2000–2001

Consumption category		% of the Ontario population (95% confidence interval)							
		Males by age (years)				Females by age (years)			
		19–29	30–44	45–64	65+	19–29	30–44	45–64	65+
1	Drank during the past week: average ≤ 1 drink/day	32.4 (29.5–35.3)	37.1 (35.2–38.9)	37.1 (35.1–39.1)	33.7 (31.1–36.2)	31.8 (29.4–34.3)	37.4 (35.5–39.3)	36.0 (34.1–37.9)	25.5 (23.3–27.6)
2	Drank during the past week: average 1–2 drinks/day	12.9 (10.9–15.0)	11.4 (10.3–12.5)	12.6 (11.4–13.9)	9.7 (8.0–11.3)	6.3 (5.0–7.6)	5.8 (5.0–6.6)	4.6 (3.8–5.4)	3.4 (2.6–4.2)
3	Drank during the past week: average 2–3 drinks/day	6.4 (5.2–7.6)	4.4 (3.6–5.2)	5.0 (4.1–5.8)	3.3 (2.4–4.3)	1.6 (1.0–2.2)	1.0 (0.7–1.4)	0.9 (0.5–1.3)	1.0 (0.4–1.5)
4	Drank during the past week: average 3–4 drinks/day	3.2 (2.1–4.2)	1.7 (1.3–2.2)	2.0 (1.5–2.5)	1.0 (0.6–1.5)	0.5 (0.2–0.9)	0.3 (0.1–0.4)	0.1 (0.0–0.2)	0 (0–0)
5	Drank during the past week: average ≥ 4 drinks/day	3.4 (2.5–4.2)	1.8 (1.3–2.2)	1.4 (1.0–1.8)	1.3 (0.6–1.9)	0.5 (0.1–0.8)	0.2 (0.1–0.3)	0.1 (0–0.2)	0 (0–0)
6	No drinking during the past week but drank during the past year ≤ 1 time/month	9.0 (7.0–10.9)	11.8 (10.3–13.3)	10.5 (9.3–11.7)	11.9 (10.2–13.7)	18.3 (16.3–20.2)	19.9 (18.2–21.6)	18.9 (17.4–20.4)	19.4 (17.6–21.2)
7	No drinking during the past week but drank during the past year 1 time/month	7.1 (5.2–9.0)	5.8 (5.0–6.7)	4.1 (3.3–4.9)	3.5 (2.7–4.3)	8.6 (7.1–10.0)	5.9 (5.1–6.8)	5.5 (4.5–6.5)	3.6 (2.7–4.6)
8	No drinking during the past week but drank during the past year 2–3 times/month	6.4 (4.9–8.0)	5.3 (4.4–6.3)	4.4 (3.5–5.2)	3.9 (2.8–5.1)	8.8 (7.1–10.5)	4.7 (3.9–5.5)	4.9 (4.1–5.8)	3.4 (2.5–4.3)
9	No drinking during the past week but drank during the past year 1 time/week	4.6 (3.3–5.9)	4.6 (3.8–5.4)	3.6 (2.8–4.3)	2.0 (1.4–2.5)	3.6 (2.6–4.6)	2.6 (1.9–3.3)	2.8 (2.2–3.5)	2.2 (1.5–2.9)
10	No drinking during the past week but drank during the past year 2–3 times/week	1.9 (0.9–2.9)	1.8 (1.3–2.2)	1.9 (1.4–2.3)	1.8 (1.1–2.4)	1.5 (0.9–2.1)	1.1 (0.8–1.5)	1.1 (0.7–1.5)	1.3 (0.7–1.9)
11	No drinking during the past week but drank during the past year 4–6 times/week	0.1 (0.1–0.3)	0.5 (0.1–0.9)	0.2 (0–0.4)	0.3 (0–0.6)	0.1 (0–0.1)	0.1 (0–0.2)	0.2 (0.1–0.4)	0.2 (0–0.3)
12	No drinking during the past week but drank during the past year every day	0.2 (0.1–0.4)	0.2 (0.1–0.4)	0.4 (0.2–0.6)	1.3 (0.6–1.9)	0.1 (0.1–0.3)	0.1 (0–0.3)	0.1 (0–0.2)	0.1 (0–0.2)
13	Has had ≥ 1 drink in lifetime: used to regularly drink > 12 drinks/week	0.4 (0.2–0.7)	2.7 (2.0–3.3)	4.6 (3.8–5.3)	5.3 (4.3–6.4)	0.4 (0.2–0.6)	0.9 (0.6–1.2)	1.2 (0.8–1.6)	0.7 (0.3–1.0)
14	Has had ≥ 1 drink in lifetime: did not regularly drink > 12 drinks/week	4.8 (3.5–6.1)	5.7 (4.7–6.7)	7.0 (6.0–8.1)	13.5 (11.6–15.4)	6.9 (5.7–8.2)	9.8 (8.7–10.9)	13.7 (12.2–15.3)	24.4 (22.4–26.4)
15	Lifetime abstainers	7.2 (5.4–9.0)	5.2 (4.2–6.3)	5.2 (4.1–6.4)	7.4 (5.7–9.0)	11.0 (8.9–13.1)	10.1 (8.6–11.6)	9.7 (8.3–11.2)	14.8 (12.9–16.6)

Table 2 Median quantities of alcohol consumed (grams per day) for alcohol consumption categories by sex and age group

Consumption category	Males by age (years)				Females by age (years)			
	19–29	30–44	45–64	65+	19–29	30–44	45–64	65+
1 Drank during the past week: average ≤ 1 drink/day	4.8	4.8	5.6	5.5	4.1	3.7	3.7	3.5
2 Drank during the past week: average 1–2 drinks/day	18.2	18.4	19.8	22.2	17.6	18.3	19.1	25.4
3 Drank during the past week: average 2–3 drinks/day	32.7	32.6	33.6	36.7	32.3	30.6	31.5	38.9
4 Drank during the past week: average 3–4 drinks/day	48.6	47.2	47.6	47.8	48.1	49.0	44.3	44.7
5 Drank during the past week: average ≥ 4 drinks/day	73.1	68.1	70.9	67.9	59.9	67.1	85.8	58.3
6 No drinking the past week but drank during past year ≤ 1 time/month	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
7 No drinking during the past week but drank during the past year 1 time/month	0.5	0.7	0.5	0.5	0.5	0.5	0.5	0.5
8 No drinking during the past week but drank during the past year 2–3 times/month	1.8	2.1	1.6	1.1	2.2	1.2	1.1	1.1
9 No drinking during the past week but drank during the past year 1 time/week	5.0	3.8	3.4	1.9	3.8	3.4	2.5	1.9
10 No drinking during the past week but drank during the past year 2–3 times/week	19.2	9.6	9.0	6.1	12.0	8.3	6.4	5.3
11 No drinking during the past week but drank during the past year 4–6 times/week	34.3	19.3	21.0	11.5	20.5	15.0	13.5	9.7
12 No drinking during the past week but drank during the past year everyday	42.6	27.1	25.6	17.8	13.6	21.1	15.5	13.6
13 Has had ≥ 1 drink in lifetime: used to regularly drink > 12 drinks/week	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3
14 Has had ≥ 1 drink in lifetime: did not regularly drink > 12 drinks/week	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2

methods described by Parkin (2011). We used the following formula:

$$\text{PAF} = \frac{\sum (p_x \times \text{ERR}_x)}{1 + \sum (p_x \times \text{ERR}_x)}$$

where p_x is the proportion of the population in consumption category x and ERR_x is the excess relative risk ($\text{RR}_x - 1$) in consumption category x .

We calculated the ERR for each consumption category x using the following formula:

$$\text{ERR}_x = \exp(R_g \times G_x) - 1$$

where R_g is the increase in risk per gram of alcohol intake and G_x is the quantity of alcohol consumed in grams per day in consumption category x .

To estimate 95% confidence intervals (CIs) around the PAF estimates, we used Monte Carlo simulation in @RISK (@RISK: Risk Analysis Add-In for Microsoft Excel, Professional Edition, version 7.0.0, Palisade Corporation, 2015). We defined the input parameters by their reported point estimates and CIs, using a lognormal distribution to define the relative risk estimates and a normal distribution to define the exposure prevalence estimates. We set the number of iterations to 10,000 and used the 2.5th and 97.5th percentiles of the output PAF distribution as the lower and upper limits of the 95% CI.

The PAFs were applied to incident cancer cases diagnosed in 2012, the most recent data available at the time of analysis, that were extracted from the Ontario Cancer Registry. The OCR is a population-based registry containing

information on all new invasive cancer cases diagnosed in the province, except for squamous and basal cell carcinoma. By using the 2000/2001 CCHS and by applying PAFs based on these data to cancer cases diagnosed in 2012, we assumed a latency period of 12 years. This was done because the 2000/2001 CCHS contained the earliest data on alcohol consumption in the Ontario population that were available to us. Also, it is known that there is a latency period between the time of alcohol exposure and the time of cancer diagnosis, but the duration of that latency period is not well established. It is also likely that the latency period varies by cancer type due to differences in the process of carcinogenesis (Boffetta and Hashibe 2006). Cancer incidence data were extracted for age groups 31–41, 42–56, 57–76, and 77+. For each cancer type, the number of alcohol-attributable cancer cases was calculated by sex and age group by multiplying the total number of cases diagnosed in 2012 by the PAF for the corresponding sex and age group (e.g., exposure prevalence data for the 19–29 age group was applied to cancer incidence data for the 31–41 age group).

Potential impact of drinking within the LRADG or WCRF/AICR guidelines

The primary analysis assumes that alcohol consumption at the population level is reduced to zero (i.e., alcohol is completely eliminated). Because this is likely not feasible, we estimated the alcohol-attributable cancer incidence assuming two different scenarios, assuming consumption had not exceeded the levels recommended by (1) the LRADG and (2) the

WCRF/AICR guidelines. We modeled each scenario separately by assuming that any CCHS respondents who reported consuming more alcohol than recommended by the daily and weekly limits during the past week instead consumed the recommended maximum amount. Prior to estimating exposure prevalence, we made the following assumptions:

1. LRADG: We assumed that any male respondent who reported consuming more than three drinks on any day during the past week instead consumed three drinks on that day. If, after this assumption was made, the respondent reported consuming more than 15 drinks during the past week, we assumed that he consumed 15 drinks. We assumed that any female respondent who reported consuming more than two drinks on any day during the past week instead consumed two drinks on that day. If, after this assumption was made, the respondent reported consuming more than 10 drinks during the past week, we assumed that she consumed 10 drinks.
2. WCRF/AICR guidelines: We assumed that any male respondent who reported consuming more than two drinks on any day during the past week instead consumed two drinks on that day. We assumed that any female respondent who reported consuming more than one drink on any day during the past week instead consumed one drink on that day.

Under each alternative exposure scenario, we estimated the number of cancer cases attributable to alcohol consumption and calculated the potential impact fraction (PIF) based on methods described by Pandeya and colleagues (Pandeya et al. 2015). The PIF is equivalent to the proportional difference between the observed number of cancer cases and the expected number under the alternative exposure scenarios, which we calculated using the following formula:

$$\text{PIF} = \frac{\text{cases}_{\text{obs}} - \text{cases}_{\text{exp}}}{\text{cases}_{\text{obs}}}$$

where $\text{cases}_{\text{obs}}$ is the number of cancer cases observed in 2012 and $\text{cases}_{\text{exp}}$ is the number of cancer cases expected under the alternative exposure scenario.

Results

In 2000–2001, most Ontario adults aged 19 years and older reported consuming alcohol in the past year (84% of males and 75% of females). More males than females reported drinking at higher levels of consumption across all age groups; the highest prevalence of drinking at the heaviest level of consumption (an average of ≥ 4 drinks/day) was observed among males aged 19–29 years (Table 1).

The estimated numbers and proportions of cancer cases attributable to alcohol consumption by sex and cancer type are shown in Table 3. In 2012, 1295 (95% CI 1093–1499) new cancer cases diagnosed in Ontario are estimated to be attributable to alcohol consumption of any amount based on the 2000/2001 CCHS (848 [719–980] cases in males and 447 [324–576] cases in females). This represents approximately 1.7% (1.4–1.9%) of all new cancer cases and 5.7% (4.8–6.5%) of alcohol-related cancer cases (i.e., cancers of the oral cavity and pharynx, esophagus, colon and rectum, liver, larynx, and female breast) that were diagnosed that year among Ontario adults. A larger proportion of cancer cases in males are estimated to be attributable to alcohol consumption (11.5% [9.7–13.2%] of alcohol-related cancers) than in females (2.9% [2.1–3.7%] of alcohol-related cancers), primarily because males have historically consumed more alcohol.

Cancers of the upper aero-digestive tract have the highest proportions of alcohol-attributable cases because of their higher alcohol-related risk. Alcohol consumption based on the 2000/2001 CCHS accounted for an estimated 23.1% (20.3–26.0%) of oral cavity and pharyngeal cancers, 21.4% (17.7–25.2%) of esophageal cancers (squamous cell carcinoma), and 14.7% (11.7–17.9%) of laryngeal cancers diagnosed in Ontario during 2012. The cancer type with the greatest number of alcohol-attributable cases was oral cavity and pharynx, with an estimated 434 (382–489) cases attributable to alcohol consumption based on the 2000/2001 CCHS. While the proportions of colorectal and female breast cancer attributable to alcohol consumption are lower, the absolute numbers of attributable cases are substantial because colorectal and female breast cancers are among the most common cancer types in Ontario. Alcohol consumption based on the 2000/2001 CCHS accounted for an estimated 367 (224–516) colorectal cancer cases and 280 (164–401) female breast cancer cases diagnosed in Ontario during 2012.

Potential impact of drinking within the LRADG or WCRF/AICR guidelines

Assuming no Ontario adults had exceeded the LRADG, an estimated 974 (822–1124) cancer cases would have been attributable to alcohol consumption (638 [539–737] in males and 336 [246–426] in females); this represents an estimated 321 fewer cancer cases diagnosed in 2012 compared with the attributable cases based on alcohol consumption reported in the 2000/2001 CCHS (Table 4 and Fig. 1). Assuming an even more conservative scenario where no Ontario adults had exceeded the WCRF/AICR guidelines, an estimated 813 (690–935) cancer cases would have been attributable to alcohol consumption (591 [498–682] in males and 222 [162–281] in females); this represents an estimated 482 fewer cancer cases diagnosed in 2012. Adopting the more conservative

Table 3 Proportion (%) and number of cancer cases attributable to different scenarios of alcohol consumption, by sex and cancer type, 2012

Cancer type	Cancer cases attributable to...					
	Consumption as reported in 2000/2001 CCHS		Consumption assuming it had not exceeded LRADG		Consumption assuming it had not exceeded WCRF/AICR guidelines	
	% (95% CI)	Number (95% CI)	% (95% CI)	Number (95% CI)	% (95% CI)	Number (95% CI)
Males						
Oral cavity and pharynx	29.0 (25.5–32.6)	375 (330–423)	20.7 (18.3–23.0)	268 (237–298)	19.0 (16.9–21.2)	246 (219–274)
Colon and rectum	5.8 (3.6–8.2)	284 (173–400)	4.6 (2.8–6.5)	225 (136–315)	4.3 (2.6–6.0)	210 (127–291)
Liver	12.0 (8.2–16.0)	91 (62–120)	9.4 (6.4–12.2)	71 (48–92)	8.7 (6.0–11.5)	66 (45–87)
Larynx	16.4 (13.0–19.9)	56 (44–68)	12.6 (10.1–15.1)	43 (34–51)	11.8 (9.4–14.1)	40 (32–48)
Esophagus (SCC)	28.0 (23.2–33.0)	42 (35–49)	20.6 (17.3–24.0)	31 (26–36)	19.3 (16.2–22.3)	29 (24–33)
All alcohol-related cancers	11.5 (9.7–13.2)	848 (719–980)	8.6 (7.3–10.0)	638 (539–737)	8.0 (6.7–9.2)	591 (498–682)
Females						
Oral cavity and pharynx	10.2 (8.8–11.7)	59 (51–68)	7.3 (6.4–8.2)	42 (37–48)	4.8 (4.2–5.4)	28 (25–31)
Colon and rectum	2.0 (1.2–2.8)	83 (50–117)	1.5 (0.9–2.1)	64 (39–90)	1.0 (0.6–1.4)	43 (26–60)
Female breast	2.7 (1.6–3.9)	280 (164–401)	2.1 (1.2–2.9)	211 (125–297)	1.3 (0.8–1.9)	138 (81–194)
Liver	4.1 (2.8–5.4)	14 (9–18)	3.1 (2.1–4.1)	10 (7–14)	2.1 (1.4–2.7)	7 (5–9)
Larynx	5.6 (4.4–6.9)	3 (3–4)	4.2 (3.3–5.1)	3 (2–3)	2.8 (2.2–3.4)	2 (1–2)
Esophagus (SCC)	9.6 (7.8–11.6)	8 (7–10)	7.0 (5.8–8.3)	6 (5–7)	4.7 (3.9–5.5)	4 (3–5)
All alcohol-related cancers	2.9 (2.1–3.7)	447 (324–576)	2.2 (1.6–2.7)	336 (246–426)	1.4 (1.0–1.8)	222 (162–281)
Both sexes						
Oral cavity and pharynx	23.1 (20.3–26.0)	434 (382–489)	16.5 (14.6–18.4)	310 (275–345)	14.6 (13.0–16.2)	274 (244–305)
Colon and rectum	4.0 (2.5–5.7)	367 (224–516)	3.2 (1.9–4.4)	289 (175–405)	2.8 (1.7–3.9)	253 (154–350)
Female breast	2.7 (1.6–3.9)	280 (164–401)	2.1 (1.2–2.9)	211 (125–297)	1.3 (0.8–1.9)	138 (81–194)
Liver	9.6 (6.5–12.7)	105 (71–139)	7.4 (5.1–9.7)	81 (56–106)	6.7 (4.6–8.8)	73 (50–96)
Larynx	14.7 (11.7–17.9)	59 (47–72)	11.3 (9.0–13.5)	46 (36–55)	10.4 (8.3–12.5)	42 (33–50)
Esophagus (SCC)	21.4 (17.7–25.2)	50 (41–59)	15.7 (13.2–18.3)	37 (31–43)	14.0 (11.8–16.2)	33 (27–38)
All alcohol-related cancers	5.7 (4.8–6.5)	1295 (1093–1499)	4.2 (3.6–4.9)	974 (822–1124)	3.5 (3.0–4.1)	813 (690–935)

SCC squamous cell carcinoma

WCRF/AICR guidelines is therefore estimated to have a larger impact on the alcohol-related cancer burden in Ontario (PIF 2.1%) than the LRADG guidelines (PIF 1.4%). Assuming alcohol consumption had not exceeded the levels specified in the LRADG and the WCRF/AICR guidelines, the greatest reduction in the alcohol-attributable proportion of cancer cases and in the absolute number of attributable cases is observed for cancer of the oral cavity and pharynx.

Discussion

We estimate that 1295 (1093–1499) new cases of cancer diagnosed in Ontario during 2012 are attributable to alcohol consumption, representing approximately 1.7% (1.4–1.9%) of all new cancer cases. If no Ontario adults had exceeded the LRADG, an estimated 321 fewer cancer cases could have been diagnosed in 2012 (PIF 1.2%). If no Ontario adults had exceeded the WCRF/AICR guidelines, an

estimated 482 fewer cancer cases could have been diagnosed in 2012 (PIF 1.8%).

Our estimated proportion of cancer cases attributable to alcohol consumption is consistent with recent studies. Grundy and colleagues (Grundy et al. 2016) estimated that 1.6% of cancer cases in Alberta were attributable to alcohol consumption. Parkin (2011) estimated that 4.0% of all cancers in the UK were alcohol-attributable, while Pandeya and colleagues (Pandeya et al. 2015) estimated that 2.8% of all cancers diagnosed in Australian adults could be attributed to alcohol consumption. The higher proportions of alcohol-attributable cases reflect the higher levels of alcohol consumption in these countries compared with Ontario. A study of six European countries (Denmark, Germany, Greece, Italy, Spain, and the UK) (Schutze et al. 2011) estimated that 10% of cancers in men and 3% of cancers in women were attributable to alcohol consumption, while another study (Praud et al. 2016) estimated that 5.5% of cancers worldwide were alcohol-attributable. The difference between these estimates and our

Table 4 Numbers of cancer cases and potential impact fractions (PIF) under different scenarios of alcohol consumption, by sex and cancer type, 2012

		Not exceeding LRADG			Not exceeding WCRF/AICR guidelines		
	Number of observed cancer cases, 2012	Number of cancer cases expected	Number of cancer cases prevented	PIF (%)	Number of cancer cases expected	Number of cancer cases prevented	PIF (%)
Males							
Oral cavity and pharynx	1296	1189	107	8.3	1167	129	10.0
Colon and rectum	4857	4798	59	1.2	4783	74	1.5
Liver	755	735	20	2.6	730	25	3.3
Larynx	341	328	13	3.8	325	16	4.7
Esophagus (SCC)	149	138	11	7.4	136	13	8.7
All alcohol-related cancers	7398	7188	210	2.8	7141	257	3.5
Females							
Oral cavity and pharynx	583	566	17	2.9	552	31	5.3
Colon and rectum	4233	4214	19	0.4	4193	40	0.9
Female breast	10,218	10,149	69	0.7	10,076	142	1.4
Liver	338	334	4	1.2	331	7	2.1
Larynx	62	62	0	0	61	1	1.6
Esophagus (SCC)	84	82	2	2.4	80	4	4.8
All alcohol-related cancers	15,518	15,407	111	0.7	15,293	225	1.4
Both sexes							
Oral cavity and pharynx	1879	1755	124	6.6	1719	160	8.5
Colon and rectum	9090	9012	78	0.9	8976	114	1.3
Female breast	10,218	10,149	69	0.7	10,076	142	1.4
Liver	1093	1069	24	2.2	1061	32	2.9
Larynx	403	390	13	3.2	386	17	4.2
Esophagus (SCC)	233	220	13	5.6	216	17	7.3
All alcohol-related cancers	22,916	22,595	321	1.4	22,434	482	2.1

SCC squamous cell carcinoma

estimates for Ontario may be related to the methods used to estimate alcohol-attributable cancer incidence (e.g., these studies used a triangulation algorithm combining survey data and per-capita consumption data to model alcohol consumption) as well as higher levels of alcohol consumption. Pandeya and colleagues (Pandeya et al. 2015) also estimated the potential impact of reducing alcohol consumption within two different guidelines and found that adopting stricter guidelines had a greater impact on reducing the number of alcohol-attributable cancer cases.

We made several assumptions in our analysis. We made a conservative assumption when estimating the impact of drinking within the LRADG or WCRF/AICR guidelines by assuming everyone who exceeded the guidelines met them instead of reducing their consumption to levels further below the recommended limits. We assumed that former drinkers have the same magnitude of increased cancer risk as current drinkers consuming similar amounts of alcohol, but applied a more conservative estimate of the amount of alcohol consumed. For former drinkers who used to regularly drink more than

12 drinks per week, we assigned the minimum number of drinks that were regularly consumed by these drinkers previously in their lifetime (i.e., 12 drinks per week). For former drinkers who did not regularly drink more than 12 drinks per week, we assigned the same quantity as was assigned to the category with the lowest consumption.

A known limitation of self-reported data from population surveys such as the CCHS is the underestimation of alcohol consumption (Shield and Rehm 2012). Therefore, our results likely underestimate the cancer incidence attributable to alcohol consumption. Previous studies have attempted to address this limitation by adjusting for undercoverage in survey data using sales data (Cancer Care Ontario 2014). This adjustment, however, assumes that drinkers of all ages, sexes, and drinking level underestimate their alcohol consumption to the same extent, which is not supported by evidence from recent studies (Stockwell et al. 2014; Stockwell et al. 2016). This evidence also suggests that underreporting is likely to vary by population and survey. Because we were unable to precisely account for variation in underreporting across different subgroups

Note: i.e., SCC squamous cell carcinoma

Fig. 1 Number of cancer cases prevented assuming different scenarios of alcohol consumption, both sexes combined, by cancer type, 2012

within the population, it was not appropriate to apply the same methods used by previous studies to adjust for underreporting.

Another limitation is that we assumed that a latency period of 12 years between alcohol exposure and cancer diagnosis was appropriate because the 2000/2001 CCHS was the earliest data source with detailed information on alcohol consumption that we had access to. If we had used a different latency period where alcohol consumption levels were higher or lower than in 2000/2001, our PAF estimates would have been underestimates or overestimates in comparison, respectively. However, alcohol consumption patterns in Ontario have changed slowly over time (Cancer Care Ontario 2014), so it could be hypothesized that using a shorter latency period would not impact the estimated alcohol-attributable cancer incidence greatly. Future research could explore the impact of a longer latency period as more years of cancer incidence data become available.

A further limitation was that some of the sex, age, and consumption category subgroups were based on small sample sizes and the exposure prevalence estimates for these subgroups have high variability. However, we attempted to incorporate the variability and uncertainty in the exposure prevalence estimates when calculating 95% CIs for our PAF estimates. Additionally, we may have underestimated the alcohol-attributable cancer burden because we did not include cancer types for which there is emerging evidence of an association between alcohol consumption and increased cancer risk. We did not consider the synergistic interaction between alcohol consumption and tobacco smoking, whereby a multiplicative increase in risk is observed for head and neck cancers and esophageal squamous cell carcinoma (International Agency for Research on Cancer 2012; Hashibe et al. 2009), because reliable relative risk estimates for these interactions have not been established. Finally, we only considered cancer in our

analysis; future research could focus on other alcohol-related outcomes.

In conclusion, we estimate that over 1000 cancer cases diagnosed in Ontario in 2012 are attributable to alcohol consumption. While completely eliminating alcohol consumption in the population is likely not feasible, our estimates suggest that over 300 cancer cases could potentially be prevented if consumption had been reduced to the levels recommended by the LRADG. If consumption had not exceeded the more conservative WCRF/AICR guidelines, it is estimated that nearly 500 cancer cases could have been prevented. Strategies to limit alcohol consumption to the levels recommended by drinking guidelines, and preferably to the WCRF/AICR guidelines, could potentially reduce the cancer burden in Ontario.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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