The effect of alcohol minimum unit pricing and cancer warning labels on cancer incidence and mortality in Canada: an epidemiological modelling study

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Summary

Background Alcohol consumption increases cancer risk and is responsible for substantial cancer incidence and mortality. Alcohol policies have the potential to reduce cancer burden but remain under-implemented. Several Canadian jurisdictions are considering minimum unit pricing (MUP) and alcohol warning label (AWL) strategies. We aimed to assess the effect of these policies on cancer incidence and mortality in Canada.

Methods We estimated baseline counts of alcohol-attributable cancer incident cases and mortalities in Canada, 2022, and modelled the effect of five alcohol policy scenarios comprised of MUP and AWLs. We used cancer registry and mortality data, representative alcohol use surveys, and product-level alcohol sales data. We used the International Model of Alcohol Harms and Policies to estimate alcohol-attributable burden at baseline and in each scenario. Scenarios tested were cancer warning labels (scenario 1); multi-message rotating labels, which consisted of a cancer warning label, a standard drink label, and a low-risk drinking guidelines label on a rotating basis (scenario 2); an MUP at CA$1·75 per standard drink (scenario 3); an MUP at $2·00 (scenario 4); and a combined scenario with a $2·00 at MUP and a cancer warning label (scenario 5).

Findings Alcohol caused an estimated 9498 (95% uncertainty estimate 8950–10 049) cancer cases and 3866 (3624–4106) cancer deaths in Canada in 2022. All policy scenarios were estimated to reduce alcohol use and cancer burden, with stronger effects from more stringent interventions. For example, a $2·00 MUP with cancer labels was projected to reduce the number of incident cases of alcohol-attributable cancer by 674 (484–911; 7·1% [5·1–9·6]) and deaths by 216 (155–292; 5·6% [4·0–7·5]) when effects were fully realised. The largest proportional benefits were seen among lower-income populations and younger age groups.

Interpretation Alcohol policies, particularly those combining pricing and labelling, could substantially reduce the cancer burden and health inequalities.

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Introduction

Cancer is a leading cause of global mortality, responsible for approximately one in six deaths[1] and substantially contributing to premature mortality, ranking among the top three causes of death among individuals aged 30–69.[1] Beyond its health effect, cancer imposes substantial social and economic burdens, with the extent of these costs varying by cancer type, geography, and gender.[2] A substantial proportion of cancer cases and mortalities are preventable, with modifiable risk factors such as tobacco use, high BMI, and alcohol consumption playing important roles. Globally, Tran and colleagues[3] estimated that modifiable factors were responsible for 4·45 million deaths, or 44·4% of all cancer deaths, in 2019.

Alcohol is a group 1 carcinogen as classified by WHO and is recognised as a risk factor for cancers of the oral cavity and pharynx, oesophagus, larynx, colorectum, liver, pancreas, prostate, and breast.[4,5] Alcohol increases cancer risk through several mechanisms, including ethanol and acetaldehyde exposure, oxidative stress, hormonal changes, and chronic inflammation,[6] and alcohol-attributable cancer risk increases with both the cumulative quantity of alcohol consumed and the duration of alcohol exposure.[7] Regarding duration, studies[8] have shown that the latency period between alcohol use and cancer onset might be 10 years or longer.

In 2020, an estimated one in 24 cancer cases worldwide were attributable to alcohol consumption and thus could have been prevented in the absence of exposure to alcohol.[9] As alcohol-attributable cancers constitute a substantial public health and economic burden, reducing consumption through evidence-based policy might be key towards lowering future cancer incidence and mortality. Further, alcohol-attributable harms are known to disproportionately affect populations with lower socioeconomic status (SES), despite similar or lower total and heavy use than populations with high SES.[10]

Research in context

Evidence before this study

Alcohol policies have been suggested as one path towards mitigating the alcohol-attributable cancer burden. To inform this study, we searched PubMed and Google Scholar for studies regarding the realised or modelled effect of alcohol policies on alcohol consumption and cancer incidence and mortality. We used combinations of the terms “alcohol consumption” (alcohol drinking or alcohol), “cancer outcomes” (incidence, mortality or death), and “alcohol policies” (minimum unit price, pricing or price, tax or taxation, health warnings, or warning labels) and searched for articles published between Jan 1, 2000, and Dec 22, 2025. The search yielded 120 studies. A Canadian study affixed alcohol warning labels (AWLs) to containers and reported a substantial decrease in alcohol sales, and minimum unit price (MUP) implementations in Scotland and Wales were found to be associated with decreased alcohol consumption. A Canadian modelling study noted the superiority of MUP policies compared with across-the-board tax or price increases in reducing alcohol consumption. Evidence on cancer-related AWLs has largely focused on awareness and knowledge of cancer risk, with limited linkages to downstream health or cancer outcomes. Search results regarding modelled or realised alcohol policy effects on cancer outcomes were sparse and few studied differential effects by socioeconomic position. Notably, a modelling study predicted reduced alcohol use upon MUP implementation and the largest health improvements for the lowest socioeconomic group. A modelling study in the European region estimated that a 100% excise tax increase would substantially reduce alcohol-attributable cancer cases and deaths. No published studies have estimated the effect of AWLs on cancer outcomes and Canadian MUP modelling studies were sparse.

Added value of this study

To our knowledge, this is the first study to investigate the modelled effect of AWLs on alcohol-attributable cancer incidence and mortality. Further, this study adds to the global literature modelling MUPs, alcohol consumption, and cancer outcomes. We modelled five policy scenarios in Canada in 2022, including MUPs at CA\$1·75 and \$2·00, mandatory cancer labels, multi-message rotating labels, and a combined \$2·00 MUP with cancer labels. Across all scenarios, alcohol use and the number of alcohol-attributable cancer incident cases and deaths were expected to decline. A key study strength is socioeconomic analyses by household income quintiles, which indicated that the greatest relative benefits were experienced by lower income groups.

Implications of all the available evidence

By quantifying the expected effect of interventions already under active debate in Canada and other high-income settings, this modelling study shows the potential for combined economic and informational policies to reduce the cancer burden and narrow socioeconomic inequalities. These findings reinforce global calls for stronger implementation of effective alcohol control strategies.

Two alcohol policy approaches that have shown effectiveness in reducing alcohol use and might therefore hold promise for cancer prevention are minimum unit pricing (MUP) and alcohol warning labels (AWLs) on beverage containers, such as bottles and cans. Alcohol MUP is a policy that establishes a minimum price per standard drink (PPSD), hence increasing the price of cheap, high alcohol-by-volume (ABV) products.[11] MUP has been shown to reduce alcohol sales and, consequently, alcohol-attributable hospital admissions and mortality in Scotland, Ireland, Wales, the Northern Territory of Australia, and the Canadian province of Manitoba.[12–14] Although other alcohol policy interventions, for example, sales tax increases, minimum prices (which are not equivalent to minimum unit prices), and store density limits[15–18] have been shown to reduce alcohol use and related harms, the current policy discussion in Canada is focused on MUP and AWLs; we have therefore investigated these two policies. A previous study[19] from our research group modelled the effect on alcohol use and alcohol-attributable mortality of two MUP levels, as well as three alcohol tax policy changes regarding federal excise tax. As that study reported the superiority of MUPs as a means of reducing consumption and related harms compared with strategies that raise taxes across the full spectrum of alcohol products, we have focused on MUP in the current study and have not modelled across-the-board tax increases.

AWLs provide consumers with information about alcohol’s health risks,[20] including cancer. This information is important as fewer than half of adults in Canada,[21] the USA,[22] and Europe[23] are aware of the alcohol–cancer link. Well-designed AWLs—prominently placed with clear graphic or textual warnings—can increase awareness of alcohol-related harms and influence behaviour, and those highlighting cancer risks appear especially effective in shifting perceptions and reducing consumption.[24–26] A real-world quasi-experimental study in Yukon, Canada, found that AWLs, which included a cancer warning, were associated with a 6·6% decline in the local per capita alcohol consumption of labelled products.[27]

This study aimed to assess the potential cancer prevention benefits of implementing MUP and AWLs. Canada provides a strong test case because of its policy landscape, where most provincial governments operate partial or complete retail monopolies, allowing for centralised policy implementation. We modelled five policy scenarios towards answering two key research questions: (1) what is the potential effect of implementing a MUP, AWLs, or both, on alcohol use and alcohol-attributable cancer incidence and mortality? And (2) how might this effect vary by sex, age group, income quintile, cancer site, and province?

Methods

Overview

To establish a baseline, we estimated the number of alcohol-attributable cancer incident cases and cancer mortalities Canada in 2022 using burden of disease methodology.[28,29] In each of the five policy scenarios, this baseline was compared with modelled estimates of the number of alcohol-attributable cancer cases and mortalities. The epidemiological modelling used was mathematically deterministic, wherein the data inputs in the model determined final outputs. This modelling procedure has been used in previous alcohol policy studies;[30–32] the purpose is to model cancer outcome effects on the basis of projected policy-induced alcohol use changes.

In scenario estimation, the modelling procedure used estimates of fully-realised effect of the hypothetical policy implementations on both alcohol use and alcohol-attributable cancer outcomes—ie, the technique assumes that policy scenarios were implemented far enough in the past for cancer latency periods to have elapsed after drinking behaviours were policy modified to accumulate the full effect of implementation; throughout the study we refer to this as the fully-realised effect on cancer outcomes to differentiate from instantaneous effects.

In an epidemiological context, estimating the number of alcohol-attributable outcomes is equivalent to estimating the number of cancer cases and deaths that would not have occurred in the absence of population exposure to alcohol use.

Data sources

We used data from 2022, except when available data was less recent. Canadian cancer mortality and incidence data were accessed through Statistics Canada. Mortality data[33] were available by age group, sex, cancer site, and year for 2022. The most recent cancer incidence data[34] by province, age group, sex, and cancer site at the time of study were from 2020. Incident data were adjusted to 2022, at the province–age group–sex level, by a ratio of the population in 2022 divided by the population in 2020. Prevalence of current and former drinkers and between-population relative consumption ratios in subgroups came from two cycles (2015–16 and 2017–18) of the Canadian Community Health Survey (CCHS), a large, nationally representative health survey.[35] These two 2-year cycles were combined and were the most recent available data that included the socioeconomic measures needed for this study. Respondents missing required demographic or alcohol use variables were excluded from analysis. Administrative alcohol sales data for 2022, by province and fiscal year, were converted to calendar year from fiscal years 2021–22 and 2022–23.[7] We used population data on July 1, 2022, grouped by province, sex, and 5-year age group.[38] Product-level alcohol price and sales data for 2021 were from British Columbia (from the BC Liquor Distribution Branch) and Ontario (from the Liquor Control Board of Ontario).

Relative risk (RR) functions corresponding to the meta-analysed risk between average daily alcohol use and each cancer site were from WHO's Global Status Report on Alcohol and Health.[39] The functional equations for the risk functions were from Shield and colleagues.[40] Of the two oesophageal cancer subtypes, only squamous cell carcinoma is causally related to alcohol. Proportions of 38·5% in males and 67·5% in females were applied from Cattelan and colleagues[41] to reflect the alcohol-attributable component of oesophageal cancer. Mortality data for cancers of the oral cavity and pharynx included nasopharyngeal cancer, which is not causally related to alcohol use.[29] Mortality counts for this cancer site were adjusted downwards by 5·6% to account for the percentage of nasopharyngeal cancer deaths in this group.[33]

Cancer incidence data for Quebec (2018–20) and Nova Scotia (2019–20) were unavailable at the time of study. We calculated mean incidence counts for each cancer site, sex, and age group in the 3 years before the missing data—ie, 2015–17 for Quebec and 2016–18 for Nova Scotia,[34] and adjusted these by the respective provincial population growth rates.[38] Mortality data for Yukon (2018–22) were unavailable. We used a similar method with mean cancer deaths for 2009–16, by sex and cancer site, calculated and adjusted for population growth.

Modelling alcohol use, incident cancer cases, and cancer mortality by household income quintile

To estimate the effects of changes in alcohol policy change by SES, we began by categorising alcohol use data into household income quintiles. The CCHS groups respondents into income deciles based on area-based household income; adjacent deciles were combined to create quintiles.[35] By income quintile, we calculated the survey-weighted population proportions in subgroups defined by province, sex and age group. These proportions were then applied to the cancer incidence and death counts with the result being disaggregated cancer incidence and mortality counts by province, sex, age group and income quintile.

Estimating baseline alcohol-attributable incident cancer cases and deaths

Cancer sites that are causally related to alcohol use were identified from Canada's national cost of substance study.[28] For each of seven cancer sites (oral cavity and pharynx, oesophageal, colorectal, liver, pancreatic, laryngeal, and breast), incident cases and deaths were enumerated by province or territory, sex, and age group. For mortality, the underlying cause of death was used, which is defined as the disease or injury which initiated the train of events leading directly to death.[33]

We used alcohol-attributable fractions (AAFs) to estimate the proportion of cases and deaths of each cancer site that would not have occurred in the absence of alcohol use. AAFs were calculated using the International Model of Alcohol Harms and Policies (InterMAHP).[42] The following equation presents a generalised AAF used by InterMAHP:

$$AAF_{c,p,s,a,i}=\frac{PFD_{p,s,a,i}\,[RRFD_{c,s}-1]+\int_{0\cdot 03}^{150}P_{p,s,a,i}(x)[RR_{c,s}(x)-1]dx}{1+PFD_{p,s,a,i}[RRFD_{c,s}-1]+\int_{0\cdot 03}^{150}P_{p,s,a,i}(x)[RR_{c,s}(x)-1]dx}$$

where $AAF_{c,p,s,a,i}$ is the AAF for each cancer site, province or territory, sex, age group, and household income quintile. $PDF_{p,s,a,i}$ is the prevalence of former drinkers by province or territory, sex, age group, and income quintile; $RRFD_{p,s,a,i}$ is the RR of former drinkers for each cancer site and sex; $P_{p,s,a,i}(x)$ is the continuous prevalence distribution of average daily alcohol use in grams of ethanol per day; $RR_{c,s}(x)$ is the RR function corresponding to each cancer site and sex;[40] and 0·03 and 150 are the lower and upper limits of average daily alcohol use in grams of ethanol (used consistently for all regions and subgroups). Prevalence distributions are modelled from CCHS alcohol use statistics using a gamma distribution methodology as first suggested by Kehoe and colleagues[43] and formalised for InterMAHP.[42] Briefly, mean daily alcohol use within each population subgroup is combined with prevalence of use information and population statistics and a one-parameter gamma distribution model is used to infer the population distribution of mean daily use.

Last, to produce final baseline estimates of alcohol-attributable cancer cases and deaths, the numbers of incident cases and deaths were multiplied by the corresponding AAFs, by cancer site, province or territory, sex, age group, and household income quintile.

Definition of policy scenarios

Five policy scenarios were chosen for modelling. Scenario 1 was the requirement of a cancer warning label on alcohol containers. This policy was tested experimentally in a labelling study in Yukon, Canada, thus providing an effect size.[27] Scenario 2 was the requirement of a multi-message rotating (MMR) label series, which includes a cancer warning, information about low-risk drinking guidelines and standard drink information. This policy was also tested in the Yukon labelling study.[27] Scenario 3 was the implementation of an MUP of CA$1·75, corresponding to a previous recommendation of the Canadian Alcohol Policy Evaluation (CAPE).[44] Scenario 4 was the implementation of an MUP of $2·00, corresponding to the current recommendation from CAPE;[45] Scenario 5 was the implementation of an MUP of $2·00 and the requirement for a cancer warning label.

Modelled impact of each scenario on alcohol use and alcohol-attributable cancer incidence and mortality

Changes in alcohol use in each of the five policy scenarios were drawn from literature regarding the effect of real-world policy change or real-world research experiments on alcohol sales. A systematic review[26] assessed existing literature regarding the effectiveness of alcohol containers labels on several different themes, including warning label requirements, perception and awareness,

	Cancer label	MMR label	MUP $1·75	MUP $2·00	Cancer label plus MUP $2·00
Females					
Income quintile 1	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–6·6% (–8·1 to –6·3)	–12·4% (–15·2 to –9·5)	–14·5% (–18·9 to –10·6)
Income quintile 2	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–5·0% (–6·1 to –4·8)	–9·6% (–11·8 to –7·4)	–11·8% (–15·7 to –8·5)
Income quintile 3	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–2·3% (–2·8 to –2·2)	–6·6% (–8·0 to –5·1)	–8·8% (–12·1 to –6·2)
Income quintile 4	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–1·6% (–2·0 to –1·5)	–4·6% (–5·6 to –3·5)	–6·9% (–9·8 to –4·7)
Income quintile 5	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–0·7% (–0·9 to –0·7)	–2·7% (–3·4 to –2·1)	–5·1% (–7·7 to –3·3)
Subtotal	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–3·2% (–4·0 to –3·1)	–7·2% (–8·8 to –5·5)	–9·4% (–12·8 to –6·7)
Males					
Income quintile 1	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–8·5% (–10·5 to –8·1)	–16·8% (–20·6 to –13·0)	–18·8% (–24·2 to –14·1)
Income quintile 2	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–6·5% (–8·0 to –6·2)	–13·6% (–16·7 to –10·5)	–15·7% (–20·4 to –11·6)
Income quintile 3	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–2·7% (–3·3 to –2·6)	–9·3% (–11·4 to –7·2)	–11·5% (–15·4 to –8·3)
Income quintile 4	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–1·9% (–2·3 to –1·8)	–6·5% (–7·9 to –5·0)	–8·7% (–12·1 to –6·2)
Income quintile 5	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–0·9% (–1·1 to –0·8)	–3·9% (–4·8 to –3·0)	–6·2% (–9·0 to –4·2)
Subtotal	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–4·1% (–5·0 to –3·7)	–10·0% (–11·9% –7·7),	–12·2% (–16·2 to –8·9)
Total	–2·4% (–4·5 to –1·2)	–6·6% (–11·8 to –2·4)	–3·7% (–4·5 to –3·4)	–8·6% (–10·4 to –6·6)	–10·8% (–14·5 to –7·8)

Data are percentage change (95% uncertainty estimate). 1 is the lowest income quintile (lowest income) and 5 is the highest (highest income). Prices are CA$. MMR=multi-message rotating. MUP=minimum unit price.

Table 1: **Predicted alcohol use changes under five alcohol policy scenarios, by sex and household income quintile, Canada, 2022**

	Baseline	Cancer label	MMR label	MUP $1·75	MUP $2·00	Cancer label plus MUP $2·00
Incident cases						
Females						
Income quintile 1	515 (469 to 561)	–8 (–15 to –4); –1·6% (–2·9 to –0·8)	–22 (–40 to –8); –4·3% (–7·7 to –1·6)	–22 (–27 to –21); –4·3% (–5·3 to –4·1)	–42 (–51 to –32); –8·1% (–9·9 to –6·2)	–49 (–63 to –36); –9·4% (–12·3 to –7·0)
Income quintile 2	541 (491 to 592)	–11 (–20 to –5); –2·0% (–3·6 to –1·0)	–29 (–51 to –11); –5·3% (–9·5 to –2·0)	–22 (–27 to –21; (–4·1% (–5·0 to –3·9)	–42 (–51 to –32); –7·7% (–9·5 to –6·0)	–51 (–68 to –37); –9·5% (–12·6 to –6·9)
Income quintile 3	628 (570 to 687)	–14 (–26 to –7); –2·3% (–4·2 to –1·1)	–39 (–69 to –11); –6·1% (–10·9 to –2·3)	–14 (–17 to –13); –2·2% (–2·6 to –2·0)	–38 (–47 to –30); –6·1% (–7·5 to –4·7)	–51 (–71 to –36); –8·2% (–11·3 to –5·8)
Income quintile 4	721 (656 to 788)	–17 (–32 to –9); –2·4% (–4·4 to –1·2)	–47 (–84 to –17); –6·5% (–11·6 to –2·4)	–11 (–13 to –10); –1·6% (–1·9 to –1·5)	–33 (–40 to –25); –4·5% (–5·6 to –3·5)	–49 (–70 to –34); –6·8% (–9·7 to –4·7)
Income quintile 5	1007 (917 to 1098)	–25 (–46 to –13); –2·5% (–4·6 to –1·3)	–69 (–122 to –25); –6·8% (–12·2 to –2·5)	–8 (–9 to –7); –0·7% (–0·9 to –0·7)	–28 (–35 to –22); –2·8% (–3·5 to –2·2)	–53 (–80 to –34); –5·2% (–7·9 to –3·4)
Subtotal	3411 (3102 to 3726)	–75 (–139 to –38); –2·2% (–4·1 to –1·1)	–205 (–366 to –75); –6·0% (–10·7 to –2·2)	–77 (–94 to –70); –2·3% (–2·8 to –2·1)	–183 (–224 to –142); –5·4% (–6·6 to –4·2)	–253 (–352 to –178); –7·4% (–10·3 to –5·2)
Males						
Income quintile 1	1404 (1350 to 1458)	–14 (–26 to –7); –1·0% (–1·8 to –0·5)	–38 (–68 to –14); –2·7% (–4·8 to –1·0)	–49 (–60 to –44); –3·5% (–4·3 to –3·3)	–96 (–118 to –75); –6·9% (–8·4 to –5·3)	–108 (–137 to –81); –7·7% (–9·8 to –5·7)
Income quintile 2	1187 (1139 to 1234)	–15 (–28 to –8); –1·3% (–2·4 to –0·6)	–41 (–74 to –15); –3·5% (–6·2 to –1·3)	–41 (–50 to –37); –3·5% (–4·2 to –3·3)	–85 (–105 to –66); –7·2% (–8·8 to –5·6)	–98 (–128 to –73); –8·3% (–10·7 to –6·1)
Income quintile 3	1249 (1199 to 1298)	–19 (–35 to –9); –1·5% (–2·8 to –0·8)	–51 (–92 to –19); –4·1% (–7·4 to –1·5)	–21 (–26 to –18); –1·7% (–2·1 to –1·6)	–73 (–89 to –56); –5·8% (–7·1 to –4·5)	–90 (–120 to –65); –7·2% (–9·6 to –5·2)
Income quintile 4	1187 (1141 to 1233)	–20 (–37 to –10); –1·7% (–3·2 to –0·9)	–55 (–99 to –20); –4·7% (–8·4 to –1·7)	–16 (–20 to –13); –1·3% (–1·6 to –1·3)	–54 (–67 to –42); –4·6% (–5·6 to –3·5)	–73 (–101 to 52); –6·2% (–8·5 to –4·4)
Income quintile 5	1059 (1018 to 1100)	–20 (–37 to –10); –1·9% (–3·5 to –0·9)	–55 (–99 to –20); –5·2% (–9·3 to –1·9)	–7 (–8 to –7); –0·7% (–0·8 to –0·6)	–32 (–40 to –25); –3·0% (–3·7 to –2·3)	–52 (–75 to –35); –4·9% (–7·1 to –3·3)
Subtotal	6087 (5848 to 6323)	–88 (–163 to –44); –1·4% (–2·7 to –0·7)	–241 (–432 to –88); –4·0% (–7·1 to –1·4)	–134 (–164 to –119); –2·2% (–2·7 to –2·1)	–341 (–418 to –264); –5·6% (–6·9 to –4·3)	–421 (–561 to –305); –6·9% (–9·2 to –5·0)
Total	9498 (8950 to 10049)	–163 (–302 to –82); –1·7% (–3·2 to –0·9)	–446 (–798 to –163); –4·7% (–8·4 to –1·7)	–211 (–258 to –189); –2·2% (–2·7 to –2·1)	–524 (—642 to –405] (–5·5% (–6·8 to –4·3)	–674 (–913 to –482); –7·1% (–9·6 to –5·1)
Deaths						
Females						
Income quintile 1	201 (179 to 223)	–2 (–3 to –1); –0·8% (–1·5 to –0·4)	–5 (–8 to –2); –2·3% (–4·0 to –0·8)	–5 (–6 to –4); –2·3% (–2·8 to –2·1)	–8 (–10 to –7); –4·2% (–5·2 to –3·3)	–10 (–13 to –7); –4·9% (–6·4 to –3·6)
Income quintile 2	195 (174 to 218)	–2 (–4 to –1); –1·2% (–2·2 to –0·6)	–6 (–11 to –2); –3·3% (–5·8 to –1·2)	–5 (–6 to –5); –2·5% (–3·0 to –2·3)	–9 (–11 to –7); –4·7% (–5·8 to –3·7)	–11 (–15 to –8); –5·8% (–7·7 to –4·2)
Income quintile 3	205 (182 to 228)	–3 (–6 to –2); –1·6% (–2·9 to –0·8)	–9 (–16 to –3); –4·3% (–7·7 to –1·6)	–3 (–4 to –3); –1·5% (–1·9 to –1·4)	–9 (–11 to –7); –4·3% (–5·3 to –3·4)	–12 (–16 to –8); –5·8% (–8·0 to –4·1)
Income quintile 4	221 (196 to 246)	–4 (–7 to –2); –1·8% (–3·3 to –0·9)	–11 (–19 to –4); –4·9% (–8·8 to –1·8)	–3 (–3 to –2); –1·2% (–1·5 to –1·1)	–8 (–9 to –6); –3·4% (–4·2 to –2·6)	–11 (–16 to –8); –5·1% (–7·3 to –3·5)
Income quintile 5	302 (268 to 337)	–6 (–11 to –3); –2·0% (–3·7 to –1·0)	–16 (–29 to –6); –5·4% (–9·6 to –2·0)	–2 (–2 to –2); –0·6% (–0·7 to –0·6)	–7 (–8 to –5); –2·2% (–2·7 to –1·7)	–13 (–19 to –8); –4·2% (–6·3 to –2·7)
Subtotal	1125 (999 to 1252)	–17 (–32 to –9); –1·5% (–2·8 to –0·8)	–47 (–84 to –17); –4·2% (–7·4 to –1·5)	–17 (–21 to –16); –1·5% (–1·8 to –1·4)	–41 (–50 to –32); –3·6% (–4·5 to –2·8)	–57 (–79 to –40); –5·1% (–7·1 to –3·5)
Males						
Income quintile 1	628 (601 to 654)	–5 (–9 to –2); –0·8% (–1·5 to –0·4)	–14 (–24 to –5); –2·2% (–3·8 to –0·8)	–17 (–21 to –15); –2·8% (–3·4 to –2·6)	–34 (–42 to –27); –5·5% (–6·7 to –4·2)	–38 (–49 to –29); –6·1% (–7·8 to –4·6)
Income quintile 2	559 (535 to 583)	–6 (–11 to –3); –1·1% (–1·9 to –0·5)	–16 (–29 to –6); –2·9% (–5·1 to –1·1)	–16 (–19 to –14); –2·8% (–3·5 to –2·7)	–33 (–41 to –26); –5·9% (–7·3 to –4·6)	–38 (–49 to –28); –6·8% (–8·8 to –5·1)
Income quintile 3	567 (543 to 591)	–7 (–13 to –4); –1·3% (–2·3 to –0·6)	–20 (–35 to –7); –3·5% (–6·2 to –1·3)	–8 (–9 to –8); –1·4% (–1·7 to –1·3)	–28 (–34 to –21); –4·9% (–6·0 to –3·8)	–34 (–46 to –25); –6·0% (–8·1 to –4·4)
Income quintile 4	517 (495 to 539)	–8 (–14 to –4); –1·5% (–2·7 to –0·7)	–21 (–37 to –8); –4·0% (–7·3 to –1·5)	–6 (–7 to –6); –1·2% (–1·4 to –1·1)	–21 (–25 to –16); –4·0% (–4·9 to –3·1)	–28 (–38 to –20); –5·4% (–7·4 to –3·8)
Income quintile 5	470 (450 to 490)	–8 (–15 to –4); –1·7% (–3·1 to –0·8)	–22 (–39 to –8); –4·6% (–8·4 to –1·7)	–3 (–3 to –3); –0·6% (–0·7 to –0·6)	–13 (–16 to –10); –2·7% (–3·4 to –2·1)	–21 (–30 to –14); –4·4% (–6·4 to –2·9)
Subtotal	2741 (2625 to 2857)	–34 (–62 to –17); –1·2% (–2·3 to –0·6)	–92 (–165 to –34); –3·4% (–6·0 to –1·2)	–50 (–59 to –46); –1·8% (–2·2 to –1·7)	–128 (–157 to –99); –4·7% (–5·7 to –3·6)	–159 (–212 to –115); –5·8% (–7·7 to –4·2)
Total	3866 (3624 to 4106)	–51 (–94 to –25); –1·3% (–2·4 to –0·7)	–139 (–248 to –51); –3·6% (–6·4 to –1·3)	–67 (–80 to –61); –1·7% (–2·1 to –1·6)	–169 (–208 to –131); –4·4% (–5·4 to –3·4)	–216 (–290 to –155); –5·6% (–7·5 to –4·0)

Data are n or percentage change (95% uncertainty estimate). Prices are CAN$. MMR=multi-message rotating. MUP=minimum unit price.

Table 2: **Estimated number of alcohol-attributable cancer incident cases and deaths, at baseline and under five alcohol policy scenarios, by sex and income quintile, Canada, 2022**

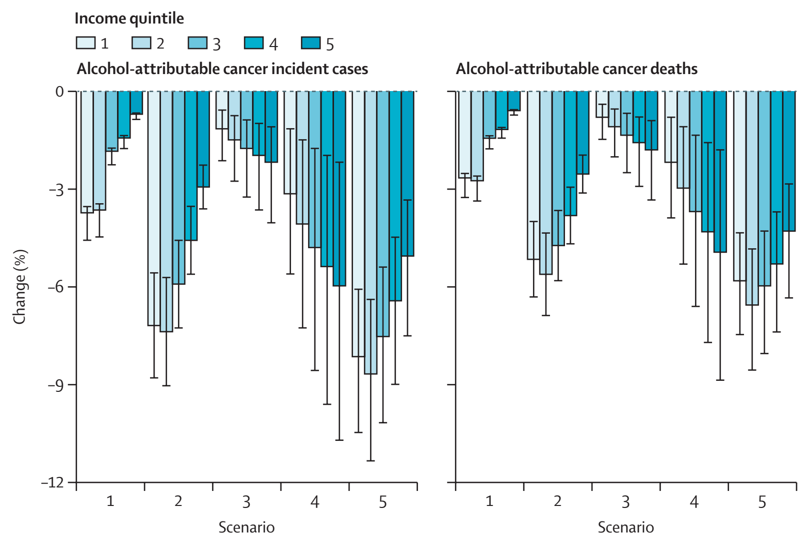

Figure 1: **Percentage changes in the number of alcohol-attributable cancer incident cases and deaths, by alcohol policy scenario and household income quintile, Canada, 2022**
Income quintile 1 is the lowest (least income) and income quintile 5 is the highest (most income). Scenario 1 is a cancer warning label on alcohol containers, scenario 2 is a multi-message rotating label on alcohol containers, scenario 3 is a minimum unit price of CAN$1·75, scenario 4 is a minimum unit price of $2·00, and scenario 5 is a cancer warning label on alcohol containers and a minimum unit price of $2·00.

and effect on alcohol sales. To best inform the changes in alcohol use resulting from labelling interventions, we decided to focus on published articles that studied behaviour change and not the intention to change.

Table 1 presents estimated alcohol use reductions in each scenario. To model the potential effect of alcohol labels on alcohol use, the study done in Yukon, Canada, in 2017–18 was used as it is the only study to date that has experimentally tested the effect of MMR labels. Zhao and colleagues[27] reported that the cancer label intervention was associated with a 2·4% reduction in per capita sales of labelled products and the MMR label intervention a 6·6% reduction.

Alcohol use changes under each MUP scenario were estimated for each income quintile. Anderson and colleagues[12] reported modelled estimates of percent changes in grams of alcohol purchased and prices paid per gram of ethanol associated with MUP implementations in Scotland and Wales.[12] Upon request, the first author provided these findings disaggregated by income quintile (Peter Anderson, Newcastle University, Newcastle, UK, and Maastricht University, Maastricht, Netherlands, personal communication). For each income quintile, MUP elasticities were calculated as the change in grams of alcohol purchased divided by the change in mean price per gram. Second, administrative product-level alcohol sales data in Ontario and British Columbia (together accounting for 52% of Canada's population) were analysed to calculate mean PPSD and price distributions of alcohol sales quantities by PPSD, analogous to methods used previously.[19] These baseline mean PPSD values were inflation adjusted to 2022 prices and made income quintile-specific using proportional differences in mean price per gram costs by income quintile (provided by Anderson with the previous results[12]). Third, the effect of each MUP scenario was modelled by increasing PPSD values below $1·75 and $2·00 to exactly those values. Mean PPSDs were recalculated using these new distributions and were further adjusted for inflation and made income quintile specific. Percentages changes in mean PPSD, by income quintile, were then calculated. Last, percentage changes in alcohol use were calculated by multiplying income quintile-specific percentage changes in mean PPSD by income quintile-specific MUP elasticities from the first step.

Alcohol use changes in scenario 5 were derived multiplicatively from scenarios 1 and 4. As the modelled policies differed in terms of primary motivation, with MUP related to economics and labelling to alcohol-related health knowledge, a multiplicative model was chosen as motivations did not overlap.

We used InterMAHP to calculate AAFs (both point estimates and uncertainty estimates [UEs]) for each scenario, by region, sex, age group, income quintile, and cancer site. Former and current drinker prevalence was held constant.[46] Modelled alcohol use changes modified the gamma distribution and new scenario-specific AAFs were multiplied by case and death counts to estimate alcohol-attributable outcomes. Percentage reductions in alcohol-attributable cancer outcomes were estimated by dividing scenario-based changes in alcohol-attributable outcome counts by the baseline number of alcohol-attributable outcome counts, in each jurisdiction, sex, age group, and income quintile subgroup for each cancer site. The modelling technique used was designed to estimate the fully-realised effect of the policy implementation—ie, the change in alcohol-attributable cancer outcomes that would be expected had the implementation been far enough in the past to allow for the alcohol–cancer latency period to have passed.

We calculated UEs using the 95% CI of effect sizes of alcohol use change following AWL and MUP interventions. For the AWL interventions, the published CIs were from the Yukon labelling study[27] and, for the MUP intervention, CIs representing uncertainty around elasticity estimates were from Anderson and colleagues.[12] UEs were deterministically calculated by InterMAHP using the upper and lower 95% CIs from the aforementioned studies on MUP and AWL. For each AAF, the modelling technique would produce a point estimate, as well as an upper and lower 95% UE, which was then followed through all further calculations. Statistical analyses were done in R (version 3.6.1).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Table 1 depicts the estimated effects of each policy scenario on alcohol use. All policy scenarios were estimated to reduce consumption, compared with baseline estimates from administrative sales data. The MMR label was associated with a larger reduction in alcohol use per capita (–6·6% [95% UE –11·8 to –2·4) than cancer warnings alone (–2·4% [–4·5 to –1·2]) and an MUP of $2·00 had a larger estimated effect on use (–8·6% [–10·4 to –6·6]) than the $1·75 MUP (–3·7% [–4·5 to –3·4]). The largest reduction was modelled to be from an MUP of $2·00 combined with a cancer warning label (–10·8% [–14·5 to –7·8]). Notably, effects were consistently larger among males compared with females for policy scenarios involving MUP (table 1).

In 2022, alcohol was estimated to be causally responsible for 9498 (95% UE 8950–10 049) cancer cases (3411 [3102–3726] female and 6087 [5848–6323] male) and 3866 (3624–4106) deaths (1125 [999–1252] female and 2741 [2625–2857] male) in Canada (table 2). Across the seven alcohol-related cancer sites, there were 68 926 incident cancer cases (44 502 [64·6%] female and 24 423 [35·4%] male) and 26 365 cancer deaths (14 360 [54·5%] female and 12 005 [45·5%] male; appendix p 7). As such, alcohol-attributable outcomes comprised 13·8% of all incident cancer cases and 14·7% of all cancer deaths within these seven cancer sites. The proportion of cases and deaths that were attributed to alcohol among these seven cancer sites was higher for males (24·9% of cases and 22·8% of deaths) than for females (7·7% of cases and 7·8% of deaths; appendix p 7).

As with alcohol use, fully-realised reductions in alcohol-attributable cancer incidence (446 cases [95% UE 163–798]; 4·7% [1·7–8·4]) and alcohol-attributable cancer mortality (139 deaths [51–248]; 3·6% [1·3–6·4]) associated with the multi-message rotating label were more than double the effect of the cancer warning alone (table 2). Similarly, an MUP of $2·00 was estimated to reduce alcohol-attributable cancer deaths by 169 (131–208), more than two times the reduction of an MUP of $1·75. The largest modelled reduction came from combining a $2·00 MUP with a cancer warning label, which was estimated to reduce alcohol-attributable cancer incidence by 674 cases (484–911) and alcohol-attributable cancer deaths by 216 (155–292).

Figure 1 shows estimated fully-realised percentage changes in the number of alcohol-attributable incident cancer cases and deaths, by income quintile. Absolute and percentage changes by income quintile are shown in the appendix (p 2). Income-related disparities were evident, with the largest absolute reductions in both alcohol-attributable incident cases and mortalities observed in the lowest and second-lowest income quintiles for scenarios involving MUP. The MUP of $2.00 plus cancer warning label was estimated to reduce incident cases of alcohol-attributable cancer by 8·1% (95% UE 6·1–10·5) and alcohol-attributable cancer deaths by 5·8% (4·3–7·5) in the lowest income quintile, the largest and second-largest absolute reduction among income quintiles, respectively. By contrast in this scenario, the highest income quintile had smaller relative reductions, with an estimated reduction of 5·1% (3·3–7·5) in alcohol-attributable cancer incidence and an estimate reduction of 4·3% (2·8–6·3) in alcohol-attributable cancer deaths.

See Online for appendix

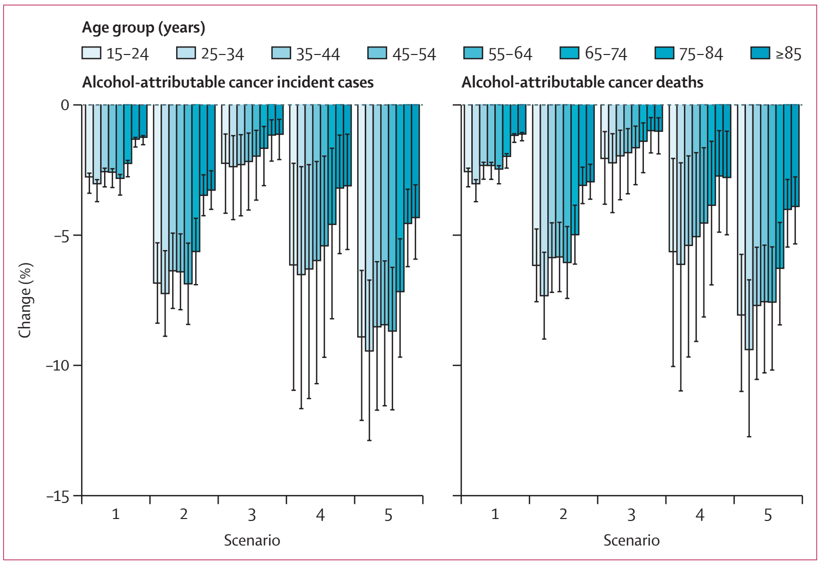

Figure 2: **Percentage changes in the number of alcohol-attributable cancer incident cases and deaths, by alcohol policy scenario and age group, Canada, 2022**

Scenario 1 is a cancer warning label on alcohol containers, scenario 2 is a multi-message rotating label on alcohol containers, scenario 3 is a minimum unit price of CAN$1·75, scenario 4 is a minimum unit price of $2·00, and scenario 5 is a cancer warning label on alcohol containers and a minimum unit price of $2·00.

Figure 2 and the appendix (p 3) show fully-realised percentage and absolute changes in alcohol-attributable cancer outcomes by age group, with the largest relative reductions in younger age groups and the largest absolute reductions in older age groups. In scenario 5, the largest absolute reductions were for those aged 55–64 years, who were projected to have 213 fewer alcohol-attributable incident cancer cases (95% UE 154–285) and 53 fewer alcohol-attributable cancer deaths (38–73), and those aged 65–74 years, who were project to have 204 fewer cases (147–274) and 72 fewer deaths (51–97). Younger age groups, although experiencing smaller absolute reductions because of lower baseline incident and mortality counts, still showed substantial relative reductions. For example, in scenario 5, those aged 25–34 years were modelled to have 11 (8–14) fewer alcohol-attributable incident cases, corresponding to a 9·5% (6·8–12·9) reduction.

Table 3 shows the fully-realised absolute and percentage changes in the number of incident cases of alcohol-attributable cancer and deaths by cancer site and policy scenario. The largest estimated reductions in alcohol-attributable cancer cases and deaths were seen in oral cavity and pharynx cancer, where combining a $2·00 MUP with a cancer warning label was projected to reduce incident cancer cases by 227 (95% UE 165–303), a reduction of 13·2% (9·6–17·6), and deaths by 64 (45–84), a reduction of 12·8% (9·4%, 17·3%). Breast cancer, one of the most prevalent alcohol-related cancers, was estimated to see a reduction of 193 (135–268) in alcohol-attributable incident cancer cases and of 32 (22–45) in alcohol-attributable cancer deaths. Counts of alcohol-attributable incident cases of colorectal cancer, the most common alcohol-related cancer in this analysis, were projected to drop by 152 cases (110–206).

The appendix (pp 5, 8) shows the estimated fully-realised percentage declines in alcohol-attributable cancer incidence and mortality, by province and policy scenario. More populous provinces—eg, Ontario, Quebec, and British Columbia—consistently reported the largest relative and absolute reductions in the number of alcohol-attributable cancer cases and mortalities, across all five scenarios. As together these three provinces made up most of Canada's population, national-level relative reductions in the number of alcohol-attributable cancer incident cases and mortalities were similar.

Discussion

This study shows that Canada's high level of alcohol use is responsible for a large burden of cancer in Canada. In 2022, nearly 9500 cancer incident cases and nearly 3900 cancer deaths would not have occurred in the absence of alcohol exposure. Incident cancer cases due to alcohol were found to be substantially higher than a previous estimate;[48] this trend should be studied prospectively. All five alcohol policy scenarios—two involving MUPs, two involving AWLs, and

	Baseline	Cancer label	MMR label	MUP $1·75	MUP $2·00	Cancer label plus MUP $2·00
Incident cases						
Females						
Cancer site						
Oral cavity and pharynx cancer	311 (283 to 340)	−8 (−16 to −4); −2·7% (−5·0 to −1·4)	−23 (−40 to −8); −7·3% (−13·0 to −2·7)	−8 (−10 to −8); −2·7% (−3·3 to −2·6)	−20 (−25 to −16); −6·5% (−7·9 to −5·0)	−28 (−39 to −20); −9·0% (−12·4 to −6·3)
Oesophageal cancer	92 (82 to 102)	−2 (−4 to −1); −2·2% (−4·1 to −1·1)	−6 (−10 to −2); −6·0% (−10·7 to −2·2)	−2 (−3 to −2); −2·3% (−2·9 to −2·2)	−5 (−6 to −4); −5·5% (−6·8 to −4·3)	−7 (−10 to −5) −7·6% (−10·5 to −5·3)
Colorectal cancer	329 (295 to 364)	−5 (−10 to −3); −1·6% (−3·0 to −0·8)	−15 (−26 to −5); −4·5% (−8·0 to −1·6)	−5 (−7 to −5); −1·7% (−2·0 to −1·6)	−13 (−16 to −10); −4·0% (−4·9 to −3·1)	−18 (−25 to −13); −5·5% (−7·7 to −3·9)
Liver cancer	308 (273 to 344)	−1 (−1 to 0); −0·2% (−0·5 to −0·1)	−2 −(−4 to −1); −0·7% (−1·2 to −0·2)	−1 (−1 to −1); −0·2% (−0·3 to −0·2)	−2 (−2 to −1); −0·6% (−0·7 to −0·4)	−2 (−3 to −2); −0·8% (−1·1 to −0·6)
Pancreatic cancer	94 (83 to 105)	−1 (−2 to −0); −0·9% (−1·8 to −0·5)	−2 (−4 to −1); −2·6% (−4·7 to −0·9)	−1 (−1 to −1); −1·0% (−1·2 to −0·9)	−2 (−3 to −2); −2·3% (−2·8 to −1·8)	−3 (−4 to −2); −3·2% (−4·5 to −2·2)
Laryngeal cancer	27 (24 to 30)	−1 (−1 to 0); −2·1% (−3·9 to −1·0)	−2 (−3 to −1); −5·7% (−10·1 to −2·1)	−1 (−1 to −1); (−2·1%(−2·6 to −2·0)	−1 (−2 to −1); −5·0% (−6·2 to −3·9)	−2 (−3 to −1); −7·0% (−9·7 to −4·9)
Breast cancer	2250 (2061 to 2442)	−57 (−106 to 29); −2·5% (−4·7 to −1·3)	−156 (−278 to −57); −6·9% (−12·4 to −2·5)	−59 (−72 to −56); −2·6% (−3·2 to −2·5)	−140 (−171 to −108] (−6·2% (−7·6 to −4·8)	−193 (−268 to −135] (−8·6% (−11·9 to −6·0)
Subtotal	3411 (3102 to 3411)	−75 (−139 to −38); −2·2% (−4·1 to −1·1)	−205 (−366 to −57); −6·0% (−10·7 to −2·2)	−77 (−94 to −73); −2·3% (−2·8 to −2·1)	−183 (−224 to −142] (−5·4% (−6·6 to −4·2)	−253 (−352 to −178); −7·4% (−10·3 to −5·2)
Males						
Cancer site						
Oral cavity and pharynx cancer	1406 (1355 to 1455)	−41 (−76 to −21); −2·9% (−5·4 to −1·5)	−113 (−201 to −41); −8·0% (−14·3 to −2·9)	−65 (−79 to −62); −4·6% (−5·7 to −4·4)	−162 (−199 to −126] (−11·6%(−14·1 to −9·0)	−199 (−264 to −145); −14·2% (−18·8 to −10·3)
Oesophageal cancer	297 (286 to 309)	−7 (−13 to −3); −2·3% (−4·3 to −1·2)	−19 (−34 to −7); −6·4% (−11·5 to −2·3)	−11 (−14 to −11); −3·8% (−4·6 to −3·6)	−28 (−34 to −22); −9·4% (−11·6 to −7·3)	−34 (−46 to −25); −11·6% (−15·4 to −8·4)
Colorectal cancer	3226 (3096 to 3355)	−29 (−53 to −14); −0·9% (−1·6 to −0·4)	−79 (−141 to −29); −2·4% (−4·4 to −0·9)	−41 (−51 to −39); −1·3% (−1·6 to −1·2)	−108 (−132 to −83); −3·3% (−4·1 to −2·6)	−134 (−180 to −97); −4·2% (−5·6 to −3·0)
Liver cancer	580 (556 to 603)	−4 (−7 to −2); −0·7% (−1·2 to −0·3)	−11 (−19 to −4); −1·8% (−3·3 to −0·7)	−6 (−7 to −5); −1·0% (−1·2 to −0·9)	−15 (−18 to −12); −2·6% (−3·2 to −2·0)	−19 (−25 to −13); −3·2% (−4·3 to −2·3)
Pancreatic cancer	357 (342 to 372)	−2 (−4 to −1); −0·5% (−1·0 to −0·3)	−5 (−10 to −2); −1·5% (−2·7 to −0·5)	−3 (−4 to −3); −0·8% (−1·0 to −0·8)	−8 (−9 to −6); −2·1% (−2·6 to −1·6)	−9 (−13 to −7); −2·6% (−3·5 to −1·9)
Laryngeal cancer	221 (212 to 229)	−5 (−10 to −3); −2·4% (−4·4 to −1·2)	−14 (−26 to −5); −6·4% (−11·6 to −2·4)	−8 (−10 to −8); −3·6% (−4·4 to −3·4)	−20 (−25 to −16); −9·2% (−11·3 to −7·1)	−25 (−33 to −18); −11·3% (−15·1 to −8·2)
Breast cancer	0	NA	NA	NA	NA	NA
Subtotal	6087 (5848 to 6323)	−88 (−163 to −44); −1·4% (−2·7 to −0·7)	−241 (−432 to −88); −4·0% (−7·1 to −1·4)	−134 (−165 to −127); −2·2% (−2·7 to −2·1)	−341 (−418 to −264] (−5·6% (−6·9 to −4·3)	−421 (−561 to −305] (−6·9% (−9·2 to −5·0)
Total	9498 (8950 to 10 049)	−163 (−302 to −82); −1·7% (−3·2 to −0·9)	−446 (−798 to −163); −4·7% (−8·4 to −1·7)	−211 (−259 to −200); −2·2% (−2·7 to −2·1)	−524 (−642 to −405); −5·5% (−6·8 to −4·3)	−674 (−911 to −484); −7·1% (−9·6 to −5·1)

(Table 3 continues on next page)

	Baseline	Cancer label	MMR label	MUP $1·75	MUP $2·00	Cancer label plus MUP $2·00
(Continued from previous page)						
Deaths						
Females						
Cancer site						
Oral cavity and pharynx cancer	84 (75 to 94)	−2 (−4 to −1); −2·6% (−4·8 to −1·3)	−6 (−10 to −2); −7·0% (−12·4 to −2·6)	−2 (−3 to −2); −2·5% (−3·1 to −2·4)	−5 (−6 to −4); −6·1% (−7·4 to −4·7)	−7 (−10 to −5); −8·4% (−11·7 to −5·9)
Oesophageal cancer	79 (70 to 88)	−2 (−3 to −1); −2·2% (−4·0 to −1·1)	−5 (−8 to −2); −5·9% (−10·6 to −2·2)	−2 (−2 to −2); −2·3% (−2·8 to −2·1)	−4 (−5 to −3); −5·4% (−6·6 to −4·1)	−6 (−8 to −4); −7·4% (−10·3 to −5·2)
Colorectal cancer	116 (102 to 129)	−2 (−3 to −1); −1·5% (−2·8 to −0·8)	−5 (−9 to −2); −4·2% (−7·5 to −1·5)	−2 (−2 to −2); −1·5% (−1·8 to −1·4)	−4 (−5 to −3); −3·6% (−4·4 to −2·8)	−6 (−8 to −4); −5·1% (−7·1 to −3·5)
Liver cancer	352 (310 to 395)	−1 (−1 to 0); −0·2% (−0·4 to −0·1)	−2 (−4 to −1); −0·6% (−1·1 to −0·2)	−1 (−1 to −1); −0·2% (−0·3 to −0·2)	−2 (−2 to −1); −0·5% (−0·6 to −0·4)	−3 (−4 to −2); −0·7% (−1·0 to −0·5)
Pancreatic cancer	91 (81 to 102)	−1 (−2 to 0); −0·9% (−1·7 to −0·5)	−2 (−4 to −1); −2·5% (−4·5 to −0·9)	−1 (−1 to −1); −0·9% (−1·1 to −0·9)	−2 (−2 to −2); −2·2% (−2·7 to −1·7)	−3 (−4 to −2); −3·1% (−4·3 to −2·1)
Laryngeal cancer	8 (7 to 9)	0 (0 to 0); −1·9% (−3·6 to −1·0)	0 (−1 to 0); −5·3% (−9·5 to −1·9)	0 (0 to 0); −1·9% (−2·3 to −1·8)	0 (0 to 0); −4·6% (−5·6 to −3·6)	−1 (−1 to 0); −6·4% (−9·0 to −4·5)
Breast cancer	394 (354 to 434)	−10 (−18 to −5); −2·5% (−4·6 to −1·2)	−27 (−47 to −10); −6·8% (−12·1 to −2·5)	−10 (−12 to −9); −2·4% (−3·0 to −2·3)	−23 (−28 to −18); −5·9% (−7·2 to −4·5)	−32 (−45 to −22); −8·2% (−11·4 to −5·7)
Subtotal	1125 (999 to 1252)	−17 (−32 to −9); −1·5% (−2·8 to −0·8)	−47 (−84 to −17); −4·2% (−7·4 to −1·5)	−17 (−21 to −16); −1·5% (−1·8 to −1·4)	−41 (−50 to −32); −3·6% (−4·5 to −2·8)	−57 (−79 to −40); −5·1% (−7·1 to −3·5)
Males						
Cancer site						
Oral cavity and pharynx cancer	398 (382 to 414)	−12 (−22 to −6); −2·9% (−5·4 to −1·5)	−32 (−57 to −12] (−8·0% (−14·2 to −2·9)	−18 (−22 to −17); −4·5% (−5·5 to −4·3)	−45 (−55 to −35); −11·3% (−13·8 to −8·8)	−57 (−74 to −40); −13·9% (−18·5 to −10·1)
Oesophageal cancer	256 (245 to 266)	−6 (−11 to −3); −2·3% (−4·3 to −1·2)	−16 (−30 to −6); −6·4% (−11·5 to −2·3)	−9 (−12 to −8); −3·7% (−4·5 to −3·5)	−24 (−29 to −18); −9·3% (−11·4 to −7·2)	−29 (−39 to −21); −11·4% (−15·3 to −8·3)
Colorectal cancer	1157 (1108 to 1207)	−9 (−17 to −5); −0·8% (−1·5 to −0·4)	−26 (−46 to −9); −2·2% (−4·0 to −0·8)	−13 (−16 to −12); −1·1% (−1·4 to −1·1)	−35 (−43 to −27); −3·0% (−3·7 to −2·3)	−43 (−58 to −31); −3·7% (−5·0 to −2·7)
Liver cancer	506 (484 to 528)	−3 (−6 to −2); −0·6% (−1·1 to −0·3)	−9 (−15 to −3); −1·7% (−3·0 to −0·6)	−4 (−5 to −4); −0·9% (−1·1 to −0·8)	−12 (−14 to −9] (−2·3% (−2·8 to −1·8)	−15 (−20 to −10); −2·9% (−3·9 to −2·1)
Pancreatic cancer	354 (339 to 370)	−2 (−3 to −1); −0·5% (−1·0 to −0·3)	−5 (−9 to −2); −1·4% (−2·6 to −0·5)	−3 (−3 to −3); −0·8% (−0·9 to −0·7)	−7 (−9 to −5); −2·0% (−2·5 to −1·5)	−9 (−12 to −6); −2·5% (−3·3 to −1·8)
Laryngeal cancer	69 (66 to 73)	−2 (−3 to −1); −2·3% (−4·3 to −1·2)	−4 (−8 to −2); −6·3% (−11·3 to −2·3)	−2 (−3 to −2); −3·4% (−4·2 to −3·3)	−6 (−7 to −5); −8·8% (−10·8 to −6·8)	−8 (−10 to −5); −10·9% (−14·6 to −7·9)
Breast cancer	0	..	..	..	..	..
Subtotal	2741 (2625 to 2857)	−34 (−62 to −17); −1·2% (−2·3 to −0·6)	−92 (−165 to −34); −3·4% (−6·0 to −1·2)	−50 (−62 to −46); −1·8% (−2·2 to −1·7)	−128 (−157 to −99); −4·7% (−5·7 to −3·6)	−159 (−212 to −115); −5·8% (−7·7 to −4·2)
Total	3866 (3624 to 4106)	−51 (−94 to −25); −1·3% (−2·4 to −0·7)	−139 (−248 to −51); −3·6% (−6·4 to −1·3)	−67 (−82 to −62); −1·7% (−2·1 to −1·6)	−169 (−208 to −131); −4·4% (−5·4 to −3·4)	−216 (−292 to −155; (−5·6% (−7·5 to −4·0)

Data are n or percentage change (95% uncertainty estimate). Prices are CAN$. MMR=multi-message rotating. MUP=minimum unit price. NA=not applicable.

***Table 3:* Estimated number of alcohol-attributable cancer incident cases and deaths, at baseline and under five alcohol policy scenarios, by sex and cancer site, Canada, 2022**

one combining both—showed robust reductions in alcohol use and alcohol-attributable cancer incidence and mortality. The modelling procedure was designed to estimate the fully-realised effect of these five policy scenarios. Across policy scenarios, a MMR label was estimated to reduce use and harm by more than solely a cancer warning label, and a higher MUP of $2·00 had a higher estimated effect than an MUP of $1·75. The largest fully-realised reduction from the modelling in alcohol use and harm from alcohol-attributable cancer was seen from a combined policy of a cancer warning label plus a $2·00 MUP. To the best of our knowledge, this is the first study to model the effect of AWLs on cancer incidence and mortality. These findings add to the evidence base and policy development efforts as further evidence indicates that increasing consumer knowledge of the alcohol–cancer link might be associated with support for alcohol policies.[49]

The current study adds to the literature modelling the effect of alcohol policies on cancer outcomes. A previous modelling study in the Canadian context found that an MUP of $1·75 in 2016 was estimated to lead to an alcohol use reduction more than double (8·7% *vs* 3·8%) that of a 55% increase in alcohol excise tax.[19] When adjusted for inflation, this $1·75 MUP in 2016 would be equivalent to $2·06 in 2022—similar to our $2·00 MUP model. As the 55% increase in excise tax would be equivalent to a 6·3% across-the-board increase in alcohol prices[19,50] and a meta-analysis of alcohol elasticities found an all-beverage elasticity of –0·44,[51] we conclude that an ad valorem tax that results in an alcohol price increase of approximately 20–25% would have to be levied to result in an alcohol use decrease equivalent to our modelled scenario 5. Kilian and colleagues[52] modelled excise tax increases in the WHO European region, finding that a 100% excise tax increase would result in substantial reductions in alcohol-attributable cancer cases (–5·9%) and deaths (–5·7%). A German macrosimulation study found 4–5% cancer reductions associated with alcohol price increases,[53] and studies in the Australian[54] and American[55] contexts found that interventions limiting alcohol use might lead to reductions in cancer rates.

Importantly, population subgroups, by sex, household income quintile, and age group, responded differentially to simulated policy changes in important ways. For example, people in the lowest income quintiles experienced larger reductions in alcohol-attributable cancer incidence and mortality in the MUP and combined scenarios; this finding might highlight a policy pathway towards narrowing health inequalities across Canada. A previous MUP modelling study also reported greater health benefits in the lowest socioeconomic group, although that study was not specific to cancer outcomes.[56] Our study provides added evidence of a potential pathway towards mitigating the effects of the alcohol harm paradox, which states that more disadvantaged groups experience greater levels of alcohol-attributable harm despite reporting similar or lower alcohol intake levels.[57] Males were estimated to be more responsive to both MUP and combined policy scenarios than females; this finding is important as our study found that males experience 1·8 times more alcohol-attributable incident cancers and 2·4 times more alcohol-attributable cancer deaths. By cancer site, modelled alcohol policies resulted in decreases of the largest magnitude in breast cancer for females and oral cavity and pharynx cancer for males. Notably, younger age groups also showed reductions in alcohol-attributable cancer outcomes, underscoring the potential for these policies to yield long-term public health benefits across the life course.

This study has limitations related to model assumptions and interpretation. Our findings should not be interpreted as expected instantaneous effects upon policy implementation; findings should instead be understood as approximate effects that would occur after cancer's latency period had passed after policy implementation and given model assumptions hold. A key limitation is that the modelling technique used was designed to estimate the fully-realised effect on alcohol use and alcohol-attributable cancer outcomes of alcohol policy scenarios. Because many cancers have a latency period of 10 years or more between exposure and incidence,[8] our technique assumes scenarios were enacted far enough in the past for latency periods to have elapsed, that policy scenarios were constant over this time (eg, by adjusting MUP levels for inflation year after year), and that changes in drinking behaviours caused by the policy scenarios were consistent. Results of our study should not be interpreted as the effect size that would occur instantaneously upon the introduction of these policies. Whereas some studies[52] model cancer incident rate changes between policy implementation and outcome measurement to account for latency effects, our technique does not. As Canadian alcohol purchasing data are sparse, data from Scotland and Wales[12] were used to disaggregate mean PPSD by income quintile, as well as to inform MUP elasticities. There were several key assumptions relating to using income quintile-specific MUP effect sizes from Scotland to inform our modelling in the Canadian context. First, by income quintile, we assumed that proportional differences in mean PPSD are similar between Scotland in 2018 and Canada in 2022 and, second, that MUP elasticities experienced by income quintiles in Scotland would be similar to those experienced in Canada by income gradient. These assumptions should be considered when interpreting our findings.

Further limitations were introduced because of data constraints. The Canadian Community Health Survey was the only available source including data on both alcohol use and household income quintile. As 2015–18 had the most recent data available, prevalence data of current and former drinkers used were from several years before the study year. Cancer incidence and mortality data were not disaggregated by income quintile. Survey-based population proportions were used in each province, sex, and age group to distribute incident cases and deaths into income quintiles within each population subgroup. This method might introduce inaccuracies; however, a study from Canada found a modest negative gradient between income and rates of cancer incidence, with the lowest income quintile having a rate ratio of 1·02 compared with the highest income quintile.[58] As this gradient is quite gradual the overall effect would be expected to be small or negligible. Future work should attempt to furnish administrative cancer incident and mortality data by household income quintile and other socioeconomic variables.

There were further limitations. The US Centers for Disease Control and Prevention additionally recognises prostate cancer as causally related to alcohol use[59] and the World Cancer Research Fund recognises alcohol's contribution to cancer of the stomach.[60] Meta-analyses[5] report positive relationships between alcohol use volumes and risk of various other cancers including cancers of the cervix, kidney, and pancreas. Our study therefore probably underestimates the true cancer burden of alcohol use. For modelled scenario 5, the alcohol use changes were calculated using a multiplicative, instead of additive, method. A sensitivity analysis using an additive approach, as in a previous modelling study,[46] found slightly more conservative results. Across the ten sex–income quintile subgroups, the largest difference between the additive and multiplicative methods in terms of the absolute percentage reduction in alcohol per capita was 0·004%: this finding had a negligible effect on the study findings. 95% UEs were based on 95% CIs from published effect sizes of MUP and AWL studies and did not include other sources of uncertainty from RR functions or alcohol use statistics. This limitation will lead to inaccuracies and possible underestimation of the uncertainty ranges. Data were not disaggregated by ethnicity. Our study assumed that cancer RR functions were stable and appropriate for a Canadian context, although they were extracted from a global study[40] and that the effect on alcohol use of alcohol labelling interventions was uniform by sex and income quintile. This last limitation was assumed as there were no studies available decomposing labelling effect by population subgroups.

In conclusion, the results of this modelling study suggest that alcohol policy interventions, particularly those combining a cancer warning label with a minimum unit price of $2·00, have the potential to lead to reductions in alcohol-attributable cancer incidence and mortality. The largest proportional benefits were seen among lower-income populations and younger age groups, highlighting the potential of these policies to reduce the overall alcohol-attributable cancer burden and narrow health inequalities.

Contributors

AS, TS, and KWL contributed to study conceptualisation; AS and KWL contributed to data curation, formal analysis, and data validation; AS, KWL, and TS contributed to the methodology; TS and AS supervised the study; and AS, KWL, JMC, EH, and TS wrote and revised the paper. All authors are responsible for the decision to submit the manuscript.

Declaration of interests

We declare no competing interests.

Data sharing

All data used in this study were publicly accessible and were de-identified in the case of survey and mortality information. Upon request to the corresponding author, the authors will provide computer coded methodologies and step-wise project datasets. The authors will provide these methodologies and data up to a period ending 5 years after publication.

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