

# Impact on alcohol-related mortality of a rapid rise in the density of private liquor outlets in British Columbia: a local area multi-level analysis

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## ABSTRACT

**Aims** To study relationships between rates of alcohol-related deaths and (i) the density of liquor outlets and (ii) the proportion of liquor stores owned privately in British Columbia (BC) during a period of rapid increase in private stores. **Design** Multi-level regression analyses assessed the relationship between population rates of private liquor stores and alcohol-related mortality after adjusting for potential confounding. **Setting** The 89 local health areas of BC, Canada across a 6-year period from 2003 to 2008, for a longitudinal sample with  $n = 534$ . **Measurements** Population rates of liquor store density, alcohol-related death and socio-economic variables obtained from government sources. **Findings** The total number of liquor stores per 1000 residents was associated significantly and positively with population rates of alcohol-related death ( $P < 0.01$ ). A conservative estimate is that rates of alcohol-related death increased by 3.25% for each 20% increase in private store density. The percentage of liquor stores in private ownership was also associated independently with local rates of alcohol-related death after controlling for overall liquor store density ( $P < 0.05$ ). Alternative models confirmed significant relationships between changes in private store density and mortality over time. **Conclusions** The rapidly rising densities of private liquor stores in British Columbia from 2003 to 2008 was associated with a significant local-area increase in rates of alcohol-related death.

**Keywords** Alcohol regulation, alcohol consumption, government monopoly, mortality, privatization.

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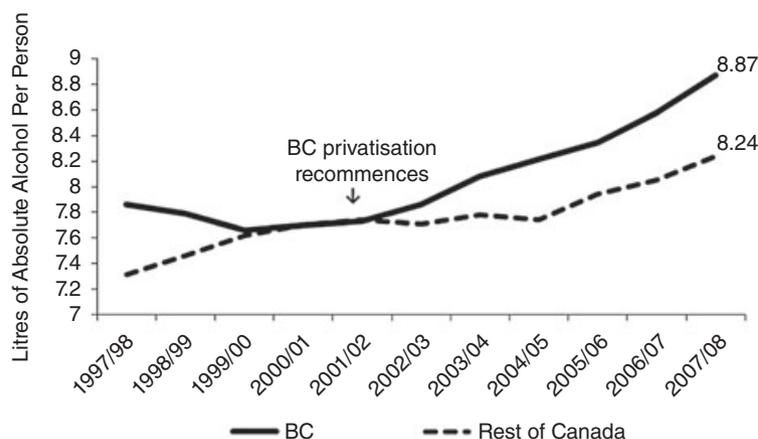
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## INTRODUCTION

A number of jurisdictions in Scandinavia and North America retain some form of government monopoly of their local liquor markets. Norway, Finland, Sweden, Iceland, the Faroe Islands and most Canadian provinces control, to some degree, the retail distribution of alcohol. In the United States, 19 jurisdictions can be designated as 'alcohol control states' in the sense that there is some government ownership of some aspects of the retail distribution of alcohol, often restricted to wine and/or spirits. Recent comparative analysis of control versus non-control US jurisdictions support the conclusion that the former succeed in collecting greater revenues from the sale of liquor with less alcohol-related harm [1,2].

Government control of the business of selling liquor is controversial and is often seen as anti-competitive. However, independent reviews of scientific evidence suggest that there are substantial public health and safety benefits from government control of the liquor industry [3,4]. While not always realized in practice, government alcohol monopolies provide readily accessible policy levers to reduce levels of alcohol-related harm which are supported strongly by scientific evidence. These 'levers' include the capacity to enact the following regulatory policies:

- (i) to restrict outlet density and thereby consumption and related harm [3].
- (ii) to restrict access to minors and obviously intoxicated people by enforcement of purchasing laws



NB: Liquor sales obtained for fiscal years (i.e. 12 months ending March 31) and population estimates as of 1 July within the same fiscal year

**Figure 1** Per capita 15+ absolute alcohol consumption, BC and rest of Canada from 1997/1998 to 2007/2008

- and high quality staff selection and training programmes [5];
- (iii) to limit the availability of high risk products, e.g. cheap high-strength drinks favoured by some high-risk drinkers [6];
  - (iv) to create price incentives for consumers to favour lower alcohol versus higher alcohol content drinks [7];
  - (v) to restrict or prohibit promotions which encourage over-consumption [8]; and
  - (vi) to restrict the trading hours at which stores may operate [9].

All these regulatory powers are not, of course, restricted to alcohol monopolies. Whether in so-called licence or monopoly states in the United States, local jurisdictions such as towns, cities and counties in the United States have planning and zoning policies which provide them with options to restrict outlet densities, flexibly enforce access to alcohol by minors and restrict promotions and trading hours. Therefore, it has been known for many years that differences between licence and monopoly states are often a matter of degree rather than kind [10].

This paper presents further analyses of an unusual policy experiment which has been unfolding in British Columbia (BC), Canada. Over the period 2002 until 2007 the province experienced a rapid growth in the number of private liquor stores accompanied by a small decline in government alcohol monopoly stores. A recently published analysis of the impact on liquor sales [11] found that among 89 communities in that province there was a significant association between increasing density of liquor stores and local per capita sales from alcohol while controlling for a number of socio-demographic differences and potential statistical biases. Furthermore, this first study also found that when density of liquor outlets was held constant, the proportion of liquor stores in private hands also significantly predicted the level of local per capita alcohol sales.

One response to our first report focusing on the impact on per capita liquor sales [11] was to suggest that the rate of increase in consumption was no different than that observed in the rest of Canada, i.e. the increases in consumption were probably unrelated to privatization. As illustrated in Fig. 1 below, in fact the rate of increase in per capita consumption of alcohol in BC has been higher than in the rest of Canada, with a widening gap in more recent years coinciding with the onset of privatization. Per capita alcohol consumption in some other individual provinces, notably Alberta (which is fully privatized), Prince Edward Island, Newfoundland and Saskatchewan (all monopoly provinces) has also been increasing at a similar pace to BC, but in the absence of major changes in the density and/or type of retail alcohol outlets [12,13] and broad economic factors other than privatization may be responsible in these cases. A unique feature for BC, however, is that there was a declining trend in consumption until the onset of partial privatization, after which that trend reversed.

The present study seeks to test the hypothesis that the increase in private liquor stores associated with the rapid privatization of the liquor market in BC between 2002 and 2007 was also associated with higher local rates of alcohol-related mortality. As in our first paper, we will examine whether such associations are significant in relation to both (i) the increase in population density of all types of liquor stores (i.e. both private and government) and (ii) whether the ratio of private to government liquor stores predicts rates of alcohol-related mortality independently from the overall population density of liquor stores.

## METHODS

The study design involved analysis of time-series cross-sectional panel data [14] comprising 6 years of annual alcohol-related mortality rates for each of British

Columbia's 89 local health areas (LHAs). Annual 'densities' or population rates of four types of liquor outlet (restaurant, government liquor store, bar and private store) were computed for each LHA. The purpose of the overall analysis was to investigate the relationship between these densities of different liquor outlets and local rates of alcohol-related mortality after adjustment for potential confounding from socio-demographical factors, spatial and temporal effects of observations. While data were available for smaller periods of time, the analysis focused on annual data because (i) there are seasonal variations in outlet density in many areas reflecting the effects of tourism and (ii) periods shorter than 1 year may not be sensitive to changes in rates of death, many of which are caused by chronic rather than the acute effects of alcohol.

#### Data sources

##### *Alcohol-related death data*

Quarterly data on alcohol-related deaths for the 89 BC local health areas (LHAs) were obtained from the BC Vital Statistics Agency Quarterly Digest [15]. These data,

which are available online (<http://www.vs.gov.bc.ca/stats/quarter/index.html>), capture deaths in which 'alcohol' is mentioned on the death certificates whether because the cause of death is, by definition, related to alcohol (e.g. alcoholic poisoning) or because it is identified on the death certificate as a contributory factor to an illness or injury [16].

The different causes of alcohol-related death recorded between 2003 and 2008 [16] are summarized in Table 1 below to indicate some of the complexity underlying this simple summary measure. The latest data available from the BC Vital Statistics Agency report a total of 1937 deaths in 2003, 1983 in 2004, 2016 in 2005, 2086 in 2006, 2074 in 2007 and 2011 in 2008. The numbers for more recent years will increase slightly as results of coronial inquiries are provided. There is evidence from other studies that population rates of chronic alcohol-related disease fluctuate simultaneously with changes in per capita alcohol consumption, despite the length of time it can take for an individual to develop such conditions as alcoholic cirrhosis [4]. Annual alcohol-related mortality rates for each LHA were computed to investigate the association of the mortality rates with outlet density.

**Table 1** Alcohol-related deaths by cause and ICD-10 code in British Columbia in 2003–2008.

Cause of death	ICD-10 code(s) <sup>a</sup>	2003–2008 <sup>b</sup>	
		<i>n</i>	%
Directly related to alcohol			
Alcohol intoxication	F100	224	1.87
Alcoholic psychoses/dependence	F101–F109	601	5.02
Alcoholic neurological disorders	G312, G621, G721	0	0.00
Alcoholic cardiomyopathy	I426	100	0.84
Alcoholic gastritis	K292	12	0.11
Alcoholic liver disease	K70	1311	10.96
Alcohol-induced chronic pancreatitis	K860	12	0.11
Alcohol poisoning	X45, X65	110	0.92
Subtotal		2372	17.82
Indirectly related to alcohol			
Certain infectious/parasitic diseases	A00–B99	375	3.12
Neoplasms	C00–D48	1426	11.92
Endocrine/nutritional/metabolic	E00–E243, E248–E89	335	2.80
Mental disorders	F00–F09, F11–F99	153	1.26
Neurological diseases	G00–G311, G318–G620, G622–G720, G722–G99	146	1.20
Circulatory	I00–I425, I427–I99	2504	18.93
Diseases of the respiratory system	J00–J98, U049	811	6.78
Digestive system diseases	K00–K291, K293–K69, K71–K85, K861–K92	707	5.91
Urinary system diseases	N00–N39, N990, N991, N995	120	1.00
Unintentional injury	V01–X44, X46–X59, Y40–Y86, Y88	1778	13.86
Suicide	X60–X64, X66–X84, Y87	612	5.11
Homicide	X85–Y09, Y871	58	0.48
All other causes		569	4.76
Subtotal		9594	80.18
Total		11 966	100.00

Source: BC Vital Statistics Agency [16]. <sup>a</sup>ICD-10: International Classification of Diseases 10th revision. <sup>b</sup>A total of 11 966 alcohol-related deaths according to the Vital Statistics Agency Quarterly Digest [15].

*Liquor outlet data*

Liquor outlet data were obtained from the Liquor Distribution Branch (LDB) of the BC Ministry of Public Safety and Solicitor General. The data were organized into 89 BC local health areas (LHAs) and into 4- or 5-week periods per annum for the fiscal years from 2003/04 to 2008/09. Each fiscal year begins 1 April and ends 31 March of the following year. There are four categories of outlets distinguished in the data: restaurants, bars, government liquor stores (GLS) and private liquor stores. Calendar yearly outlet densities for years 2003–08 were calculated to investigate the association of annual alcohol-related mortality rates with outlet densities.

*Population data*

Provincial population data was obtained from BC STATS (<http://www.bcstats.gov.bc.ca/DATA/pop/popstart.asp>) classified into five health authorities (HAs) collectively containing 16 health service delivery areas (HSDAs) which, in turn, and contained 89 LHAs. This data set combines information from the 2006 Census of Canada along with population projections for non-census years. Annual population data were used to estimate rates of liquor outlet density and also alcohol-related mortality per 10 000 population aged 15 years and older for each LHA.

*Socio-economic data*

Several socio-economic and demographic variables included in the analyses were selected on the basis of their potential to confound local rates of mortality [17,18]. Data on family income, education and ethnicity were taken from the 2006 population census. The data were obtained from the BC STATS website ([http://www.bcstats.gov.bc.ca/data/sep/lha/lha\\_main.asp](http://www.bcstats.gov.bc.ca/data/sep/lha/lha_main.asp)). The specific local area socio-economic indicators included in the analysis were: percentage of age 15+ population aged between 20 and 29 years, ratio of males to females, proportion of families with low income, proportion of aboriginal people and proportion of the population who had not completed post-secondary school education. The variables were chosen because they have a known relationship with the level of alcohol consumption and/or mortality risk in Canadian populations [17,18]. The incidence of low income was determined based on low-income cut-offs (LICOs) established by Statistics Canada and are used in the annual Statistics Canada data tables [19]. Population density was estimated from the total population in each area divided by the relevant land area (km<sup>2</sup>). This highly skewed variable was categorized for analysis into two broadly equal groups (<3.846 and

≥3.846) in order to capture substantial variation across the 89 LHAs used in the study.

**Statistical analyses***Rates of alcohol-related death by year, HA and LHA*

Analysis of variance (ANOVA) was performed to test differences in the rate of alcohol-related deaths between each of the five HAs in British Columbia and also between the 89 LHAs [20]. Simple linear regression analyses were performed to test for linear trends in the rates over time (year) [20].

*Multi-level models of the relationship between rates of mortality and liquor outlet density*

Three different analytical approaches were explored: (i) a mixed method with random effects to control for spatial and temporal factors, (ii) a model with LHA-specific fixed effects to control for all purely cross-sectional differences in the outcome across local areas and (iii) a differenced model assessing the relationship between annual changes in rates of liquor outlet density and alcohol-related mortality. The fixed-effects and differenced approaches are generally more conservative, but less efficient than the mixed model [21]. Both these approaches reduce the possibility of omitted-variable bias by discarding purely cross-sectional differences in the outcome measure, either by introducing LHA-specific dummy variables or by looking at changes in outcomes rather than their level. The fixed-effect approach loses statistical efficiency via the degrees of freedom used for the dummy variables, while the second approach sacrifices a year of data to accomplish the differencing. The mixed-model approach improves efficiency by using random effects (error components) to account for purely cross-sectional differences in the outcome, and may be judged unbiased if the random effects are uncorrelated with exogenous measures in the model. A Hausman test statistic was used to evaluate whether the mixed-model approach meets this standard and can thus be assumed to be unbiased [22]. This test indicated that the mixed model's results were not statistically different from those of the fixed-effect model ( $P = 0.2147$ ). For this reason, only the more efficient mixed-model results are presented in detail below.

Regression models were conducted both with and without controls for economic, demographic, temporal and geographic variation as well as with and without controls for the population density of each of the four kinds of liquor outlet examined (i.e. government liquor stores, private liquor stores, bars and restaurants). The fixed-effects models used LHA-specific dummy variables to account for any unexplained differences in alcohol-mortality probability between areas across the entire study period.

**Table 2** Coding guideline of variables in multivariate regression analyses.

Variable	Description	Indicator
<b>Dependent</b>		
log-rate	Log-transformed alcohol-related mortality rate per 10 000 in LHA	Numeric
<b>Independent</b>		
res	Restaurant density per 1000 adults in LHA	Numeric
gls	GLS density per 1000 adults in LHA	Numeric
bar	Bar density per 1000 adults in LHA	Numeric
pri	Private store density per 1000 adult in LHA	Numeric
plsp	% Private stores to stores in LHA	Numeric
dls	GLS and private density in LHA	Numeric
dop	Bar and restaurant density in LHA	Numeric
ha	Health authorities	1–5 categories
hsda	Health service delivery areas	1–16 categories
lha	Local health areas	1–89 categories
year	Time variable in LHA	1–6 calendar years
P2029	% Population 20–29 to total in LHA	Numeric
rmf	Ratio of males to females in LHA	Numeric
lif	% Low-income families in LHA	Numeric
abo	% Aboriginals in LHA	Numeric
pse	% Adults without completed post-secondary school education in LHA	Numeric
pd	Population density (people/m <sup>2</sup> ) in LHA	<3.846 and ≥3.846

LHA: local health area.

SAS codes for the fully-adjusted model I (Table 4): Proc mixed data = mixedmodel; Class ha hsda lha year pd; Model lograte = res gls bar pri pd p2029 rmf lif abo pse/solution cl; Random intercept/subject = ha; Random intercept/subject = hsda; Random intercept/subject = lha; Random year; Run; SAS codes for model II (Table 5): Proc mixed data = mixedmodel; Class ha hsda lha year pd; Model lograte = plsp dls dop pd p2029 rmf lif abo pse/solution cl; Random intercept/subject = ha; Random intercept/subject = hsda; Random intercept/subject = lha; Random year; Run;

Multi-level models were used to model the data in which LHA, HSDA, HA and year (all treated as categorical variables) were treated as random-effect variables [21,23,24]. These mixed-effects multi-level models control effectively for temporal autocorrelation and intraclass correlations among units within cells of the design, i.e. the tendency for observations adjacent in time-periods or within spatial units (89 LHAs nested within 16 HSDA nested within five HAs) to be similar to each other. Measures from one geographic area may be highly correlated, whereas those from different areas may be more independent of each other [21,23,24]. People within one population or area are more likely to share similar characteristics than people who come from different populations or areas. Data analysis needs to take into account such groupings, otherwise spurious statistically significant results are more likely [25,26]. To the extent that groups of people living in adjacent areas share similar backgrounds and behaviours and communicate with one another, loss of spatial independence between units may remain a problem. The multi-level analyses conducted will have dealt with spatial autocorrelation to some degree by virtue of nesting 89 LHAs within 16 HSDAs themselves nested within five HAs. In addition, the intraclass correlations arising from this spatial nesting of regions within areas are reported. As a sensitivity analysis, we also analysed differenced data in

which a stationary process was used to produce a data set in which mean, variance and autocorrelation structure did not change over time [27]. This approach involved the analysis of change scores in annual rates of alcohol-related mortality and outlet density, adjusted for potential confounding of socio-demographic factors. Variables included in the mixed models are presented in Table 2.

Tests for normality of the distribution of all continuous variables were conducted [26]. Logarithmic data transformation was required to approximate only the normal distribution for the alcohol-related mortality variables but not the independent variables. The models assumed that annual trends were linear in time and that the effect of outlet density was to increase or decrease levels of yearly alcohol-related mortality rate. Univariate analysis was used to select variables for inclusion in regression analyses in all three models. Those for which univariate tests had a *P*-value < 0.20 were included [28]. All selected covariates by univariate analysis were included in the models regardless of their statistical significance. The rationale for this approach is to provide as much control of confounding as possible within the given data set [28]. This is based on the fact that it is possible for individual variables not to exhibit strong confounding, but when taken collectively, considerable confounding may be present in the data [28].

All statistical analyses were conducted using SAS statistical software, version 9.1 [29]. We performed the test of normality of the outcome using SAS PROC UNIVARIATE, ANOVA using SAS PROC ANOVA and trend and analysis using SAS PROC REG [20,29,30]. The Hausman test was performed using the SAS TSCSREG procedure [31]. The multi-level regression analysis was conducted using the SAS MIXED procedure [29,30]. The coefficient and 95% confidence interval (CI) was used for the estimate of logarithm of yearly alcohol-related mortality rate with yearly number of four categories of establishment per 1000 adults aged 15 years and older. All significance tests assumed two-tailed  $P$  values or 95% CIs.

## RESULTS

### Alcohol-related mortality rate

There were 534 observations of yearly alcohol-related mortality rate estimated using multi-level (mixed) model (89 LHAs  $\times$  6 years). The mean annual rate of alcohol-related mortality for the 89 LHAs included for was 8.09 per 10 000 population [standard deviation (SD) = 6.05, min = 1.04 and max = 50.35] with a significant difference between these 89 areas ( $F_{(88,df)} = 10.46$  and

$P < 0.0001$ ). There was also a significant difference between health authorities ( $F_{(4,df)} = 11.06$  and  $P < 0.0001$ ) and between health service delivery areas ( $F_{(15,df)} = 9.46$  and  $P < 0.0001$ ) but not across years ( $F_{(1,df)} = 1.14$  and  $P = 0.2529$ ).

### Outlet density

Table 3 presents mean rates of outlets per 1000 adults aged 15 years and older for different types of outlet across LHAs over the study period. Bars and restaurants accounted for the largest number of licensed outlets and government liquor stores the fewest.

Table 4 shows that alcohol sales from government liquor stores tended to decrease over time, bar sales were steady, while the sales from restaurants and private stores tended to increase during the study period. By the end of the study period, sales from private liquor stores were almost equal to those from government stores. Furthermore, the increase in sales of private stores on their own account for nearly all the increase in per capita consumption of alcohol over the study period—small changes for government stores (a decrease) and restaurants (an increase) were similar in size.

**Table 3** Mean rate of outlets per 1000 adults aged 15 years and older across 89 BC local health areas by types of outlet in British Columbia in 2003–2008.

Outlet	<i>n</i> observations	Mean	SD	Minimum <sup>a</sup>	Maximum
Restaurant	534	1.491	0.900	0.001	4.837
Government store	534	0.157	0.253	0.001	2.410
Bar	534	1.088	0.845	0.001	6.426
Private store	534	0.590	0.572	0.001	4.630

<sup>a</sup>One or more outlets were zero among four local health areas (LHAs) and the estimates were artificially set at 0.001. SD: standard deviation.

**Table 4** Calendar year alcohol sales (in 1 000 000 litres of ethanol) for four categories of establishments and number of outlets in BC for years 2003 to 2008.

<i>100 000 litres of absolute alcohol sold and average number of outlets</i>										
Year	Restaurants		GLS <sup>a</sup>		Bars		Private stores		Total	
	Litres (million)	<i>n</i> Outlets								
2003	1.9	3849	14.6	222	4.0	1833	7.1	727	27.6	6630
2004	2.0	3936	14.0	220	3.9	1841	8.5	799	28.4	6797
2005	2.1	4040	13.2	213	3.9	1849	10.1	895	29.3	6996
2006	2.3	4149	13.1	208	3.9	1832	11.2	943	30.5	7078
2007	2.4	4165	12.9	201	3.9	1818	12.2	969	31.5	7156
2008	2.4	4163	13.3	199	3.8	1812	13.0	977	32.6	7182

<sup>a</sup>GLS: government liquor store.

### Multi-level model of alcohol-related mortality and outlet density

Table 5 presents multi-level regression models of the relationship between local area rates of alcohol-related mortality (per 10 000 population) and rates of different outlet types (per 1000 population aged 15+ years) and over the 6 years of the study.

The fully adjusted estimates for private stores indicate significant positive associations between rates of alcohol-related mortality and densities of both private liquor stores and bars. An inverse relationship was found between rates of government liquor stores and alcohol-related mortality. According to the fully adjusted mixed model, the rate of alcohol-related deaths increased by 27.5% with each extra private liquor store per 1000 residents or the rate increased by 3.25% with a 20% increase in private liquor stores.

Table 6 presents a multi-level analysis of the relationship between rates of alcohol-related death per 10 000 population and percentage of liquor stores in private hands controlling for overall density of liquor stores (government and private) and on-premise outlets (i.e. bars and restaurants) as well as temporal, spatial and demographic characteristics at the health region level (LHA). The percentage of liquor stores in private hands and the density of on premise outlets (bars and restaurants combined) both significantly predicted the rate of alcohol-related deaths ( $P < 0.05$ ).

A sensitivity analysis was conducted in which annual rates of alcohol-related mortality were adjusted for under-reporting, with larger adjustments for more recent years. An identical pattern of results was obtained. In addition, both the fixed effects and the model using differencing (not presented here) found substantial and significant effects of overall liquor store density on mortality but not for the percentage of liquor stores in private hands.

### DISCUSSION

The purpose of the present study was to test the hypothesis that a substantial increase in the number of private liquor stores per head of population in BC following the partial privatization of the government retail alcohol monopoly in 2002 [11] was associated with increased local rates of alcohol-related deaths. Approximately 80% of these deaths recorded during the study period were related to the chronic effects of alcohol and 20% the acute effects. The results of this study support the conclusion that these local area level changes in the density of private liquor stores over a comparatively short period of time were associated significantly and positively with local rates of alcohol-related mortality.

The 6-year period spanning the calendar years 2003–08 was chosen for the study as the authors were able to obtain detailed local area data concerning types of liquor outlets and rates of alcohol-related death across 89 local health areas in BC. During the study period there was a 34.4% increase [correction added on 25 January 2011, after first online publication: 40.2% has been changed to 34.4%] in the number of private liquor stores accompanied by an 84.3% increase in litres of ethanol sold through these outlets. During this period the number of government liquor stores and their sales both decreased slightly. The overall increase in alcohol-related mortality reported by the BC Vital Statistics Agency was not statistically significant after controlling for all other exogenous variables. A conservative trend in these data needs to be noted, however, with more recent years tending to have slightly more underestimation than earlier years. This fact was minimized in this study by excluding data from the most recent year—2009. This source of potential bias in the data may reduce the likelihood of finding a positive relationship between mortality and the substantially increasing density of private liquor

**Table 5** Relationship between log-transformed annual alcohol-related mortality rate per 10 000 population and annual number of different liquor outlets per 1000 population aged 15 years and over in BC in 2003–2008.

Outlet	Unadjusted <sup>a</sup>		Estimate and 95% CI from mixed model <sup>d</sup>			
	Estimate	95% CI	Partially adjusted <sup>b</sup>		Fully adjusted <sup>c</sup>	
Restaurant	0.165	0.107–0.224***	0.103	0.023–0.183*	0.051	–0.038–0.141
GLS	0.727	0.521–0.932***	0.198	–0.106–0.502	–0.568	–0.941–0.195**
Bar	0.362	0.305–0.418***	0.244	0.142–0.345***	0.203	0.039–0.367*
Private	0.538	0.455–0.621***	0.340	0.202–0.477***	0.275	0.089–0.461**

F-test: \* $P \leq 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ . <sup>a</sup>Single outlet measure in model. <sup>b</sup>Each individual outlet measure in model including health authority, health service delivery area, local health area, year, % of people aged 20–29, ration of males to females, % of low income family, % of Aboriginals, % of population aged 15–54 without completed post-secondary school education and population density in mixed models. <sup>c</sup>The effect of four outlet measures simultaneously in model including socio-economic variables and taking spatial and temporal effects into account. <sup>d</sup>Health authority, health service delivery area, local health area and year were treated as random effects in fully adjusted mixed models and estimate of intraclass correlation coefficient (ICC) =  $(0.0011 + 0.0012 + 0.0755 + 0.00069)/(0.0011 + 0.0012 + 0.0755 + 0.0009 + 0.1224) = 0.391$ , indicating that 39.1% of the variation in yearly alcohol-related mortality rate occurs between health regions and years. CI: confidence interval; GLS: government liquor store.

**Table 6** Multi-level analysis of the relationship between log-transformed alcohol-related mortality rate (per 10 000 population) and percentage of liquor stores in private hands controlling for overall outlet density as well as temporal, spatial and demographic characteristics at local health area level.

Variable	Estimate	95% CI of the estimate	
		Lower	Upper
<b>Fixed effect</b>			
% Liquor stores that are private (PLSP)	0.006	0.001	0.011*
Density of liquor stores (GLS + private) (DLS) <sup>a</sup>	0.103	-0.027	0.232
Density of on premise (restaurants + bars) (DOP)	0.084	0.020	0.148*
% Population aged 20–29 versus total (p2029)	-0.040	-0.064	-0.016*
Ratio of male versus female (RMF)	0.889	-0.667	2.445
% Low-income families versus all families (LIF)	0.001	-0.011	0.013
% Aboriginal (ABO)	0.006	0.001	0.012*
% People aged 25–54 without completed PSE (PSE) <sup>b</sup>	0.039	0.026	0.051***
Population density (number of residents/km <sup>2</sup> ) (PD)			
<3.846	-0.242	-0.455	-0.030*
≥3.846	0.000		
<b>Covariance parameter estimates</b>			
<b>Random effect</b>		Estimate <sup>c</sup>	Standard error
Level III: health authority (5 HA)		0.0029	0.0091
Level II: health service delivery area (16 HSDA)		0.0020	0.0086
Level I: local health area (89 LHA)		0.0748	0.0170
Level I: year (6)		0.0007	0.0013
Residual		0.1246	0.0084
Model $\chi^2 = 442.7$ and $P < 0.0001$			

F-test: \* $P \leq 0.05$ ; \*\*\* $P < 0.001$ . <sup>a</sup>GLS: government liquor store. <sup>b</sup>PSE: post-secondary education. <sup>c</sup>Estimate of intraclass correlation coefficient (ICC):  $(0.0029 + 0.0020 + 0.0748 + 0.0006)/(0.0029 + 0.0020 + 0.0748 + 0.0007 + 0.1246) = 0.392$ , indicating that 39.2% of the variation in quarterly alcohol-relevant mortality rate occurs between health regions and years. CI: confidence interval.

stores during the study period. A sensitivity analysis in which adjustments were made to rates of alcohol-related mortality taking account of greater under-reporting in more recent years also found an identical pattern of results to those presented in this paper for the unadjusted data.

The main multi-level regression analysis used to test the relationships of interest indicated that each additional private liquor store per 1000 residents and (aged 15 years or more) increased local alcohol-related mortality by 27.5%—or a 20% increase in private store density increased local alcohol-related mortality by 3.25%. This is likely to underestimate the true effect given the likelihood of some underestimation of alcohol-related mortality in more recent years. A model with fixed effects for local health area found significant relationships between density of private liquor outlets and alcohol-related mortality, but a Hausman test suggested that the more efficient mixed-effects model was appropriate to assess the relationships of interest [22]. A further model examining annual change scores also found significant relationships between the density of liquor stores and mortality over time. Collectively, these results suggest strongly that the BC model of privatization has probably contributed to increases in alcohol-related mortality both

through increasing the overall density of liquor outlets as well as the proportion of these in private hands. This finding is also consistent with a substantial literature finding strong relationships between the density of liquor outlets and rates of alcohol-related harm [3].

The results are also consistent with an earlier study of the effects of BC liquor privatization which found that both the overall population density of liquor stores and the proportion of these in private hands predicted rates of per capita alcohol sales independently [11].

The available mortality data did not distinguish between acute and chronic causes of death—based on other international findings it might be anticipated that some causes of death (e.g. liver cirrhosis and injuries) will be related more closely to current per capita alcohol sales than other kinds of alcohol-related illness [32]. Future research could investigate usefully whether there are differential sensitivities over time in changes in different types of death in response to changes in the form and overall availability of alcohol.

A common thread between the two studies is confirmation of the well-established connection between density of liquor outlets and rates of both per capita alcohol consumption and alcohol-related deaths. There are many reasons for supposing that government liquor

stores are better instruments for minimizing public health and safety consequences than private stores. These include greater compliance with laws regarding the sale of alcohol to minors and obviously intoxicated people, shorter trading hours and an absence of price discounting as noted in our introduction.

It is concluded that, consistent with the wider international literature [3], the increase in the number of liquor stores in BC per head of population following the 2002 partial privatisation has led to both increases in rates of alcohol consumption and of alcohol-related deaths.

#### Declarations of interest

None.

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