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The relationship between minimum alcohol prices, outlet densities and alcohol-attributable deaths in British Columbia, 2002–09

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ABSTRACT

Aim To investigate relationships between periodic increases in minimum alcohol prices, changing densities of liquor stores and alcohol-attributable (AA) deaths in British Columbia, Canada. **Design** Cross-section (16 geographic areas) versus time–series (32 annual quarters) panel analyses were conducted with AA deaths as dependent variables and price, outlet densities and socio-demographic characteristics as independent variables. **Setting and participants** Populations of 16 Health Service Delivery Areas in British Columbia, Canada. **Measurements** Age–sex-standardized rates of acute, chronic and wholly AA mortality; population densities of restaurants, bars, government and private liquor stores; minimum prices of alcohol in dollars per standard drink. **Findings** A 10% increase in average minimum price for all alcoholic beverages was associated with a 31.72% [95% confidence interval (CI): ± 25.73%, $P < 0.05$] reduction in wholly AA deaths. Significantly negative lagged associations were also detected up to 12 months after minimum price increases for wholly but not for acute or chronic AA deaths. Significant reductions in chronic and total AA deaths were detected between 2 and 3 years after minimum price increases. Significant but inconsistent lagged associations were detected for acute AA deaths. A 10% increase in private liquor stores was associated with a 2.45% (95% CI: ± 2.39%, $P < 0.05$), 2.36% (95% CI: ± 1.57%, $P < 0.05$) and 1.99% (95% CI: ± 1.76%, $P < 0.05$) increase in acute, chronic and total AA mortality rates. **Conclusion** Increases in the minimum price of alcohol in British Columbia, Canada, between 2002 and 2009 were associated with immediate and delayed decreases in alcohol-attributable mortality. By contrast, increases in the density of private liquor stores were associated with increases in alcohol-attributable mortality.

Keywords Alcohol-attributable mortality, alcohol outlet density, cross-section versus time–series design, minimum alcohol price, mixed model.

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INTRODUCTION

Alcohol use is related to a wide range of physical, mental and social harms [1]. Alcohol affects practically every organ in the human body, is a causal factor in more than 60 major types of diseases and injuries and results in approximately 2.5 million deaths globally each year [1,2]. This means that about 4% of all deaths world-wide are attributable to alcohol. Recently, there has been increased research attention and policy interest in the application of minimum alcohol prices as a measure to both reduce alcohol-related problems and increase government revenues [3]. There are different models for the application of minimum pricing. In Canada, where minimum liquor prices have been set by provincial government monopolies (in some instances for several decades), they are defined typically as the minimum price for a litre of beverage without any reference to ethanol content. In the United Kingdom, however, moves are under way to introduce minimum prices defined for 'units' of ethanol (1 unit = 8 g ethanol in the United Kingdom) and in Saskatchewan, Canada minimum prices were overhauled recently to reflect more clearly the ethanol content of the drinks to which they were applied [4].

Two recent studies conducted in British Columbia (BC) and Saskatchewan have shown significant reductions in alcohol consumption following the introduction of increased minimum prices [5,6]. These effects were demonstrated despite a relatively small number of products being affected by minimum price increases. In BC this was approximately 24% of spirit products [5], and in Saskatchewan 11% of all products on the market [6]. However, to date, no empirical studies have been conducted which investigate associations between minimum price increases and alcohol-attributable (AA) mortality. The present study will utilize data uniquely available in BC for the years 2002–09 to explore associations between changes to minimum alcohol prices and rates of acute, chronic and wholly AA mortality.

One complication of using BC as a case study for this particular time-period is another important alcohol policy that was being implemented progressively between 2002 and 2009: the partial privatization of alcohol retail sales resulting in a substantial expansion of private liquor stores [7,8]. This marked increase in density of private liquor stores was associated with an increase in total alcohol-related mortality [8]. It was therefore important to control for changes in alcohol outlet density in the present study in order to estimate the unique associations between minimum alcohol prices and AA mortality.

METHODS

Study design

A cross-section versus time–series panel study [9] was designed to investigate the impacts of alcohol outlet densities and periodic increases to minimum prices of different beverages on AA mortality, while adjusting for confounding effects of trend, season, socio-economic and demographic characteristics (age and sex, family income, percentage of aboriginal population, percentage of visible minorities, percentage of population without secondary school completion and population density), regional differences and temporal autocorrelation. The data were collated from 16 geographic regions defining Health Service Delivery Areas (HSDAs) for 32 annual quarters from 1 January 2002 to 31 December 2009.

Data sources

Data on AA deaths

AA deaths were estimated based on population-attributable fractions (PAFs) for alcohol and the number of deaths for each of the disease or injury categories [1]. PAFs are the proportional reduction in population mortality that would occur if exposure to a risk factor such as alcohol use was eliminated or reduced. They are calculated based on estimated population exposure to alcohol and established risk relations between consumption and different disease categories. Mortality data used in this study were received from the BC Statistics Agency by types of death, HSDA, quarter and year. Ethics approval was obtained from the University of British Columbia Behavioural Research Ethics board (H06-04043). These data are held securely at the BC Centre for Disease Control. The underlying cause of death code (UCOD) was used in the computation of AA mortality and the approach of computing AA fractions can be seen elsewhere [10,11]. An attributable fraction was applied in computing the number of acute and chronic AA deaths. The acute AA conditions include unintentional and intentional injuries while chronic AA conditions comprise all other causes of death (see Table 1). The wholly AA conditions include alcoholic psychoses, alcohol dependence, alcohol abuse, alcoholic cardiomyopathy, alcoholic gastritis, chronic pancreatitis (alcohol-induced), fetal alcohol syndrome, excess alcohol blood level, accidental poisoning and exposure to alcohol and intentional self-poisoning by and exposure to alcohol. The conditions in the wholly AA category are also included in the categories of acute and chronic AA conditions. They are of special interest because they do not depend on the population-attributable fraction methodology, which may introduce unknown biases. Quarterly acute, chronic, wholly and total AA age–sex-standardized mortality rates per 100 000 population by calendar year were computed using the 2001 BC population as the standard population for each HSDA [12] for use as the dependent variables in the cross-sectional time–series models.

Minimum prices for alcohol sales

Rates of minimum prices for specific beverage types and dates when they were changed were obtained from the Liquor Distribution Branch (LDB) of the BC Ministry of Public Safety and Solicitor General (see: http://onlinelibrary.wiley.com/doi/10.1111/j.1360-0443.2011.03763.x/suppinfo) [5]. During the study period, the minimum price for spirits increased from $25.91 to $27 per litre of spirits beverage in August 2004, to $28.33 in September 2006, to $29.33 in January 2008 and to $30.66 in April 2009. The minimum price for packaged and draft beers increased to $3.47 and $2.18 per litre, respectively, in May 2006, to $3.54 and to $2.22 in January 2008 from $3.00 and $2.05 prior to May 2006. The minimum prices of other beverages (liqueurs, coolers and wines) remained unchanged during the study period. The average

Table 1 Alcohol-attributable conditions and the corresponding ICD-10 codes.

Alcohol-attributable conditions	*ICD-10 code*
Acute alcohol-attributable	
Unintentional injuries	
Motor vehicle accidents	V21–V892
Poisonings	X40–X49
Accidental poisoning and exposure to alcohol	X45
Falls	W00–W19
Fires	X00–X09
Drowning	W65–W74
Other unintentional injuries	Rest of V and W20–W64, W75–W99, X10–X39, X50–X59, Y40–Y86, Y88, Y89
Intentional injuries	
Self-inflicted injuries	X60–X84, Y87.0
Intentional self-poisoning and exposure to alcohol	X65
Homicide	X85–Y09, Y87.1
Other intentional injuries	Y35
Chronic alcohol-attributable conditions	
Malignant neoplasms	
Oropharyngeal cancer	C00–C14
Oesophageal cancer	C15
Liver cancer	C22
Laryngeal cancer	C32
Breast cancer	C50
Other neoplasm	D00–D48
Diabetes	
Diabetes mellitus	E10–E14
Neuropsychiatric conditions	
Alcoholic psychoses	F10.0, F10.3–F10.9
Alcoholic dependence syndrome	F10.2
Alcohol abuse	F10.1
Unipolar major depression	F32–F33
Degeneration of nervous system due to alcohol	F31.2
Epilepsy	G40–G41
Alcoholic polyneuropathy	G62.1
Cardiovascular diseases	
Hypertensive disease	I10–I15
Ischaemic heart disease	I20–I25
Alcoholic cardiomyopathy	I42.6
Cardiac arrhythmias	I47–I49
Heart failure and ill-defined complications of heart disease	I50–I52, I23, I25.0, I97.0, I97.1, I98.1
Cerebrovascular disease	I60–I69
Ischaemic stroke	I60–I62
Haemorrhagic stroke	I63–I66
Oesophageal varices	I85
Digestive disease	
Alcoholic gastritis	K29.2
Cirrhosis of the liver	K70, K74
Cholelithiasis	K80
Acute and chronic pancreatitis	K85, K86.1
Chronic pancreatitis (alcohol-induced)	K86.0
Skin diseases	
Psoriasis	L40
Conditions arising during the perinatal period (maternal use)	
Low birth weight and short gestation[a]	P05–P07
Fetal alcohol syndrome (dysmorphic)	Q86.0
Excess alcohol blood level	R78.0
Ethanol and methanol toxicity, undetermined intent	Y15

[a]Defined by the Global Burden of Disease study.

monthly consumer price index (CPI) in each quarter for all the products in BC during the period 2002–09 was incorporated into the calculation of minimum prices for each category of alcoholic beverages and expressed in terms of dollars per standard drink (one Canadian standard drink = 17.05 ml = 13.45 g). Estimates for the CPI-adjusted average minimum price of all beverages was computed as an average of minimum prices for each individual beverage type weighted by overall proportion of sales over the complete study period. We did not include an estimate of average alcohol prices in the models, as the available measure for this was only indirect (total dollar value divided by total litres of beverage sold) and in a previous study was found not to be related significantly to overall alcohol consumption [5].

Alcohol outlet data

Alcohol outlet data were also obtained from the LDB by four categories: restaurants, bars, government liquor stores (GLS) and private liquor stores (PLS). The data were aggregated into 16 HSDAs and quarterly outlet densities for 16 HSDAs for 2002–09 were calculated by the number of restaurant, GLS, bar and PLS divided by annual population aged 15 years and older.

Population data

Provincial population data, classified into 16 HSDAs, were obtained from BC STATS (http://www.bcstats.gov.bc.ca/data/pop/popstart.asp). These data were used to calculate the alcohol outlet densities per 100 000 adults aged 15 years and older for these areas for each quarter of the study period. BC STATS estimated the populations by HSDA by combining information from the 2006 Census of Canada with population projections for non-census years.

Socio-economic and demographic data

Several socio-economic and demographic variables were included in the analyses, selected for their potential to confound the main relationships of interest [8,13–16]. These variables were (i) percentages of aboriginal people, of people who identified as a visible minority, of people without secondary school completion, (ii) population density per km^2 and (iii) mean family income. This information was derived from the 2006 Canada Census [17]. The annual population density was estimated by total population in each area for each year divided by land area (km^2).

Statistical analyses

All statistical analyses were conducted using SAS version 9.3 [18,19]. All statistical significance decisions were based on two-tailed *P*-values. Descriptive analyses were performed first. Quarterly AA age–sex-standardized mortality rates were analysed to examine trend changes and seasonal differences using bivariate regression [20].

Bivariate regression analyses were also performed to examine the relationships between mortality rates and socio-economic and demographic variables. Inclusion of socio-economic and demographic covariates in the models was determined by: published evidence of a relationship with drinking outcomes, the availability of the data and finally by the results of the bivariate regression analyses investigating associations with rates of AA mortality. Specifically, any variable for which the regression analysis generated a *P*-value <0.20 was considered as a candidate for the multivariate mixed regression analyses [21]. The rationale for this approach is to provide as much control of confounding as possible within the given data set [21]. Age and sex effects were adjusted for by using age–sex-standardization [12]. Durbin–Watson statistics were calculated for testing autocorrelation/moving average effects [22] and the sandwich estimation was used to test and correct for heteroskedasticity [23].

Mixed models were used to further analyse the data while the potential confounding effects of covariates were adjusted for in the analyses. General mixed modelling approaches [24] provide straightforward and flexible methods for assessing temporal dynamics of the relationship between AA mortality rate and various community factors. Mixed models permit tests of fixed effects through either maximum likelihood (ML) or restricted maximum likelihood (REML) estimation. This permits simultaneous inference about temporal factors through the use of fixed and random effects and allows for the choice of an appropriate covariance structure for the data being analysed. In the present study, this approach permitted testing of associations between rates of AA mortality and minimum prices while adjusting for the potential confounding effects of alcohol outlet densities, socio-economic characteristics, population density, temporal trend and autocorrelation effects. The approach also allowed for adjustments to be made to control for panel-specific autocorrelation effects that were identified [18,19]. The data were de-seasonalized by calculating an index for each quarter and weighting the data to control for seasonal effects [25]. The full form of the equation used for fully adjusted mixed models can be found in Appendix S1.

RESULTS

AA deaths in HSDAs

There were 3642 acute AA deaths (38.40%) and 5842 chronic AA deaths (61.60%) in BC during the study period. Among these 9484 acute and chronic AA deaths, 1388 (14.64%) were wholly AA. Table 2 summarizes the mean rates of AA age–sex-standardized mortality rates from 2002 to 2009 for 16 HSDAs ($n = 512$). Bivariate regression analyses indicated that there were significant differences in AA mortality rates across the 16 HSDAs

Table 2 Mean of quarterly rates per 100 000 population of different types of alcohol-attributable mortality in 16 Health Service Delivery Areas of British Columbia, 2002–2009.

		Mean (SD) of quarterly alcohol-attributable mortality rate[a]							
		Acute		*Chronic*		*Wholly attributable*		*Total*	
Health service delivery area	*n*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
East Kootenay	32	4.51	1.90	4.42	1.63	1.66	1.33	8.93	2.86
Kootenay Boundary	32	4.54	1.70	5.07	1.94	1.57	1.12	9.61	2.55
Okanagan	32	3.93	0.99	4.50	0.84	1.01	0.51	8.43	1.48
T Cariboo Shuswap	32	5.20	1.15	4.96	1.06	1.10	0.68	10.16	1.79
Fraser East	32	2.52	0.51	3.86	0.79	1.26	0.67	6.38	1.04
Fraser North	32	1.62	0.32	3.12	0.46	0.71	0.39	4.74	0.58
Fraser South	32	1.91	0.24	3.01	0.56	0.75	0.37	4.92	0.63
Richmond	32	1.13	0.43	2.55	0.70	0.97	0.26	3.67	0.83
Vancouver	32	2.04	0.38	3.62	0.65	0.89	0.43	5.67	0.84
North Shore	32	2.16	0.51	3.25	0.71	1.02	0.42	5.41	0.83
South Van Island	32	2.63	0.56	4.27	0.87	0.93	0.56	6.90	1.09
Central Van Island	32	3.68	1.11	4.47	0.94	1.07	0.57	8.15	1.58
North Van Island	32	4.13	1.44	4.87	1.65	1.62	1.01	9.00	2.41
Northwest	32	4.50	2.09	6.21	2.41	2.51	1.60	10.71	3.23
Northern Interior	32	4.27	1.37	5.33	1.44	1.86	1.10	9.60	2.12
Northeast	32	4.56	1.78	4.68	1.94	1.76	0.96	9.24	2.37
Province	512	3.33	1.72	4.26	1.58	1.10	1.07	7.60	2.80

[a]All rates are age–sex-standardized with reference to the year 2001. SD: standard deviation.

for acute ($F_{(df=15)} = 37.73$ and $P < 0.0001$), chronic ($F_{(df=15)} = 17.99$ and $P < 0.0001$) and wholly alcohol-caused cases ($F_{(df=15)} = 10.97$ and $P < 0.0001$). Wholly AA mortality rates showed a decreasing trend over years ($F_{(df=1)} = 4.59$ and $P = 0.0326$). Total AA mortality was associated significantly with the percentages of the population that were aboriginal ($F_{(df=1)} = 413.92$ and $P < 0.0001$), that identified as a visible minority ($F_{(df=1)} = 482.11$ and $P < 0.0001$), that were without secondary school completion ($F_{(df=1)} = 275.99$ and $P < 0.0001$) as well as with population density ($F_{(df=1)} = 371.72$ and $P < 0.0001$) and family income ($F_{(df=1)} = 108.94$ and $P < 0.0001$). Durbin–Watson tests revealed significant first-order autocorrelation for mean quarterly chronic (Durbin–Watson statistics = 1.50 and $P = 0.0484$) and total AA mortality rates (Durbin–Watson statistics = 1.32 and $P = 0.0133$) across the study period. The sandwich estimation did not suggest heteroskedasticity effects for the outcomes (acute AA: $\chi^2_{(df=77)} = 82.16$ and $P = 0.3225$; chronic AA: $\chi^2_{(df=77)} = 73.75$ and $P = 0.5837$; wholly AA: $\chi^2_{(df=77)} = 76.31$ and $P = 0.5008$; total AA: $\chi^2_{(df=77)} = 78.08$ and $P = 0.4441$).

AA deaths and outlet density, average minimum alcohol price

Table 3 presents estimates of associations between outlet densities, mean minimum price across all beverages and different types of AA death. Three models are shown, controlling for (1) outlet densities, (2) minimum prices and (3) both these factors. The coefficient of minimum price for wholly AA mortality changed from −2.792 in model 2 to −3.172 in model 3, suggesting partial confounding of outlet density on minimum alcohol price effects. Minimum price increases were associated with decreases in wholly AA deaths, while greater density of private liquor stores was associated with increases in acute and chronic AA deaths. As can be seen in the table (model 3), a 10% increase in average minimum price (dollars per drink) for all the beverages is associated

Table 3 Associations of alcohol outlet density and average minimum price for all beverages with alcohol-attributable (AA) mortality rates in British Columbia in 2002–2009.

	Mixed model 1[a]		*Mixed model 2*[a]		*Mixed model 3*[a]	
Outlet density and price variables	*Estimate*	*95% CI*	*Estimate*	*95% CI*	*Estimate*	*95% CI*
Acute AA deaths						
Restaurants	−0.174	± 0.249			−0.158	± 0.340
Government liquor stores	0.085	± 0.118			0.105	± 0.225
Bars	0.126	± 0.350			0.054	± 0.398
Private liquor stores	0.193*	± 0.308			0.245*	± 0.239
Minimum prices			−0.083	± 2.170	0.288	± 1.786
Chronic AA deaths						
Restaurants	−0.120	± 0.167			−0.103	± 0.176
Government liquor stores	0.124	± 0.151			0.142	± 0.177
Bars	0.073	± 0.282			0.046	± 0.316
Private liquor stores	0.198*	± 0.157			0.236*	± 0.157
Minimum prices			0.046	± 1.404	0.762	± 1.573
Wholly AA deaths						
Restaurants	0.051	± 0.395			−0.046	± 0.394
Government liquor stores	−0.024	± 0.230			−0.096	± 0.236
Bars	0.611	± 0.520			0.755	± 0.530
Private liquor stores	0.051	± 0.327			−0.101	± 0.362
Minimum prices			−2.792*	± 2.373	−3.172*	± 2.573
Total AA deaths						
Restaurants	−0.200	± 0.138			−0.164	± 0.132
Government liquor stores	0.113	± 0.087			0.127	± 0.101
Bars	0.193	± 0.223			0.151	± 0.255
Private liquor stores	0.182**	± 0.167			0.199*	± 0.176
Minimum prices			−0.091	± 1.370	0.455	± 1.379

[a]Estimates are interpreted as percentage changes of alcohol-attributable mortality as minimum alcohol prices increase by 1%. All the estimates in mixed model 1 (outlet densities), 2 (minimum price) and 3 (outlet densities and minimum price) adjusted for trend (year), seasonality (de-seasonalized), % of aboriginal to total population, % of total visible minorities to total population, population density, average family income, % of population 25–54 without secondary school completion, variation between Health Service Delivery Areas (HSDAs) and time–series autocorrelation effects. Both alcohol outlet densities and minimum price were included in mixed model III. CI: confidence interval. *F*-test: *$P < 0.05$; **$P < 0.01$.

significantly with a 31.72% [95% confidence interval (CI): ± 25.73%, $P < 0.05$] reduction in wholly AA mortality rate per 100 000 people. A 10% increase in private liquor stores per 100 000 people aged 15+ is associated significantly with immediate 2.45%, 2.36% and 1.99% (95% CI: ± 2.39%, ± 1.57%, ± 1.76%, $Ps < 0.05$) increases in acute, chronic and total AA mortality rates, respectively. Multivariate autoregressive integrated moving average (ARIMA) time–series models [26,27] were also utilized as a confirmatory analysis to estimate the immediate impacts of changes to CPI-adjusted minimum prices for all beverages on the rate of AA deaths after adjusting for changes in outlet densities, trend (year), autoregressive and/or moving average effects (see Appendix S2). A 10% increase in the minimum price is associated with a 39.50% decrease in wholly AA mortality (95% CI: ± 27.54%).

Table 4 presents the estimated lag effects of minimum price increase on different types of AA mortality from 16 separate models of each type of AA deaths testing each lag effect. These show some statistically significant negative associations with wholly AA deaths up to 1 year after a minimum price change. Furthermore, there is evidence of more delayed negative associations of minimum price changes with rates of acute, chronic and total AA deaths between 2 and 3 years after minimum price changes. However, there were also two significant positive associations between minimum price changes and acute AA mortality at lag quarters 3 and 5.

AA deaths and minimum alcohol price for specific beverages

Table 5 presents estimates of both simultaneous and 2-year lagged associations between minimum price changes for each individual beverage type and different types of AA death (56 separate models). Minimum price increases for most beverages were associated with reductions in rates of wholly AA mortality, but these relationships were only statistically significant for spirits and liqueurs. A 10% increase in minimum price for spirits and liqueurs was estimated to be associated with an immediate 35.25% reduction in rate of wholly AA deaths. Significant lagged associations were observed after 2 years for beer, spirit and liqueur minimum prices on rates of acute, chronic and total AA deaths appeared. Significant lagged associations were also observed after 2 years for packaged coolers and ciders on chronic AA deaths and for spirits and liqueurs on wholly AA deaths.

Estimates of preventable AA deaths with increased minimum prices

Table 6 presents the estimated number of AA deaths per year which would be prevented based on the above

Table 4 Estimated associations between minimum alcohol prices and different types of alcohol-attributable death in British Columbia, 2002–2009 for the first quarter and lags from one to 15 annual quarters.

	Acute		*Chronic*		*Wholly attributable*		*Total*	
Lag Quarter[a]	*Estimate*[b]	*95% CI*	*Estimate*[b]	*95% CI*	*Estimate*[b]	*95% CI*	*Estimate*[b]	*95% CI*
0	0.288	± 1.786	0.762	± 1.573	−3.172*	± 2.573	0.455	± 1.379
1	−0.265	± 1.842	−0.281	± 2.103	−2.576	± 3.696	−0.092	± 1.391
2	1.775	± 2.515	−0.708	± 1.048	−3.486*	± 2.658	0.200	± 1.276
3	2.233*	± 2.192	−0.929	± 1.039	−3.858***	± 1.863	0.295	± 0.858
4	0.170	± 2.060	0.149	± 1.026	−1.740	± 2.737	0.205	± 1.204
5	1.991***	± 1.089	−0.650	± 1.264	1.036	± 3.534	0.464	± 1.065
6	1.073	± 1.501	−1.136	± 1.737	−0.224	± 2.763	0.025	± 1.268
7	0.059	± 1.278	−1.388	± 1.559	−0.158	± 2.081	−0.753	± 0.955
8	−2.272***	± 1.217	−1.985**	± 1.227	−0.926	± 1.717	−1.918***	± 0.718
9	−0.892	± 1.622	−2.659***	± 1.322	−1.816	± 2.339	−1.816**	± 1.134
10	−1.630	± 1.975	−1.195	± 1.487	−1.102	± 2.729	−1.154*	± 0.945
11	−1.767	± 2.310	−0.957*	± 0.916	−0.257	± 2.878	−1.246*	± 1.011
12	−0.720	± 2.023	−1.323	± 1.854	−1.852	± 4.549	−0.946	± 1.252
13	−0.043	± 2.359	−1.697**	± 1.160	−0.453	± 3.717	−0.854	± 1.355
14	−1.911	± 2.770	0.317	± 1.562	0.602	± 4.985	−0.307	± 0.992
15	3.044	± 6.715	−2.522	± 4.201	3.115	± 6.399	−0.422	± 3.173

[a]Quarter represents the 3-month period in which a minimum price increase was implemented. [b]Estimates can be interpreted as percentage changes of alcohol-attributable deaths as minimum alcohol prices increase by 1%. All the estimates from 64 models adjusted for trend (year), seasonality (de-seasonalized), % of aboriginal to total population, % of total visible minorities to total population, population density, average family income, % of population 25–54 without secondary school completion, alcohol outlet densities, variation between Health Service Delivery Areas (HSDAs) and time–series autocorrelation effects. CI: confidence interval. *F*-test: $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.000$.

Table 5 Immediate and delayed impacts of minimum price increases for specific beverages on alcohol-attributable (AA) mortality in British Columbia in 2002–2009.

	Immediate effect			*Lag effect at quarter 8*		
Minimum price for specific beverage	*Estimate*[a]	*95% CI*		*Estimate*[a]	*95% CI*	
Acute AA deaths						
Packaged beer	0.657	–0.564	1.879	–0.943**	–1.593	–0.292
Spirits and liqueurs	–0.474	–2.158	1.209	–2.847*	–5.189	–0.504
Wines	–2.011	–5.042	1.019	–1.115	–4.980	2.750
Coolers and cider	–1.848	–4.757	1.061	–1.268	–5.126	2.591
Draft beer	1.050	–1.522	3.622	–2.293**	–3.918	–0.669
Draft cider	–1.964	–4.981	1.054	–1.271	–4.974	2.432
Average of all beverages	0.288	–1.498	2.074	–2.272***	–3.489	–1.055
Chronic AA deaths						
Packaged beer	0.598	–0.052	1.248	–0.890**	–1.561	–0.219
Spirits and liqueurs	–0.800	–2.178	0.577	–2.100*	–3.851	–0.349
Wines	–0.626	–3.327	2.075	–1.740	–3.771	0.291
Coolers and cider	–0.528	–3.084	2.028	–2.002*	–3.882	–0.122
Draft beer	0.948	–0.778	2.673	–2.176**	–3.742	–0.609
Draft cider	–0.461	–3.148	2.227	–1.835	–3.753	0.082
Average	0.762	–0.811	2.336	–1.985**	–3.212	–0.759
Wholly AA deaths						
Packaged beer	–0.977	–2.290	0.336	–0.001	–0.903	0.901
Spirits and liqueurs	–3.525**	–5.905	–1.145	–3.618**	–5.881	–1.355
Wines	–2.793	–8.153	2.568	3.862	–0.804	8.528
Coolers and cider	–2.828	–8.256	2.601	3.072	–1.163	7.307
Draft beer	–2.621	–6.050	0.809	0.229	–1.685	2.142
Draft cider	–2.740	–8.040	2.560	3.404	–0.763	7.571
Average	–3.172*	–5.745	–0.600	–0.926	–2.643	0.791
Total AA deaths						
Packaged beer	0.494	–0.200	1.188	–0.717***	–1.113	–0.321
Spirits and liqueurs	–0.919	–1.970	0.133	–2.018**	–3.277	–0.758
Wines	–0.990	–2.238	0.258	–0.696	–2.670	1.278
Coolers and cider	–0.898	–2.039	0.244	–0.946	–2.859	0.967
Draft beer	0.731	–0.900	2.362	–1.704***	–2.704	–0.703
Draft cider	–0.890	–2.132	0.352	–0.816	–2.734	1.102
Average	0.455	–0.924	1.835	–1.918***	–2.636	–1.200

[a]Estimates are interpreted as percent changes of alcohol-attributable mortality as minimum alcohol prices increase by 1%. All the estimates from 56 models adjusted for trend (year), seasonality (de-seasonalized), % of aboriginal to total population, % of total visible minorities to total population, population density, average family income, % of population 25–54 without secondary school completion, alcohol outlet densities, variation between Health Service Delivery Areas (HSDAs) and time–series autocorrelation effects. CI: confidence interval. $^{*}P < 0.05$ $^{**}P < 0.01$ $^{***}P < 0.001$.

Table 6 Estimates of the number and percentage of alcohol-attributable deaths per year that could have been prevented for British Columbia in 2011/12 if minimum prices had been set at specific dollars per standard drink instead of $1.15.

		$1.25/per drink†		*$1.35/per drink*		*$1.45/per drink*	
Types of death	*Total per year*	*n*[a]	*%*[b]	*n*[a]	*%*[b]	*n*[a]	*%*[b]
		Estimated immediate reductions per year					
Wholly alcohol	170	–40	–23.03	–68	–39.92	–92	–52.29
		Estimated additional reductions per year after 2 years					
Chronic	778	–100	–15.16	–184	–27.91	–248	–38.12

†One Canadian standard drink = 17.05 ml or 13.45 g. [a]Annual number of alcohol-attributable deaths which can be prevented; [b]% of alcohol-attributable deaths prevented out of total alcohol-attributable deaths.

models were minimum prices to be set at $1.25, $1.35 or $1.45 per standard drink (the actual adjusted average minimum price for all the beverages was $1.15 per drink in 2011/12) in BC. This estimate assumes that all the association observed involves causation operating in the predicted direction of price increases leading to reductions in mortality. It was estimated that setting minimum prices at $1.25 per drink would prevent 40, or 23.03%, of wholly AA deaths in the first year after implementation. Two years after implementation it was estimated that there would be 100 (15.16%) fewer chronic AA deaths per year with minimum prices of $1.25 per standard drink. Estimates for acute AA deaths prevented are not provided due to both counter-intuitiveness and the lack of stability in the lagged associations for these short-term outcomes.

Estimated additional deaths for each extra private liquor store

The models reported here also indicate that the addition of 10 extra private liquor stores across the whole province would be associated with one additional acute AA death (a 0.29% increase) and two additional chronic AA deaths (a 0.28% increase).

DISCUSSION

In this study we investigated the independent associations between simultaneous increases in minimum alcohol prices and increases in the density of private liquor stores on various measures of AA death. The major finding was that increased minimum alcohol prices were associated with immediate, substantial and significant reductions in wholly AA deaths. The size of this effect was disproportionate to the size of the minimum price increase, with a 1% increase in minimum price associated with a mortality decline of more than 3%. However, no immediate changes in rates of acute or chronic AA deaths were detected. The models indicated significant and large reductions in total, acute and chronic AA deaths approximately 2 to 3 years after minimum price increases with elasticities in the range of between −1.9 and −2.3. Examination of associations between minimum price increases for specific beverages and decreases in wholly AA mortality indicates large negative elasticities in every case, although these were only significant for the categories of spirits and liqueurs. However, the 2-year lagged effects in relation to total, acute and chronic AA mortality were found to be significant for both packaged and draft beer as well as spirits and liqueurs. It is noteworthy that the minimum price changes applied during the study period impacted only on spirits and beers, and not on the other beverages, so this pattern of results would be predicted.

One contradictory finding was that of significant positive associations between minimum price changes and acute AA deaths at lag quarters 3 and 5, despite there being a significant negative association by lag quarter 8. In theory, one would expect any impact from a price change on acute alcohol-related outcomes to be immediate and not delayed. First, one might expect that associations between price changes and both chronic and wholly AA causes of death would be delayed, given the length of time it takes for an alcohol-related disease to develop. However, it is not unusual for there to be immediate associations between changes in per capita alcohol consumption and rates of alcoholic liver cirrhosis [28]. Furthermore, the wholly AA conditions include poisonings and overdoses which are acute in nature. We also note that there is now strong evidence that minimum price increases in BC (and Saskatchewan) have been associated with significant decreases in alcohol consumption, so one would expect there to be associated reductions in harm. Considering the overall pattern of results, and while noting the lack of stability in the results for acute outcomes, we suggest none the less that our study provides credible evidence of (i) large and significant reductions in wholly AA deaths associated with co-occurring minimum price increases and (ii) significant lagged effects for chronic AA deaths. In each case, effects sizes were disproportionate to previously estimated associations between the minimum price changes and alcohol consumption.

In an earlier study we estimated much smaller effects of minimum price increases on per capita alcohol consumption, with an overall elasticity estimate of only −0.34. However, previous studies have shown that reductions in alcohol consumption can have disproportionate effects on wholly AA causes of death such as alcoholic liver cirrhosis [29,30]. Furthermore, we have suggested elsewhere that this relatively low negative elasticity for minimum price effects on alcohol consumption may be related to the practice of mainly only adjusting minimum prices for spirits which might lead to substantial substitution to cheaper beverages. This is supported by the much larger negative elasticities we estimated for Saskatchewan, where minimum price changes were implemented comprehensively across all beverage types [6]. It follows that larger effects on alcohol-related harm might be expected than were observed here if simultaneous across-the-board adjustments of minimum prices were implemented.

Minimum pricing policies can counter commercial practices 'in which retailers set very low prices, sometimes below cost, for some products to lure customers into stores' [31]. In countries where the central government does not restrict minimum pricing, local restrictions have sometimes been used to exercise this control on the sale of very cheap beverages. For example, restrictions on the sale of cheap bulk wines in Australian aboriginal communities have been shown to be associated with reductions in consumption and acute AA hospital admissions [32]. Finnish researchers reported that large reductions in alcohol prices in 2004 were followed by increases in AA mortality of 16% among men and 31% among women [33].

It is likely that increased minimum alcohol prices reduce AA mortality through increasing the retail price of cheaper beverages and thereby reducing the consumption of heavier drinkers who prefer these beverages. Other research has also suggested that impacts on mortality may be delayed by 1 or 2 years after price increases. A recent study conducted in the United Kingdom found a 1- and 2-year lagged effect of alcohol consumption on alcohol-related mortality [34].

The independent association of increased density of private liquor stores with increased AA mortality rates observed in the present study was significant, although relatively small in size. The models estimated that a 10% increase in density of private stores would be associated with an approximately 2% increase in AA deaths. However, these estimates of effect sizes are larger than in our previous study of the effects of increased liquor outlet density due to the partial privatization of the liquor market in BC, which did not adjust simultaneously for minimum price effects [8]. Experience in Canada and other countries indicates that privatizing alcohol sales is likely to increase AA deaths, injuries and social problems through increased alcohol availability and consumption. For example, studies have found lower consumption rates in US states which retain control over sales of spirits/wine and spirits and also a 9.3% lower alcohol-impaired driving death rate under age 21 years [35]. Privatization of alcohol retailing typically involves several significant changes, including increases in the number of outlets where alcohol is sold, longer hours of sale and an enhanced profit-driven interest in the alcohol market [36–38], which leads in turn to increases in alcohol consumption and alcohol-related problems. A study of the impact of privatization of alcohol sales in Alberta found significant increases in suicide mortality rates [39]. These results are also consistent with the larger set of studies identifying negative public health impacts of increased liquor outlet density in mainly privatized markets [40].

A limitation of the present study is that it was not possible to determine which groups in the population are most affected by minimum pricing and outlet density changes. Other studies suggest that through reducing alcohol consumption, minimum pricing could affect drinking behaviours of heavier drinkers who would be more likely to cut back or switch to less expensive products than other consumers and abusive drinking of price-sensitive drinkers [33,41]. However, it is worth noting that the immediate effect of minimum price on wholly AA mortality found in the present study is consistent with a strong and immediate effect on levels of alcohol consumption among hazardous and harmful drinkers [42]. Another limitation is that this was an ecological study in which the data are measures averaged over individuals, and therefore may not reflect individual level associations and may be sensitive to changes in unit aggregation [43]. However, the inherent qualities of the ecological design for epidemiological and policy analysis can be valuable for investigating potential population-wide effects [44,45].

CONCLUSION

The results of the present study, while mixed, are interpreted as indicating public health benefits from minimum alcohol prices. Specifically, increased minimum prices were associated with large and significant associations with reductions in rates of wholly AA deaths up to 12 months after their introduction. Similar negative associations with chronic AA deaths were detected between 2 and 3 years after minimum price increases. However, results for acute AA deaths were not stable, with both significantly positive and negative associations detected between 18 and 27 months post-intervention. Consistent with earlier research, significant (although smaller) associations were detected between increased density of private liquor stores and reductions in all types of AA deaths.

Declarations of interest

None.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1 Equation of mixed-model and SAS codes.
Appendix S2 ARIMA model and SAS codes.