The Effects of Alcohol Warning Labels on Population Alcohol Consumption: An Interrupted Time Series Analysis of Alcohol Sales in Yukon, Canada

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ABSTRACT. Objective: There is limited evidence that alcohol warning labels (AWLs) affect population alcohol consumption. New evidence-informed AWLs were introduced in the sole government-run liquor store in Whitehorse, Yukon, that included a cancer warning (Ca), low-risk drinking guidelines (LRDGs) and standard drink (SD) messages. These temporarily replaced previous pregnancy warning labels. We test if the intervention was associated with reduced alcohol consumption. **Method:** An interrupted time series study was designed to evaluate the effects of the AWLs on consumption for 28 months before and 14 months after starting the intervention. Neighboring regions of Yukon and Northwest Territories served as control sites. About 300,000 labels were applied to 98% of alcohol containers sold in Whitehorse during the intervention. Multilevel regression analyses of per capita alcohol sales data for people age 15 years and older were performed to examine consumption levels in the intervention and control sites before, during, and after the AWLs were introduced. Models were adjusted for demographic and economic characteristics over time and region. **Results:** Total per capita retail alcohol sales in Whitehorse decreased by 6.31% (t test $p < .001$) during the intervention. Per capita sales of labeled products decreased by 6.59% (t test $p < .001$), whereas sales of unlabeled products increased by 6.91% (t test $p < .05$). There was a still larger reduction occurring after the intervention when pregnancy warning labels were reintroduced (-9.97% and -10.29%, t test $p < .001$). **Conclusions:** Applying new AWLs was associated with reduced population alcohol consumption. The results are consistent with an accumulating impact of the addition of varying and highly visible labels with impactful messages. (*J. Stud. Alcohol Drugs, 81,* 225–237, 2020)

VARIOUS ALCOHOL POLICIES have been developed in jurisdictions worldwide with the aim of reducing the harmful use of alcohol, alcohol attributable diseases and associated social burdens (Babor et al., 2010; World Health Organization, 2018). One such measure is the application of alcohol warning labels (AWLs) on containers of alcoholic beverages (World Health Organization, 2014, 2018) to provide consumers with information about harms related to alcohol use (e.g., birth defects when pregnant women drink, impaired driving, and general health risks).

Earlier reviews concluded there is only weak evidence that AWLs can affect population drinking behavior (Babor et al., 2010; Stockwell, 2006). Other analyses emphasize the consumer's "right to know" potential risks of such a commonly consumed product as alcohol (e.g., cancer) and the need to provide advice on reducing these risks via low-risk drinking guidelines (LRDGs; Hobin et al., 2018; Vallance et al., 2018). There is a growing literature on the characteristics of effective warning labels (Blackwell et al., 2018; Martin-Moreno et al., 2013) stressing the importance of message clarity, salience, and variation as well as appropriate use of size, color, placement, and graphic design of the labels. The present study seeks to examine whether the experimental introduction of labels designed to meet these exacting criteria would have a measurable impact on population-level alcohol consumption. The remote area of Whitehorse—the capital and main population center in Yukon, a northern Canadian territory—was selected as the intervention site where alcohol for off-premise consumption is sold almost exclusively in a single government-run liquor store. This analysis is one part of a larger project evaluating this intervention that also incorporated three waves of surveys of liquor store customers in Whitehorse and also Yellowknife, the capital and main population center in neighboring Northwest Territories (NWT; Hobin et al., 2020; Vallance et al., 2020a).

Based on a randomized controlled trial and focus group study, the present research team developed a series of AWL messages designed to be rotated for an accumulating effect (Hobin et al., 2018; Vallance et al., 2018). First, a cancer warning message was developed based on evidence that Canadians generally have very low awareness of the potential risks of different cancers from consuming alcohol (Miller et al., 2016). The warning message specifically mentioned two of the most common cancers in Canada, including Yukon,

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namely cancers of the breast and colon. The second message was designed to support consumers wishing to reduce their risk of serious diseases by providing information about Canada's LRDGs (Stockwell et al., 2012). The third label message provided information about how the number of standard drinks (SDs) in regular size alcohol containers varied with different alcohol strengths.

Drinking guidelines provide recommended upper limits on the number of SDs individuals drink per day or per week in order to minimize their risk of related harms; however, many individuals have trouble determining how many SDs they are consuming, making it difficult to follow the guidelines (Kerr & Stockwell, 2012). An SD is a fixed quantity or unit of alcohol, which in Canada is defined as 17.05 ml or 13.45 g of pure alcohol (Butt et al., 2011). A Canadian study conducted among liquor store customers found that less than a third had heard of Canada's LRDGs or could define an SD of their preferred beverage type (Osiowy et al., 2015). This study also showed that consumers still have less ability to identify the number of SDs in alcohol beverage containers of either unusually high or low percent alcohol content by volume. Some have suggested that LRDG and SD labels might encourage certain drinkers to increase their consumption (Jones & Gregory, 2009). Alcohol health warnings are mandated in a number of countries (International Alliance for Responsible Drinking, 2019), but there remains limited research that has specifically investigated their effectiveness.

There is no federal requirement for alcohol warning labels in Canada, but, since 1991, both Yukon and NWT have required post-manufacture labels ("Drinking alcohol during pregnancy can cause birth effects" in Yukon, plus impaired driving and general health warnings [ID] in NWT) (Stockwell et al., 2019). Two recent national studies have confirmed that the economic costs and health harms from alcohol are substantially higher in both Yukon and NWT than in the rest of the Canada (Canadian Institute for Health Information, 2019; Canadian Substance Use Costs and Harms Scientific Working Group, 2018). In November 2011, the federal, provincial, and territorial health ministers received Canada's LRDGs (Canadian Centre on Substance Abuse, 2018). These recommend that women do not exceed 10 SDs per week or 2 per day on average and that men should have no more than 15 per week or 3 per day on average (Butt et al., 2011; Stockwell et al., 2012). Studies based on national surveys conducted in 2008–2010 found substantial noncompliance with daily and weekly LRDG limits after adjustment for underreporting (Zhao et al., 2015).

The present study was designed to test the hypothesis that the introduction of the new evidence-informed AWLs would be associated with a reduction in population-level alcohol consumption in the intervention site compared with preintervention and also with two separate neighboring region control sites that retained long-standing health warnings about pregnancy and/or impaired driving.

Method

Alcohol warning labels in Yukon

Since 1991, point-of-sale AWLs with "Warning: drinking alcohol during pregnancy can cause birth defects" in English and French (Canada's two official languages) have been put on alcohol containers in Yukon (actual size: 3.0 cm × 2.0 cm) and AWLs with "Warning: 1. Women should not drink alcoholic beverages during pregnancy because of the risk of birth defects (BD) and 2. Consumption of alcoholic beverages impairs your ability to drive a car or operate machinery, and may cause health problems" in NWT (actual size: 3.0 cm × 5.0 cm). The Yukon BD label was replaced by the newly designed AWLs in the Whitehorse liquor store from November 20, 2017, to July 31, 2018. The AWLs affixed on alcohol containers were large (actual size: 5.0 cm × 3.2 cm), were full color (as shown in Chart 1), and displayed (a) a health message linking alcohol and cancer (Ca), (b) Canada's LRDGs, and (c) SD information. Either the Ca warning "Alcohol can cause cancer including breast and colon cancers" or the LRDG messages were put on all containers from November 20 to December 19, 2017. The labeling of these messages ceased thereafter as a result of complaints made by Canadian alcohol industry bodies that the labels were "defaming" their products. The Ca label was never reintroduced, but from April 11 until July 31, 2018, the LRDG labels were reintroduced as well as the SD labels from May 28 until July 31, 2018.The types of products to which labels were applied and the timing of their application is summarized in Box 1. The BD labels were applied consistently in both the other areas of Yukon and in NWT (along with an ID message and general health concerns message) during the entire period. The BD labels were also reintroduced in Whitehorse starting in August 2018.

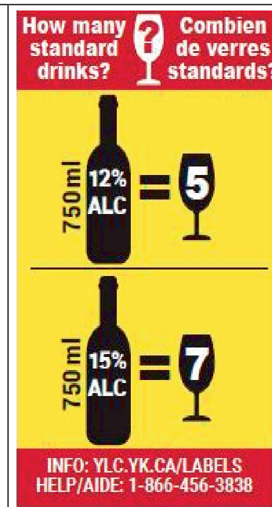
Design

An interrupted time series study (McDowall et al., 1976) was designed to investigate whether the various AWLs were associated with reduced per capita alcohol consumption during the study period. Consumption during the AWL period was compared with consumption during the period without the intervention labels and when only the BD/ID labels were put on product containers.

Data sources

We were provided with monthly retail alcohol sales data for the whole of Yukon to calculate monthly per capita al-

CHART 1. Point-of-sale warning labels placed on alcohol containers in different alcohol monopoly liquor stores in Yukon and Northwest Territories (NWT) at different times between July 2015 and December 2018

<table>
<tr><td>Label content</td><td>
</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Whitehorse, Yukon (n = 1)</td><td>• Jul. 2015–Nov. 19, 2017
• Aug.–Dec. 2018</td><td>• Nov. 20–Dec. 19, 2017</td><td>• Nov. 20–Dec. 19, 2017
• Apr. 11–Jul. 31, 2018</td><td>• May 28–Jul. 31, 2018</td></tr>
<tr><td>Rural areas in Yukon (n = 5)</td><td>• Jul. 2015–Dec. 2018</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td>NWT (n = 1)</td><td>• Jul. 2015–Dec. 2018</td><td>None</td><td>None</td><td>None</td></tr>
</table>

cohol consumption for people age 15 and older (estimated as monthly SDs per person age ≥ 15 years) with Whitehorse and the additional five surrounding areas each acting as comparison areas. Socioeconomic and demographic data by areas and times in Yukon were obtained to produce per capita alcohol consumption estimates and socioeconomic variables in order to examine and control for their potential confounding effects (Gruenewald & Ponicki, 1995; Gruenewald et al., 1995; Holder & Parker, 1992; Sloan et al., 1994; Stockwell et al., 2011). The analysis included the estimated retail alcohol sales in NWT as an additional control.

Alcohol sales data

Monthly alcohol sales data for each liquor store were obtained from the Yukon Liquor Corporation, which regulates the distribution, purchase, and sale of alcoholic beverages in Yukon. The data were structured by products, container sizes, and alcohol strengths in each area from July 2015 to December 2018. Total monthly alcohol sales data in NWT were obtained from a public website (NWT Bureau of Statistics, 2019). Mean SDs per people age 15 years and older were calculated and estimated using the monthly sales of alcohol converted to pure alcohol in SDs (sold volumes × alcohol strength × 1,000 / 17.05; one SD = 17.05 ml) for different categories of labeled and unlabeled products (Box 1). Monthly per capita SDs of total retail sales in NWT from 2015 to 2018 were estimated based on the total monthly sales in NWT and the monthly retail sales in Yukon.

Population data

We obtained population estimates for June 30 of each year from 2014 to 2018 by age groups in areas in Yukon (www.sewp.gov.yk.ca/home) and for the Indigenous population by area (www.eco.gov.yk.ca/stats/archives.html#social). Population data in NWT were obtained from Statistics Canada and used to estimate per capita alcohol consumption (Statistics Canada, 2019a). We used the spline method (DeBoor, 1981; McNeil et al., 1977) to estimate monthly total population, population age 15 and older, and the Indigenous populations for the study period. The data were used to calculate monthly per capita alcohol consumption as the main outcome variable. Percentages of the population ages 20–29, male, and Indigenous population were considered as covariates included in the analysis.

Income and customer price index data

We obtained annual personal income tax data from the Canada Revenue Agency for each of the six areas in Yukon and NWT (Canada Revenue Agency, 2012, 2013, 2014, 2015, 2016, 2017; Yukon Bureau of Statistics, 2013). Monthly customer price index (CPI) data for Yukon and NWT were

Box 1. Timeline for placement of different alcohol warning labels across six government monopoly liquor stores in Yukon and Northwest Territories serving seven separate areas

Area	Year	Months	Labels placed by product category:[a]			Unlabeled products: <200 ml, single beers[b] (D)
			Wine 750 ml, spirit 750 ml, beer 355 ml, cooler 2 L (A)	Spirit>750 ml, fortified wine, liqueurs, others (B)	Local products (excl. beer 650 ml) (C)	
NWT	2015–2018	1–12	BD/ID	BD/ID	BD/ID	
Dawson City	2015–2018	1–12	BD	BD	BD	
Faro	2015–2018	1–12	BD	BD	BD	
Haines Junction	2015–2018	1–12	BD	BD	BD	
Mayo	2015–2018	1–12	BD	BD	BD	
Watson Lake	2015–2018	1–12	BD	BD	BD	
Whitehorse	2015–2016	1–12	BD	BD	BD	
Whitehorse	2017	1–10	BD	BD	BD	
Whitehorse	2017	11	Ca/LRDG	Ca/LRDG	Ca/LRDG	
Whitehorse	2017	12	Ca/LRDG	Ca/LRDG	Ca/LRDG	
Whitehorse	2018	1	*Ca/LRDG*[c]	*Ca/LRDG*[c]	*Ca/LRDG*[c]	
Whitehorse	2018	2	*Ca/LRDG*[c]	*Ca/LRDG*[c]	*Ca/LRDG*[c]	
Whitehorse	2018	3	*LRDG*[c]	*LRDG*[c]	*LRDG*[c]	
Whitehorse	2018	4	LRDG	LRDG	*LRDG*[c]	
Whitehorse	2018	5	SD	LRDG	*LRDG*[c]	
Whitehorse	2018	6	SD	LRDG	*LRDG*[c]	
Whitehorse	2018	7	SD	LRDG	*LRDG*[c]	
Whitehorse	2018	8	BD+*SD*[c]	BD+*LRDG*[c]	BD+*LRDG*[c]	
Whitehorse	2018	9	BD+*SD*[c]	BD+*LRDG*[c]	BD+*LRDG*[c]	
Whitehorse	2018	10	BD+*SD*[c]	BD+*LRDG*[c]	BD+*LRDG*[c]	
Whitehorse	2018	11	BD+*SD*[c]	BD+*LRDG*[c]	BD+*LRDG*[c]	

[a]Labels types: BD = birth defect; BD/ID = birth defect (BD) and impaired driving and general health concern message labels (ID) used in Northwest Territories July 2015–December 2018; Ca = cancer; LRDG = low-risk drinking guidelines; SD = standard drink. [b]Unlabeled alcohol products included 650 ml or larger beer bottles made by local producers, alcohol containers smaller than 200 ml and single beers. [c]Italics added for periods in which no labels were added to new products but they would have remained on products labeled earlier but not sold.

obtained from Statistics Canada (Statistics Canada, 2019b). Average income in Canadian dollars was estimated by total tax income of all tax returns divided by the number of tax returns in each year for each area in Yukon and for NWT with adjustment for monthly CPI.

Land data

We obtained land data at 2016 census subdivisions in Yukon and NWT from Statistics Canada (Statistics Canada, 2017) to estimate population density in each of the six areas in Yukon and in NWT. The monthly population density was estimated by monthly total population in each area in Yukon and in NWT divided by land area in square kilometers.

Statistical analysis

The monthly number of SDs per adult were calculated and analyzed using the monthly retail sales of alcohol beverages converted to pure alcohol in SDs (sold volumes × alcohol strength × 1000 / 17.05, one SD = 17.05 ml or 13.45 g in Canada) divided by monthly population age 15 years and older. The per capita SDs were calculated and analyzed by total product sales (A, B, C, and D in Box 1), total labeled alcohol sales in government liquor stores (A, B, and C), the sales of products (A) with Ca/LRDG/LRDG/SD labels, the sales of products (B) with Ca/LRDG/LRDG labels, local products (C) with Ca/LRDG labels, and unlabeled products (D). Bivariate analysis was performed to examine potential confounding effects of covariates and thus should be included in multivariate regression analyses for control. Bivariate linear regression analysis was used to examine the area, year, and seasonal differences in the consumption, and F test was used to test a significant relationship. Bivariate linear regression was performed to examine the relationships between per capita SDs and population density, average income, and percentages of the population age 15 and older who were Indigenous, ages 20–29 years, and male.

The potential confounding effects were thus identified and included in multivariate regression analyses to control for the effects. We considered covariates with a bivariate relationship to alcohol sales with a p less than .20 as candidates for inclusion in the multivariate regression analyses of the consumption (Hosmer & Lemeshow, 2000). We also considered the change-in-estimate, that is, whether crude and adjusted estimates differed by 10% (Maldonado & Greenland, 1993). We detected the effects and multicollinearity by exploring the correlation matrix and using the Variance Inflation Factor (VIF) and Tolerance (Allison, 2012; Schreiber-Gregory, 2017). The potential effect of collinearity of a covariate was considered when the covariate had a high correlation (coefficient of .8 or higher) with any other covariates and/or the Tolerance value fell below .1 and the VIF value was greater than 10 (Allison, 2012; Schreiber-Gregory, 2017).

The VIF value of the average income variable is greater than 10 (17), but we still included this covariate in the models because inclusion/exclusion of the income variable did not change the effect estimates of the labeling intervention (Allison, 2012; Schreiber-Gregory, 2017). Durbin–Watson (DW) statistics were calculated for testing autocorrelation average effect (Durbin & Watson, 1951), and "sandwich estimation" was used to test and correct for heteroskedasticity (White, 1980). We also examined modified effects of region and time by using interaction terms of area-label and time-label in the models and did not identify significant effects of area or time (t test $p > .9000$); thus, no modified effects were hypothesized or presented in the study.

We then used mixed or multilevel models (Laird & Ware, 1982; Littell et al., 2006; Raffalovich & Chung, 2014), which provide straightforward but flexible methods for assessing regional and temporal dynamics of longitudinal panels of data to model the pooled monthly alcohol consumption. The multilevel model estimated the percentage immediate change (×100%) of per capita drinks for the same month when the AWLs were put on the containers of alcohol beverage products after controlling for potential confounding effects of covariates and the data themselves, including temporal and regional autoregressive effects and time trend and seasonality.

Mixed models permit tests of fixed effects through either maximum likelihood or restricted maximum likelihood estimation. These methods are superior to traditional repeated-measures analysis of variance because they allow simultaneous inference about regional and temporal factors using fixed and random effects and also apply to a variety of covariance (correlation) structures. Thus, more appropriate covariance data structures can be analyzed. We initially included area- and time-specific variables as random effect variables to examine and control for heterogeneity effect if there was an area- or time-specific heterogeneity. We included the area-specific variable as a random effect to control for the area autoregressive effect in multilevel regression models because the time-specific effect was not significant (Ayyangar, 2007; Raffalovich & Chung, 2014). We also produced effect estimates using minimum variance quadratic unbiased estimation (MIVQUE) of covariance parameters to test heterogeneous quadratic trend effects (Littell et al., 2006). While the tests found no differences in the effect estimates using the REML and MIVQUE methods, the study presented the effect estimates using the REML method. We included regional and temporal autocorrelation effects in all models. Log transformations were applied when necessary to correct for significantly skewed distributions and to make the variance stationary for dependent variables. The seasonal index method was used to de-seasonalize monthly per capita alcohol consumption to remove the effect of seasonality of alcohol consumption (Anderson et al., 1996). Adjustments for temporal autocorrelation were made if it was detected by the DW statistic (Durbin & Watson, 1951). A covariate was created to differentiate between Yukon areas (rural area and Whitehorse) and NWT so as to control for regional effects.

We conducted all statistical analyses using SAS Version 9.3 (SAS Institute Inc., Cary, NC), and the SAS PROC MIXED procedure was used to model the data and produce the effect estimates (Kleinschmidt et al., 2001; Littell et al., 2006). Further details of the equation of multilevel models and SAS codes can be found in Appendix I. (The supplemental appendix appears as an online-only addendum to this article on the journal's website.)

Results

Patterns and predictors of Yukon alcohol sales

Liquor store total sales accounted for 65.2% of all recorded sales, and liquor store retail sales accounted for 90% of liquor store total sales in Yukon and NWT during the study period, of which 98% received some kind of new intervention label during the study period. Table 1 presents estimates of the mean number of SDs of alcoholic beverages sold per person age 15 and older per month in each of the six area liquor stores in Yukon (one each in Whitehorse and five outlying areas) and the whole territory of NWT during the study period (i.e., between 2015 and 2018). There were significant differences in the estimates of total sales, sales of labeled and unlabeled products, and subtypes of sales across these areas (all F test ps < .0001). There was a significantly increased trend in the unlabeled sales over time during the study period (t test $p < .01$). The intervention site had the lowest per capita consumption for age 15 and older of 33.08 SDs per month relative to the other five areas in Yukon but close to that in NWT.

There were significant differences in each category of sales by season (F test ps < .001), with more estimated consumption in all product categories during the spring and summer months. Figure 1 shows the trends and seasonal

TABLE 1. Mean monthly per capita consumption in standard drinks by labeled[a] and unlabeled[b] alcohol products (total retail sales sold) in Whitehorse, rural areas of Yukon, and Northwest Territories for 2015–2018

	Labeled products		Unlabeled products		Total retail sales	
Variable	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Community						
NWT	34.55	(4.22)	0.86	(0.16)	35.41	(4.33)
Dawson City	61.53	(25.88)	1.80	(0.94)	63.33	(26.74)
Faro	50.66	(7.53)	0.67	(0.25)	51.33	(7.64)
Haines Junction	40.52	(7.67)	0.85	(0.28)	41.37	(7.84)
Mayo	56.90	(10.79)	0.72	(0.42)	57.62	(11.10)
Watson Lake	68.68	(16.09)	0.77	(0.22)	69.45	(16.20)
Whitehorse	32.21	(6.33)	0.86	(0.17)	33.08	(6.46)
F test *p*	.0001		.0001		.0001	
Year						
2015	52.57	(18.20)	0.75	(0.40)	53.32	(18.39)
2016	48.39	(17.63)	0.90	(0.44)	49.29	(17.88)
2017	49.01	(19.05)	0.95	(0.58)	49.96	(19.37)
2018	48.86	(18.73)	1.04	(0.68)	49.90	(19.15)
F test *p*	.6567		.0394		.7023	
t test *p* for trend	.4685		.0047		.5291	
Season						
Jan.–Mar.	37.28	(9.71)	0.67	(0.27)	37.96	(9.69)
Apr.–Jun.	53.84	(20.69)	1.15	(0.71)	54.99	(21.07)
Jul.–Sep.	57.85	(20.83)	1.12	(0.68)	58.97	(21.26)
Oct.–Dec.	46.34	(12.75)	0.78	(0.25)	47.12	(12.72)
F test *p*	.0001		.0001		.0001	

Notes: NWT = Northwest Territories. [a]Labeled products included those with cancer/low-risk drinking guidelines, standard drinks only, low-risk drinking guidelines only (Box 1). [b]Unlabeled products included 650 ml beer bottles by local producers, alcohol container < 200 ml, and single beers without any labels including birth defects.

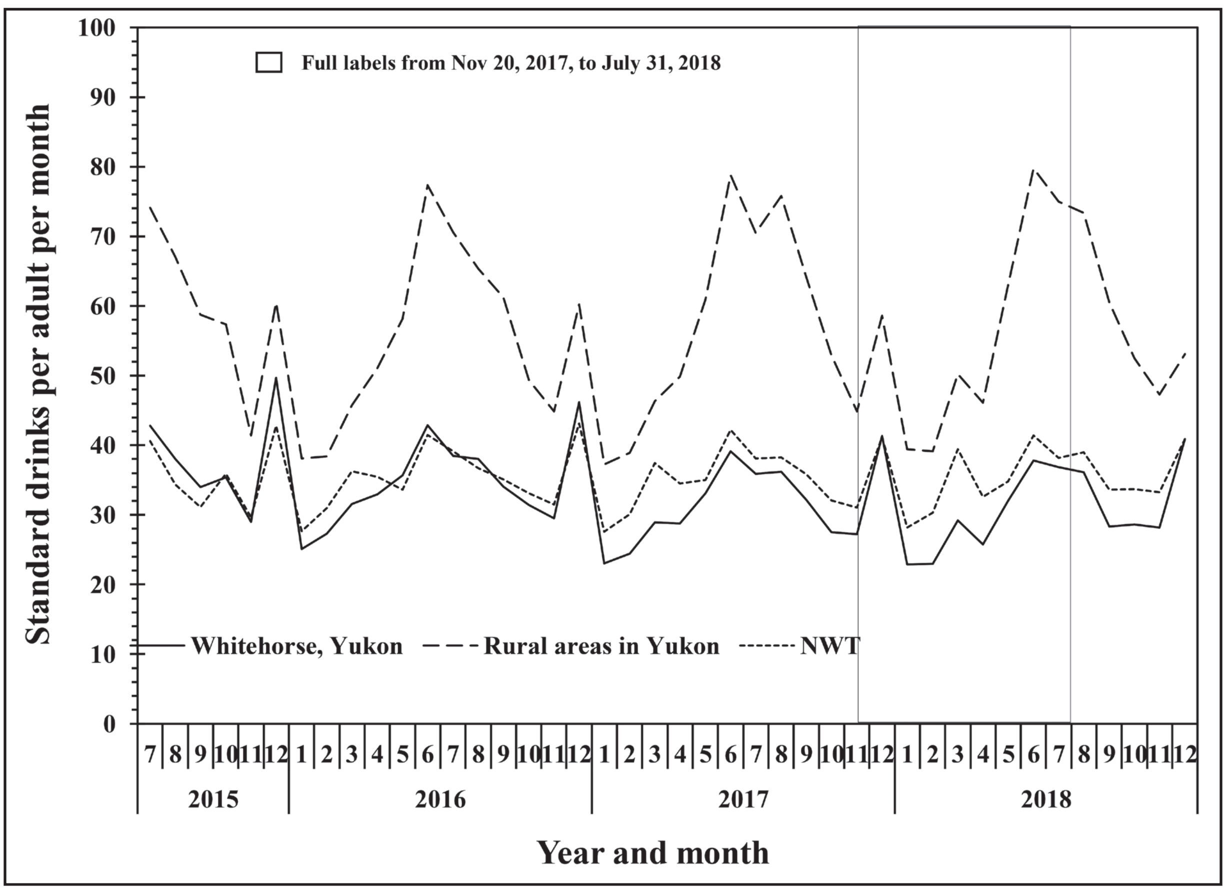


FIGURE 1. Mean number of standard drinks consumed per person age 15 years and older per month from liquor store sales in Whitehorse, rural areas of Yukon, and in Northwest Territories (NWT) during the study period

changes in these categories of monthly sales data. DW tests revealed significant first-order temporal autocorrelation for mean monthly total sales, labeled sales, and unlabeled sales (all *p*s of DW test < .0001).

Bivariate linear regression was used to examine the relationship between estimated mean monthly per capita consumption in people age 15 and older, income, and various sociodemographic variables (Table A1 in Appendix II). The level of alcohol consumption for labeled products was higher where there were more males (t test $p = .0001$), more young adults ages 20–29 (t test $p = .1849$), more Indigenous residents (t test $p = .0022$), greater population density (t test $p = .0001$), and lower average income (t test $p = .0001$). The multicollinearity analyses showed that there was no threat of multicollinearity (no coefficients of .8 or higher in the correlation matrix, a VIF less than 10, or a Tolerance value of .1) (Schreiber-Gregory, 2017). The VIF value of the income variable was 17, but inclusion/exclusion of this covariate in the models did not substantially change the effect estimates of the labeling intervention; thus, the income variable was still included in multivariate regression analyses (Allison, 2012). As a consequence, these variables were treated as potential confounders in the following multivariate mixed models.

Changes in alcohol consumption before, during, and after the labeling intervention

Table 2 presents estimated percentage changes in mean monthly per capita SDs sold during the planned intervention (i.e., from November 2017 until July 2018) compared with periods and control sites where only the BD labels (or BD and ID labels) were applied, while adjusting for temporal, regional, and demographic variations. In the model for total alcohol sales, there was an estimated reduction in per capita alcohol sales of 6.31% (t test $p < .0001$) during the newly designed AWL period in Whitehorse. During the post-intervention months (August through December 2018), a still larger reduction of 9.97% (t test $p = .0001$) was estimated. An exactly parallel trend was observed for the model used only for labeled products while controlling for sales of unlabeled products, although with a slightly higher effect size (-6.59%, t test $p < .0001$) during the intervention period and a larger effect size afterward (-10.29%, t test $p < .0001$). The third model applied only to unlabeled products found significant (6.91%, t test $p < .05$) and marked increases (9.16%, t test $p = .0946$) in consumption during the intervention and post-intervention periods.

Table 3 presents models similar to those presented in Table 2 but with the intervention period broken into three phases: (i) 2 months during which the initial combination of approximately 96,000 Ca and LRDG labels were applied to most alcoholic products in the Whitehorse liquor store for 30 days, (ii) the period after the intervention was halted as a result of industry interference and when no new labels were added (3 months), and (iii) a 4-month period during which most alcohol containers sold in Whitehorse were labeled with either an SD or LRDG label (approximately 200,000 containers). Gradually increasing reductions in total and labeled alcohol sales were observed over time, with the smallest during the initial 1-month period (i) (-2.28% for total retail sales, t test $p < .0001$) and the largest during the LRDG/SD labeling and post-intervention periods (iii). Marked and significant increases were observed in per capita sales of unlabeled products since the initial labeling intervention took effect in November 2017.

Table A2 (Appendix II) presents three more models equivalent to those in Table 3 but with subsets of alcohol sales data containing either products that received the LRDG labels or the SD labels between April and July 2018. The table also presents the sale of local products excluding beers (D in Box 1). Very similar patterns of reduced alcohol sales were observed.

Figure 2 presents the adjusted estimates of monthly SDs of total sales in Whitehorse and Yukon rural areas combined and in NWT from 2015 to 2018. The alcohol sales showed a decreased trend in Whitehorse after the newly designed AWLs were introduced in November 2017, whereas alcohol sales tended to increase slightly in Yukon rural areas and no changes in NWT.

We performed sensitivity tests to examine the robustness of the observed changes under different assumptions and degrees of control for alcohol sales in control regions without the new labeling intervention (Table 4). The first model (Model 1) compares per capita alcohol sales in Whitehorse during the intervention period with the baseline Whitehorse sales during which only the BD label was applied. The second model uses all monthly sales for both the five area liquor stores in Yukon outside of Whitehorse and the Whitehorse liquor store when only the BD label was applied as a comparison. The third model repeats the second one but includes monthly alcohol sales in NWT as a further control. As can be seen, very similar effect sizes are observed in each model with reductions of approximately 6% during the intervention period and between 9% and 10% after intervention. Model 4 presents the effect estimates for Yukon rural area alcohol sales during the Whitehorse labeling (November 2017–July 2018) and post-labeling periods (August–December 2018) versus before (July 2015–October 2017). The analysis included NWT data for adjustment. There were no significant increases (2.81% and 1.37%, respectively) in the alcohol sales in rural areas during the Whitehorse labeling intervention and post-intervention periods compared with that before the labeling intervention period. Model 5 presents the effect estimates for both Yukon rural area and NWT alcohol sales during the Whitehorse labeling (November 2017–July 2018) and post-intervention periods (August–December 2018) versus before (July 2015–October 2017) in Yukon rural areas

TABLE 2. Estimated percentage changes in mean number of standard drinks consumed per adult per month for total, labeled, and unlabeled liquor store alcohol sales in Whitehorse during the full labeling period and after the labeling intervention period compared with baseline

Labels[a]	Time period[b]	Drinks/month/adult[d]			
		% change[c]	*M*	[95% CI]	*t* test *p*
Model 1: Total alcohol sales					
Baseline (all areas) (BD/ID)	Jul. 2015–Oct. 2017	0.00	45.35	[44.47, 46.24]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	**-6.31**	**42.48**	**[41.37, 43.62]**	**.0001**
Post-intervention Whitehorse (BD)	Aug. 2018–Dec. 2018	**-9.97**	**40.83**	**[39.17, 42.56]**	**.0001**
Model 2: Total sales of labeled products					
Baseline (all areas) (BD/ID)	Jul. 2015–Oct. 2017	0.00	44.47	[43.61, 45.34]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	**-6.59**	**41.53**	**[40.43, 42.67]**	**.0001**
Post-intervention Whitehorse (BD)	Aug. 2018–Dec. 2018	**-10.29**	**39.89**	**[38.25, 41.60]**	**.0001**
Model 3: Total sales of unlabeled product					
Baseline (all areas) (BD/ID)	Jul. 2015–Oct. 2017	0.00	0.82	[0.69, 0.98]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	**+6.91**	**0.88**	**[0.72, 1.08]**	**.0182**
Post-intervention Whitehorse (BD)	Aug. 2018–Dec. 2018	+9.16	0.90	[0.74, 1.10]	.0946

Notes: **Bold** indicates statistical significance. Ref. = reference. [a]BD/ID = birth defect (BD) in Yukon plus impaired driving and general health concern message (ID) in Northwest Territories; Ca = cancer, LRDG = low-risk drinking guideline; SD = standard drink. [b]"Baseline" sales include the pre-intervention period in Whitehorse plus all sales in outer regions of the Yukon in which birth defect (BD) and Northwest Territories in which BD+ID were labels added throughout study period. [c]Percentage change in monthly per capita standard drinks ([d]) for labeling intervention period versus baseline (BD/ID). [d]Mean estimates and 95% confidence intervals (CIs) adjusted for time trend, seasonality (seasonal index method), regional and temporal regressive effects, average personal income, % population ages 20–29 years old, % males, % Indigenous population and the regional variable (rural areas and Whitehorse in Yukon and Northwest Territories). A weighting variable was used to adjust for various number of days per month. The models for labeled alcohol sales were further adjusted for unlabeled beverage sales and vice versa.

and NWT. There were also no significant increases (2.25% and 0.24%, respectively) in the alcohol sales in rural areas and NWT during the Whitehorse labeling intervention and post-intervention periods compared with that before the labeling intervention period.

Discussion

An accumulating reduction in per capita alcohol sales from liquor stores was observed in the intervention site of Whitehorse in comparison variously with the baseline period in Whitehorse, with per capita sales in five outlying control regions in Yukon, and also after adjustment for total per capita monthly alcohol sales in neighboring NWT. These statistically significant reductions were estimated in models that adjusted for a number of economic and demographic predictors of the level of alcohol consumption in different regions. It is noteworthy that in this remote area of Canada, per capita alcohol consumption estimated from sales was significantly higher in the outlying, control regions in Yukon, regions that also had a higher proportion of males, young adults, persons with low income, and non-Indigenous people. It is also important to note that significant reductions in consumption were observed only in relation to alcohol products that received the manual application of some 300,000 bright yellow and red intervention warning labels and not among products that were not labeled. In fact, there were significant increases in the consumption of unlabeled products in Whitehorse during the intervention. These products could not be labeled because they were from local or small producers, the containers were too small, or it was otherwise impractical to add labels (e.g., single containers of beer were exempt). They represented only 3% of sales. Although it is possible that factors other than the absence of labels may account for this finding, the pattern of results is consistent with some customers selecting unlabeled products to avoid seeing the series of stark warning and health messages.

The central question raised by these results is whether it is plausible to attribute the observed reductions in per capita alcohol sales to the labeling intervention. Against this interpretation is the scant evidence of changes in population consumption as a result of the much-studied introduction of U.S. warning labels in 1989 (Greenfield, 1997). Furthermore, the greatest reduction in monthly sales was observed after the application of LRDG and SD labels to product containers was completed at the end of July 2018 (Hobin et al., 2020). In favor of the hypothesis that the labeling intervention had a causal role, these labels were strikingly different from their U.S. predecessors. They were developed over 4 years, during which the literature on what constitutes effective warning labels was carefully reviewed and both a randomized experiment and a focus group study were conducted (Hobin et al., 2018; Vallance et al., 2018) to identify effective content and presentation. Thus, the labels presented messages for which there was low awareness at baseline (Vallance et al., 2020b) but that both local stakeholders and drinkers judged to be important information for consumers, that is, warnings of serious health risks for conditions prevalent in Yukon (e.g., colon and breast cancer), LRDGs (Stockwell et al., 2012), and information about the number of SDs in alcohol containers to enable consumers to follow the guidelines (Osiowy et al., 2015). The label design also followed best practices by using multiple colors, adequate size, and inclusion of images as well as text. Furthermore, a case could be made that the

Table 3. Estimated percentage changes in mean number of standard drinks per adult per month for total, labeled and unlabeled alcohol sales in Yukon during the period of Ca+LRDG/LRDG+SD labels and after the labeling intervention period compared with baseline

		Drinks/month/adult[d]			
Labels[a]	Time period	% change[b]	*M*[c]	[95% CI]	*t* test *p*
Model 1: Total alcohol sales					
Baseline (All areas) (BD/ID)	Jul. 2015–Oct. 2017	0.00	44.94	[44.05, 45.84]	ref.
(i) Ca/LRDG	Nov. 2017–Dec. 2017	**-2.28**	**43.91**	**[42.90, 44.93]**	**.0001**
(ii) No new labels added	Jan. 2018–Mar. 2018	**-4.21**	**43.04**	**[41.60, 44.54]**	**.0001**
(iii) LRDG+SD	Apr. 2018–Jul. 2018	**-11.35**	**39.83**	**[38.54, 41.28]**	**.0001**
Post-intervention Whitehorse (BD)	Aug. 2018–Dec. 2018	**-11.85**	**39.61**	**[38.30, 40.99]**	**.0001**
Model 2: Total sales of labeled products					
Baseline (All areas) (BD)	Jul. 2015–Oct. 2017	0.00	44.07	[43.32, 44.84]	ref.
(i) Ca/LRDG	Nov. 2017–Dec. 2017	**-2.41**	**43.01**	**[42.16, 43.88]**	**.0001**
(ii) No new labels added	Jan. 2018–Mar. 2018	**-4.46**	**42.11**	**[40.82, 43.43]**	**.0001**
(iii) LRDG+SD	Apr. 2018–Jul. 2018	**-11.79**	**38.87**	**[37.71, 40.08]**	**.0001**
Post-intervention Whitehorse (BD)	Aug. 2018–Dec. 2018	**-12.20**	**38.69**	**[37.55, 39.88]**	**.0001**
Model 3: Total sales of unlabeled product					
Baseline (All areas) (BD/ID)	Jul. 2015–Oct. 2017	0.00	0.70	[0.65, 0.75]	ref.
(i) Ca/LRDG	Nov. 2017–Dec. 2017	+2.68	0.72	[0.67, 0.77]	.6778
(ii) No new labels added	Jan. 2018–Mar. 2018	+6.38	0.74	[0.65, 0.85]	.4157
(iii) LRDG+SD	Apr. 2018–Jul. 2018	+14.32	0.80	[0.69, 0.93]	.0258
Post-intervention Whitehorse (BD)	Aug. 2018–Dec. 2018	+15.64	0.81	[0.70, 0.94]	.1457

Notes: **Bold** indicates statistical significance. Ref. = reference. [a]BD = birth defect (BD) in Yukon and plus impaired driving and general health concern message (ID) in Northwest Territories; Ca = cancer, LRDG = low-risk drinking guideline; SD = standard drink. [b]Percentage change in monthly per capita standard drinks ([d]) for labeling intervention period versus baseline (BD/ID). [c]Mean estimates and 95% confidence intervals (CIs) for total sales adjusted for time trend, seasonality, regional and temporal regressive effects, average personal income, % of population ages 20–29 years old, % of males, % of Indigenous population; mean estimates for labeled alcohol sales further adjusted for unlabeled beverage sales and mean estimates for unlabeled alcohol sales further adjusted for labeled beverage sales. A weighting variable was used to adjust for various number of days per month. A regional variable was included to control for the difference between Yukon (rural areas and Whitehorse) and Northwest Territories.

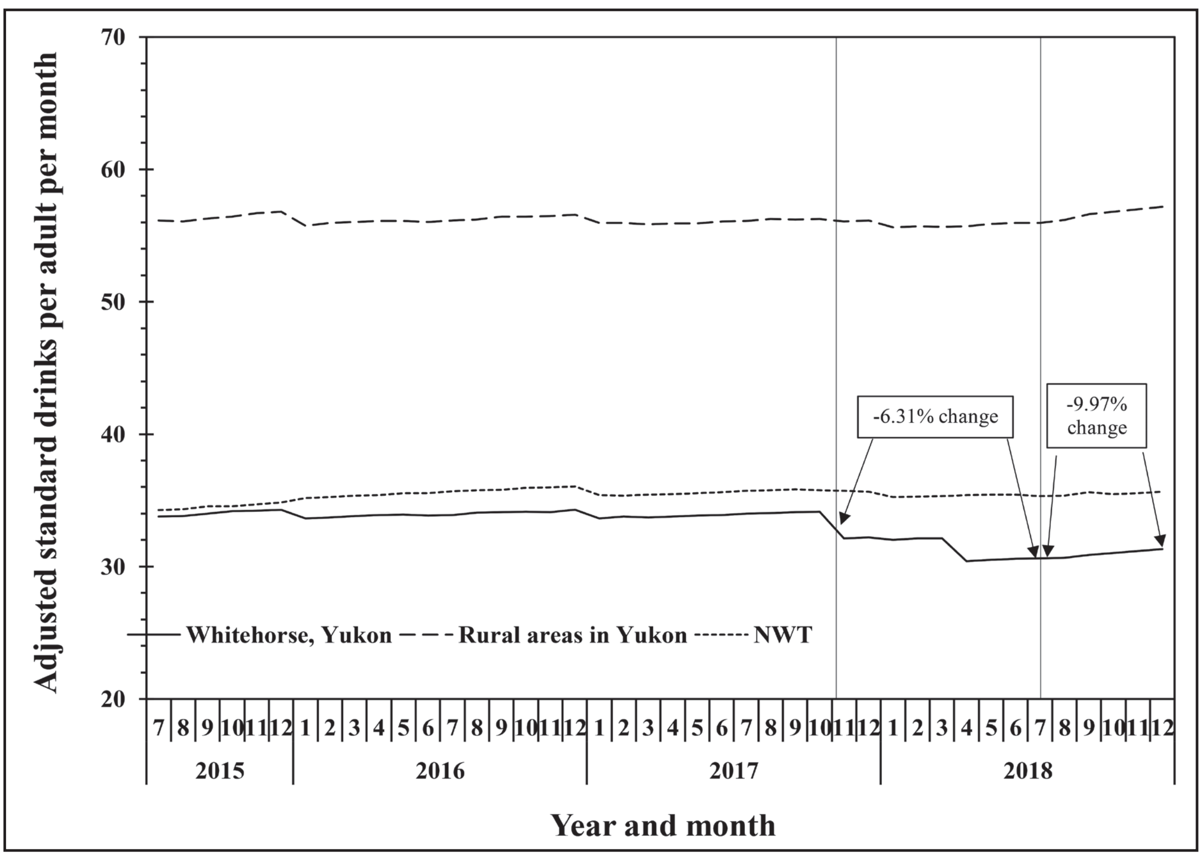


Figure 2. Adjusted mean number of standard drinks consumed per person age 15 years and older per month from liquor store sales in Whitehorse, rural areas of Yukon, and Northwest Territories (NWT) during the study period

TABLE 4. Estimated percentage changes in mean number of standard drinks per adult per month for total, labeled and unlabeled alcohol sales in Whitehorse during and after the labeling intervention period compared with baseline in Whitehorse, Yukon, and NWT

		Drinks/month/adult[d]			
Labels[a]	Time period[b]	% change[c]	*M*	[95% CI]	*t* test *p*
Model 1:					
Pre-intervention Whitehorse alcohol sales only as reference period (analysis included rural areas but no NWT data)					
Baseline (BD)	Jul. 2015–Oct. 2017	0.00	51.99	[48.74, 55.45]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	**-6.55**	**48.59**	**[45.20, 52.22]**	**.0001**
Post-intervention (BD/AWLs)	Aug. 2018–Dec. 2018	**-10.56**	**46.50**	**[43.24, 50.01]**	**.0001**
Model 2:					
Yukon-wide alcohol sales with BD only labels periods and regions as reference (no NWT data)					
Baseline (BD)	Jul. 2015–Oct. 2017	0.00	51.22	[50.80, 51.64]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	**-6.27**	**48.01**	**[47.06, 48.98]**	**.0001**
Post-Intervention (BD/AWLs)	Aug. 2018–Dec. 2018	**-10.20**	**46.00**	**[44.80, 47.22]**	**.0001**
Model 3: Yukon-wide alcohol sales (Model 2) + adjustment for NWT sales (retail sales in NWT)					
Baseline (BD/ID)	Jul. 2015–Oct. 2017	0.00	45.81	[44.27, 47.41]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	**-6.20**	**42.97**	**[41.68, 44.30]**	**.0001**
Post-intervention (BD/ID/AWL)	Aug. 2018–Dec. 2018	**-9.33**	**41.54**	**[40.08, 43.04]**	**.0005**
Model 4:					
Yukon rural alcohol sales during the Whitehorse labeling (Nov. 2017–Jul. 2018) and post-labeling periods (Aug.–Dec. 2018) versus before (Jul. 2015–Oct. 2017)					
Baseline (BD/ID)	Jul. 2015–Oct. 2017	0.00	55.16	[54.42, 55.91]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	2.81	56.71	[54.91, 58.57]	.1918
Post-intervention (BD/ID/AWLs)	Aug. 2018–Dec. 2018	1.37	55.91	[52.33, 59.74]	.7095
Model 5: Yukon rural alcohol sales during the Whitehorse labeling (Nov. 2017–Jul. 2018) and post-labeling periods (Aug.-Dec. 2018) versus before (Jul. 2015–Oct. 2017) and NWT alcohol sales (Jul. 2015 – Dec. 2018)					
Baseline (BD/ID)	Jul. 2015–Oct. 2017	0.00	45.76	[44.06, 47.52]	ref.
Intervention (Ca/LRDG/SD)	Nov. 2017–Jul. 2018	2.25	46.79	[44.12, 49.62]	.2628
Post-intervention (BD/ID/AWL)	Aug. 2018–Dec. 2018	0.24	45.87	[43.77, 48.07]	.9502

Notes: **Bold** indicates statistical significance. NWT = Northwest Territories; ref. = reference category. [a]BD/ID = birth defect (BD) warning in Yukon plus impaired driving and general health warning in NWT; Ca = cancer; LRDG = low-risk drinking guidelines; SD = standard drink; AWLs = alcohol warning labels (Ca/LRDG/SD). [b]"Baseline" sales for Models 2 and 3 include the pre-intervention period in Whitehorse plus all sales in outer regions of the Yukon when BD labels were added throughout the study period. [c]Percentage change in monthly per capita standard drinks ([d]) for labeling intervention period versus baseline (BD or BD/ID). [d]Mean estimates and 95% confidence intervals (CIs) were adjusted for time trend, seasonality, regional and temporal regressive effects, average personal income, % population ages 20–29 years old, % males in population, % Indigenous population, and region in Model 3 (Yukon rural areas, Whitehorse, and NWT). A weighting variable was used to adjust for varying number of days per month.

effect size of the reductions in per capita sales reflected the intensity of the intervention. Thus, the smallest effect size (about 3%) occurred at the outset when about 100,000 of the new cancer and LRDG labels were applied to most containers for just 30 days.

Over the following 3 months, when the reduction in sales was 5%, there was intense media coverage of the study (Hobin et al., 2020; Vallance et al., 2020c), which could have served to reinforce the labeling messages and intensify their effect even though no new labels were added. There would nonetheless have been a decreasing number of containers in the Whitehorse store still labeled with the Ca and LRDG messages. During the third 4-month phase, approximately 200,000 LRDG and SD labels were applied, and there was an effect size of approximately 7%. The post-intervention phase included a change in labeling (i.e., the return of the small BD label that had been placed on alcohol containers for more than 25 years until the beginning of this study in November 2017). Previous studies showed that health messages or warnings need to be sufficiently large as to be readily legible for consumers of all ages, be colorful and concise, contain graphic images, and be varied over time to maintain their salience to consumers (Al-Hamdani & Smith, 2017; Wigg & Stafford, 2016). The change in the warning label back to the BD label at this point itself could have created more discussion and attention to health aspects of alcohol consumption. Last, significant increases in per capita sales were observed in models examining unlabeled products, indicating a measure of specificity for the effect of the intervention warning labels.

Alcohol warning labels allow consumers to make more informed choices about what they drink and warn consumers of the potential dangers and health risks from products (Deutsche Hauptstelle für Suchtfragene, 2008; Wilkinson & Room, 2009). In providing such information, warning labels also deliver a clear message to consumers that alcohol is not an ordinary commodity (Babor et al., 2010; Deutsche Hauptstelle für Suchtfragene, 2008). After seeing the new label messages, shoppers may have stopped purchasing alcoholic beverages or decided to purchase fewer alcohol products than planned, and therefore the total or some types of products sales could be reduced during the study period.

It is important, however, to acknowledge both the advantages and limitations of the use of sales data to estimate the impacts of a policy intervention. We followed international best practices to estimate local per capita alcohol consumption, estimating total recorded sales from official sources and expressing these as a rate for the proportions of local residents age 15 and older (Stockwell & Chikritzhs, 2000; Stockwell et al., 2018). Because Yukon has a government monopoly on the sale and distribution of alcohol, the monthly data provided on recorded sales provide an excellent and accurate record of off-premise sales across all the regions included. However, these would not include sources of unrecorded alcohol consumption such as homemade and travelers' imports, although these are likely to be small, especially because Yukon is a fairly remote area.

A further weakness in these sales data is that the per capita estimates do not control for the volume of tourism; it is entirely conceivable that the results are confounded somehow by unusual variations across regions in Yukon—although this was partly addressed by the adjustments made for seasonal variation in the sales data and by the use of controls for consumption in the five outlying areas of Yukon and in NWT. 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 (Rothman & Greenland, 1998). However, the inherent qualities of the ecological design for epidemiological and policy analysis can be valuable for investigating potential population-wide effects (Cohen, 1994; Susser, 1994). The effect of the labeling intervention may also be lagged. This study did not examine any lagged effects of the labeling intervention on the consumption because of the short period observed after the labeling was implemented. However, the observed large effect for the post-intervention phase would be consistent with such an interpretation. Last, the confounding effect of other social policies or factors may exist in Whitehorse. One candidate is the legalization of cannabis that occurred Canada-wide and was implemented on October 17, 2018 (Department of Justice, 2018), when the first government-run online and retail store selling cannabis opened in Whitehorse, midway through the post-intervention period. However, in separate analyses, no differences were observed in alcohol sales from before to after October 17, 2018.

Conclusion

We found that the introduction of new AWLs displayed on the containers of alcohol products sold in a major Yukon liquor store was associated with significantly reduced per capita alcohol consumption. The accumulating effect size over time can be interpreted as being consistent with a causal effect of the labeling intervention, especially as an opposite change was observed for unlabeled products and no reductions were seen in two separate control regions within and outside Yukon where there were no changes in labeling practices. The results are also broadly consistent with those from the self-report survey data collected before, during and after the labeling interventions (Hobin et al., 2020).

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Conflict-of-Interest Statement

Tim Stockwell received research funds and travel expenses from both the Swedish and Finnish government alcohol monopolies in the past 4 years. Other authors declare no conflicts of interest.

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