Research Article

Cannabis
2024

researchmj.org
10.26828/cannabis/2024/000260

Examining the Potential Impact of Recreational Cannabis Legalization on Individuals Receiving Treatment for Substance Use Disorder: An Interrupted Time Series Study in Guelph, Ontario, Canada

Emily M. Britton[1], Radia Taisir[1], Alysha Cooper[1], Yao Li[1], Sarah Sousa[1], Yelena Chorny[2], James MacKillop[1,3-5], & Mary Jean Costello[1]

[1]Homewood Research Institute, Guelph, Ontario, Canada
[2]Homewood Health Centre, Guelph, Ontario, Canada
[3]St. Joseph's Healthcare, Hamilton, Ontario, Canada
[4]Michael G. DeGroote Centre for Medicinal Cannabis Research, McMaster University, Hamilton, Ontario, Canada
[5]Peter Boris Centre for Addiction Research, St. Joseph's Healthcare, Hamilton, Ontario, Canada

ABSTRACT

Objective: The present research evaluated the impact of legalizing recreational cannabis among individuals with substance use disorders (SUDs) who may already use cannabis at high rates. **Method:** Using an interrupted time series study design, we evaluated the potential impact of legalizing recreational cannabis among individuals seeking treatment for SUD within a hospital-based treatment setting in Guelph, Ontario. We examined 2,925 individuals who entered an inpatient SUD treatment program between April 2017 and December 2021. We performed segmented regression analyses using both the date of cannabis legalization and the date of edibles legalization as the interruption time point. We also performed stratified analyses to examine potential sex differences. **Results:** We found no significant changes in the frequency of cannabis use using either of the interruption time points. However, among the subsample who had used cannabis, there was evidence of increasing CUD severity post-legalization of edibles, as well as an overall decreasing trend in readiness to quit over time. Stratified analyses also suggested possible sex differences in frequency of cannabis use, CUD severity, and readiness to quit. **Conclusions:** Results point to some small but potentially important impacts of recreational cannabis legalization that may only continue with time. Nevertheless, there is a need to continue to monitor cannabis use trends over time to understand any potential lagged effects.

Key words: = cannabis; health policy; substance use disorder; vulnerable populations

Corresponding Author: Mary Jean Costello, PhD, Homewood Research Institute. Riverslea, 150 Delhi St, Guelph ON, N1E 6K9. Phone: (519) 838-8104, ext. 32320. Email: JCostello@hriresearch.com

On October 17, 2018, Canada became the second country after Uruguay to legalize recreational cannabis with the introduction of the federal Cannabis Act (2018). Under this new legislation, adults could legally purchase, possess, and use non-medical cannabis (dried, fresh, and oil) in limited quantities based on provincial and territorial regulations that oversee retail distribution and sales (Government of Canada, 2018). One year later, on October 17, 2019, the federal government amended the Cannabis Act to include three new classes of cannabis: edibles, topicals, and concentrates. These policy changes aimed to minimize the harms posed by cannabis, including eliminating the illicit market, reducing youth access, ensuring quality control, and increasing awareness of the health risks (Cannabis Act, 2018; Government of Canada, 2022). Nevertheless, scientists and practitioners raised concerns that legalization would lead to an increase in cannabis use and consequent harms (Hajizadeh, 2016; Svrakic et al., 2012; Windle et al., 2019). Thus, there became a pressing need to understand the impacts of this new legislation on cannabis use and associated health and well-being.

Over the past five years, several studies have examined the impact of recreational cannabis legalization among the Canadian population. These studies generally indicate modest but significant increases in the prevalence of cannabis use following legalization (see Athanassiou et al., 2023; Hall et al., 2023 for review). For example, recent results from the 2023 Canadian Cannabis Survey—a large-scale national survey conducted by Health Canada—indicated that 26% of people (aged 16+) reported using cannabis over the past 12 months, up from 22% in 2018 (Health Canada, 2024). In Ontario, which is Canada's most populous province, studies have similarly reported small but significant increases in cannabis use over time following legalization (Nigatu et al., 2020; Turna et al., 2021). In addition to an increase in cannabis use, studies have also reported increased rates of cannabis-attributable healthcare visits and cannabis-related hospitalizations during both the initial and longer-term post-legalization phases (Kim et al., 2023; Walker et al., 2023).

Although research to date has provided important insights with respect to the general population, there remains a need to study the effect of legalization on specific at-risk populations, including individuals with substance use disorders (SUDs). Research prior to legalization shows that people with psychiatric disorders, and in particular those with SUDs, tend to use cannabis at elevated rates and are more likely to have a cannabis use disorder (CUD; Lev-Ran, Le Foll, et al., 2013; Wittchen et al., 2007). Additionally, cannabis use and CUD are often elevated among those with concurrent disorders (i.e., people living with SUD and another comorbid psychiatric condition; Hango & LaRochelle-Côté, 2018; Lev-Ran, Le Strat, et al., 2013). On the other hand, frequent and long-term use of cannabis is associated with increased use of other substances that may become problematic (Hasin & Walsh, 2021; Secades-Villa et al., 2015; Subbaraman & Kerr, 2015). Given these complex relations, it may be particularly important to study the potential effects of legalization among individuals with SUDs. An increase in cannabis use or CUD within this group may necessitate adaptations in the structure or delivery of treatment programs and services to meet changing substance use patterns and possibly co-occurring psychiatric symptoms. Furthermore, as these settings include individuals with elevated pre-legalization cannabis use and CUD, they may provide insights into trends that pertain only to individuals with high levels of use.

In the present research, we used an interrupted time series (ITS) design to examine the impact of recreational cannabis legalization among individuals who entered an inpatient SUD treatment program in Guelph, Ontario. In an ITS design, the outcome of interest is measured sequentially within a population at equal time intervals before and after an intervention, thereby permitting comparison of the level and slope of the outcome pre- and post-intervention (Bernal et al., 2017). Specifically, we examined changes in the frequency of cannabis use post-legalization among the full patient population, as well as changes in severity of CUD symptoms, the proportion of those who screen positive for CUD, and readiness to quit among a subsample who had used cannabis. Given the known differences in cannabis use patterns among males and females (e.g., Calakos et al., 2017; Cuttler et al., 2016), we also explored potential sex differences as a secondary objective. Although recreational cannabis legalization occurred on October 18,

2018 in Canada, the first in-person dispensaries did not open until April 2019 in Ontario (Owram, 2019). Therefore, we considered two intervention breakpoints: the initial date of legalization (Oct. 17, 2018) and the date of edibles legalization one year later (Oct. 17, 2019), which also coincided with increasing access to cannabis and commercialization in Ontario (Myran, Staykov, et al., 2022).

METHODS

Participants and Procedure

Participants were individuals who voluntarily entered a large inpatient SUD treatment program located in Guelph, Ontario between April 17th, 2017 and December 16th, 2021. The program offered a 35-day, group-based treatment for adults aged 19+ with alcohol and/or other substance use disorders. Data were collected using a self-administered questionnaire completed as part of standard clinical practice upon admission to the program. The questionnaire included psychometrically validated measures and tools used to screen for SUD and other psychiatric disorders. All patients were informed that these data may be used for research purposes and provided implicit consent. We accessed the data retrospectively via research protocols (#16-06, #19-08) that received ethics approval from the Regional Centre for Excellence Research Ethics Board in Guelph, Ontario.

Over the study period, 2,925 individuals entered the treatment program and completed the clinical questionnaire. We excluded 27 cases that were missing data related to cannabis use or did not have a valid admission date (required to assign the case to a time period). In total, 2,898 individuals (M_{age} = 41.41, SD = 11.73; 72% male) were included in the primary analysis. Of the full sample, 1,416 people (48.8%) indicated they had used cannabis at some point within the past year. Within this subsample, we excluded people who were missing data related severity of cannabis use or readiness to quit using cannabis, resulting in a final subsample of 1,384 individuals. Table 1 presents the demographic and substance use characteristics for both the full sample and subsample who used cannabis. Supplemental Table S1 presents the demographic and substance use characteristics of individuals admitted pre- versus post-cannabis legalization. Some characteristics differed between the two groups with respect to age, education, most frequently used substance(s), and SUD profile.

Table 1. *Socio-Demographic and Substance Use Characteristics for the Full Sample (N = 2,898) and the Subsample Who Used Cannabis (N = 1384)*

Characteristic	Full sample		Used cannabis	
	n	%	*n*	%
Sex				
Male	2087	72.0	1053	76.1
Age				
< 30 years	476	16.4	350	25.3
30 to 39 years	855	29.5	496	35.8
40 to 49 years	784	27.1	331	23.9
50 to 59 years	586	20.2	166	12.0
≥ 60 years	197	6.8	41	3.0
Education				
Completed college/university	1155	39.9	462	33.4
Employment				
Employed	2152	74.3	1011	73.0
Marital Status				
Married or partnered	1236	42.7	486	35.1
Most frequently used substance(s) at admission[a]				
Alcohol	1901	65.6	760	54.9
Cannabis	636	21.9	626	45.2
Stimulants	598	20.6	333	24.1

Opioids	357	12.3	189	13.7
Sedatives	159	5.5	77	5.6
Other	66	2.3	28	2.0
Screened positive for SUD[b]				
AUD	2180	75.2	1004	72.5
CUD	718	24.8	708	51.2
Other DUD (not incl. CUD)	1438	49.6	865	62.5
Screened positive for SUD[b]				
AUD only	1132	39.1	271	19.6
DUD only (incl. CUD)	611	21.1	345	24.9
Both AUD + DUD (incl. CUD)	1040	35.9	732	52.9

Note. SUD = substance use disorder; AUD = alcohol use disorder; CUD = cannabis use disorder; DUD = drug use disorder. [a] Most frequently used substance was identified as the substance(s) with the highest response score(s) on a hybridized version of the NIDA Quick Screen question (NIDA, 2012) and Adapted NIDA-Modified ASSIST (APA, 2013). Groups are not necessarily mutually exclusive. [b] Positive screen defined as endorsing two or more criteria on the DSM-V SUD Checklist (APA, 2013). Groups are not necessarily mutually exclusive.

Outcome Measures

Cannabis use. The frequency of cannabis use was assessed using a hybridized version of the National Institute on Drug Abuse (NIDA) Quick Screen question (NIDA, 2012) and adapted NIDA-Modified ASSIST V2.0 (American Psychiatric Association [APA] 2013). Individuals rated on a scale from 0 (none) to 5 (multiple times per day) how frequently they had used cannabis over the reference period.. For data collected April 2017 to April 2018 (n = 780), cannabis use was assessed over the past year; for data collected May 2018 to December 2021 (n = 2118), cannabis use was assessed over the past 90 days. To justify combining these data, we conducted a segmented regression analysis using the level change impact model to examine whether there was a significant level change following the change in reference period. Results showed that the change in reference period was not associated with the frequency of reported cannabis use (see Supplemental Table S2).

Severity of cannabis use. The DSM-5 SUDs Checklist (APA, 2013; Hasin et al., 2013) was used to assess the severity of CUD symptoms. The checklist assesses 11 diagnostic criteria and was previously validated in relation to a structured clinical interview in the same treatment setting (Levitt et al., 2021). Response options were dichotomous (yes or no), indicating endorsement of each specific criterion. The total number of endorsed criteria was then calculated with responses ranging from 0 to 11. Like cannabis use, CUD symptoms were assessed over the past year for data collected April 2017 to April 2018 and over the past 90 days for data collected from May 2018 to December 2021. Results from a segmented regression analysis again demonstrated that the change in reference period was not significantly associated with the severity of cannabis use (see Supplemental Table S2).

Proportion of patients screening positive for CUD. A dichotomous variable was created using the total number of endorsed criteria for CUD (described above) to indicate whether the patients screened positive for CUD (total number of endorsed criteria ≥ 2) or not (total number of endorsed criteria < 2).

Readiness to quit using cannabis. A readiness ruler (Chung et al., 2011; Maisto et al., 2011) was used to assess patients' readiness to change their cannabis use. Using the ruler, patients were asked to indicate how ready they were to make a change (quit or reduce) their cannabis use. Ratings ranged from 1 to 10, where 1 represented "not at all ready" and 10 represented "already trying to make a change."

Design and Data Analysis

We used an ITS design to examine whether recreational cannabis legalization was associated with changes in the frequency of cannabis use among the full sample, as well as changes in severity of cannabis use, proportion who screened positive for CUD and readiness to quit among the subsample of patients who had used cannabis. To ensure substantive sample sizes at each time point, we examined each outcome in bi-monthly

periods using the sample of individuals who were admitted to the treatment program within the respective period. We conducted two sets of analyses using two different intervention break points: (1) the date when recreational cannabis became legal in Canada, October 17th, 2018, and (2) the date when edible cannabis products and concentrates were legal for sale in Canada, October 17th, 2019 (one year following cannabis legalization).

We analyzed the data using segmented regression analysis, modelling the association between legalization and each outcome using the level and slope change impact model (Bernal et al., 2017). For ease of interpretation, we applied a logit transformation to the screened positive for CUD outcome, since this was represented as a proportion. Each model included: (1) an intercept, (2) the time elapsed since the start of the study (representing the underlying pre-intervention trend), (3) an intervention variable coded 0 for pre-intervention and 1 for post-intervention (representing the level change immediately following the intervention), and (4) the product of the intervention and the time elapsed since the beginning of the intervention (representing the slope change following the intervention). Notably, following the recommendation of Xiao and colleagues (2021), we calculated the slope change as the product of the intervention and the time elapsed since the start of the intervention (as opposed to the start of the study) to allow for proper interpretation of the level change. Seasonality was tested using the Ollech and Webel's combined seasonality test (Ollech, 2021; Ollech & Webel, 2020) and was not detected for any of the outcomes understudy. Extreme outliers were identified using the boxplot method for each outcome. Serial autocorrelation of model residuals was examined through the Durbin-Watson test (Durbin & Watson, 1992) and accounted for with Prais-Winsten regression (Prais & Winsten, 1954) when necessary. Normality was assessed using the Shapiro-Wilk test (Shapiro & Wilk, 1965). To check heteroscedasticity of the model, the Breusch-Pagan test (Breusch & Pagan, 1979) was used and weighted least squares (WLS) regression was performed when necessary. We also explored potential sex differences using stratified analyses to compare results for males and females.

Finally, we calculated Bayes factors to determine whether null findings indicated evidence in support of the null hypothesis or were a result of insensitive data. A Bayes factor above 1 provides increasing evidence in support of the null hypothesis, whereas a Bayes factor below 1 provides increasing evidence in support of the alternative hypothesis. A Bayes factor of 1 indicates insensitive data. Thresholds of Bayes factors approximately >3 and <1/3 were used to indicate evidence in support of the null and alternative hypotheses, respectively (Dienes, 2016). All statistical analyses were performed in the statistical software, *R* (v. 4.4.1; R Core Team, 2024).

RESULTS

Segmented regression results using the date of cannabis legalization (October 17, 2018) and the date of edibles legalization (one year later; October 17, 2019) as the intervention breakpoint are presented in Table 2. Figure 1 presents the comparison of trends for each of the outcomes with and without legalization occurring.

Among the full sample, we found no significant level or slope changes in the frequency of cannabis use pre- and post-legalization using either of the intervention breakpoints. Furthermore, the Bayes factors provided evidence in favour of the null hypothesis (i.e., no change in the outcomes). Among the subsample who used cannabis, there were no level or slope changes in the average number of endorsed CUD symptoms using the date of cannabis legalization as the intervention breakpoint. However, results indicated a significant slope change using the date of edibles legalization (or one-year after cannabis legalization). As seen in Figure 1 Panel D, there is a trend of increasing CUD severity over time following the intervention breakpoint (relative to the pre-intervention trend). The Bayes factor provided some support for the alternative hypothesis in this case. However, there were no significant level or slope changes in the proportion of who screened positive for CUD. The Bayes factor provided some support for the slope change using the date one year after cannabis legalization, but it provided full support for the null hypothesis for the other level or slope changes. Finally, there were also no level or slope changes in average readiness to quit using either of the intervention breakpoints, and the Bayes factors provided strong evidence in favour of the null hypothesis. While we did not find any

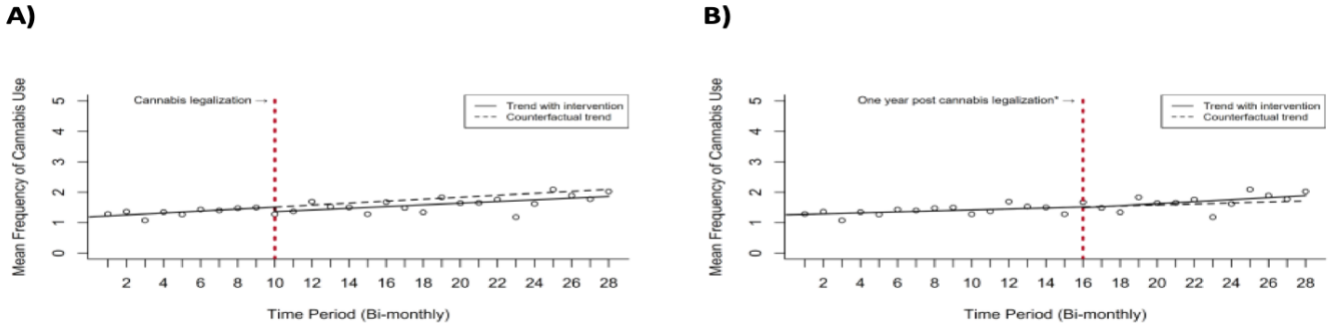
evidence of an intervention effect, the results did show an overall trend of decreasing readiness to quit over time when using the lagged intervention breakpoint.

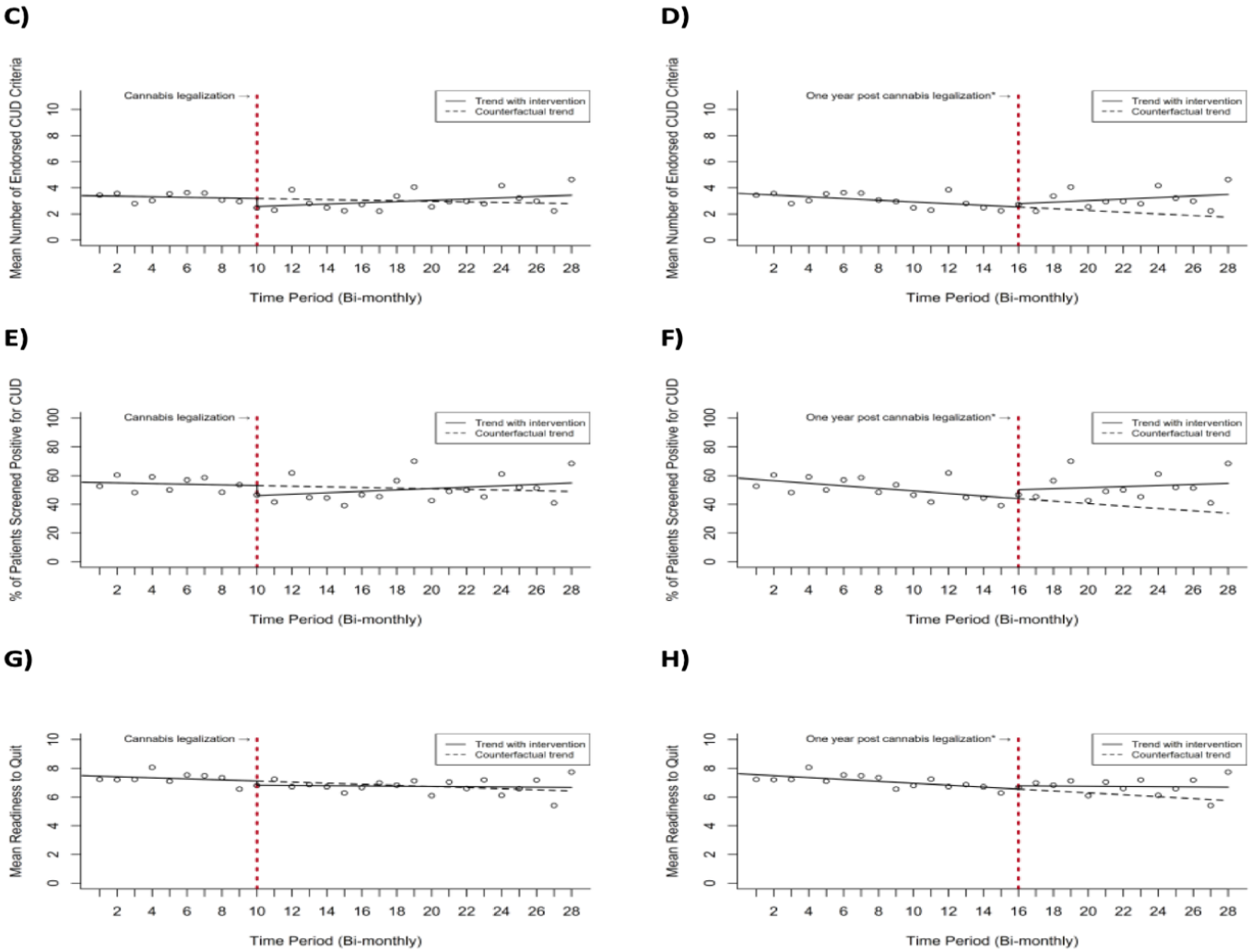
Table 2. *Segmented Regression Results Examining Associations between Recreational Cannabis Legalization and Cannabis Use Outcomes*

	Cannabis Legalization Breakpoint (Oct 17, 2018)							Edibles Legalization Breakpoint (Oct 17, 2019)						
	DW	*p*	*B*	*SE*	*t*	*p*	BF	DW	*p*	*B*	*SE*	*t*	*p*	BF
Frequency of cannabis use	2.19	.921						2.26	.937					
Intercept			1.19	0.15	8.97	<.001				1.26	0.10	12.63	<.001	
Slope			0.03	0.02	1.38	.182	2.05			0.02	0.01	1.48	.151	1.76
Level change			-0.15	0.17	-0.97	.342	3.31			-0.02	0.14	-0.17	.863	5.21
Slope change			0.00	0.03	-0.19	.853	5.20			0.02	0.02	0.96	.346	3.34
Severity of cannabis use	2.14	.823						2.14	.809					
Intercept			3.39	0.44	7.71	<.001				3.57	0.33	10.85	<.001	
Slope			-0.02	0.08	-0.28	.786	5.10			-0.07	0.04	-1.80	.084	1.04
Level change			-0.62	0.52	-1.20	.243	2.59			0.26	0.46	0.57	.575	4.50
Slope change			0.07	0.08	0.84	.407	3.71			0.12	0.06	2.14	.042	0.53
Proportion of CUD +ve	2.39	.639						2.43	.569					
Intercept			0.22	0.24	0.89	.380				0.33	0.18	1.84	.078	
Slope			-0.01	0.04	-0.22	.831	5.17			-0.04	0.02	-1.82	.081	1.01
Level change			-0.28	0.28	-1.00	.328	3.21			0.25	0.25	1.00	.328	3.21
Slope change			0.03	0.04	0.64	.527	4.31			0.05	0.03	1.63	.117	1.41
Readiness to quit	2.79	.105						2.78	.116					
Intercept			7.49	0.36	20.67	<.001				7.62	0.27	28.39	<.001	
Slope			-0.04	0.06	-0.59	.562	4.45			-0.07	0.03	-2.26	.033	0.41
Level change			-0.29	0.42	-0.69	.497	4.17			0.23	0.37	0.60	.552	4.41
Slope change			0.03	0.07	0.43	.668	4.82			0.06	0.05	1.25	.223	2.42

Note. DW = Durbin-Watson test; BF = Bayes Factor

Figure 1. *Trends for Each Outcome With and Without Legalization Occurring*





Note. *1-year lagged legalization break point coincides with the expanding commercialization of cannabis in Ontario including legalization of edibles, concentrates and topicals.
Note. Panel A-B: Frequency of cannabis use; Panel C-D: Severity of CUD symptoms; Panel E-F: Proportion of CUD +ve screened; Panel G-H: Readiness to quit using cannabis.

Stratified Analyses by Sex

Table 3 presents segmented regression results for males and females separately, using both the date of recreational cannabis legalization and date of edibles legalization (one-year lagged date). Figures 2 and 3 show the comparison of predicted trends for each of the outcomes with and without legalization for both males and females, respectively.

There was no significant level change or slope change in the frequency of cannabis use when using either of the intervention breakpoints for either males or females. However, there was some evidence of an overall increasing trend in frequency of cannabis use among the males following cannabis legalization breakpoint. Among the subsample who used cannabis, there were no level or slope changes in the average number of endorsed CUD symptoms for either males or females using the date of cannabis legalization as the intervention breakpoint. However, results indicated a significant slope change in CUD severity following the one-year lagged intervention breakpoint for males. This slope change was not significant for females, though the pattern was in the same direction. The Bayes factor provided some evidence for the alternative hypothesis for the male subgroup, but indicated insensitive data for the female subgroup. For the proportion who screen positive for CUD, there was no level change or slope change for either males or females following cannabis legalization. On contrary, following

legalization of edibles, we found significant slope change (with marginal support indicated by the Bayes factor) for females who used cannabis. For readiness to quit using cannabis, we found no significant level or slope change using either of the intervention breakpoints for either males or females. However, there was evidence of an overall trend of decreasing readiness to quit using cannabis over time among males, but not females, following the edibles legalization breakpoint.

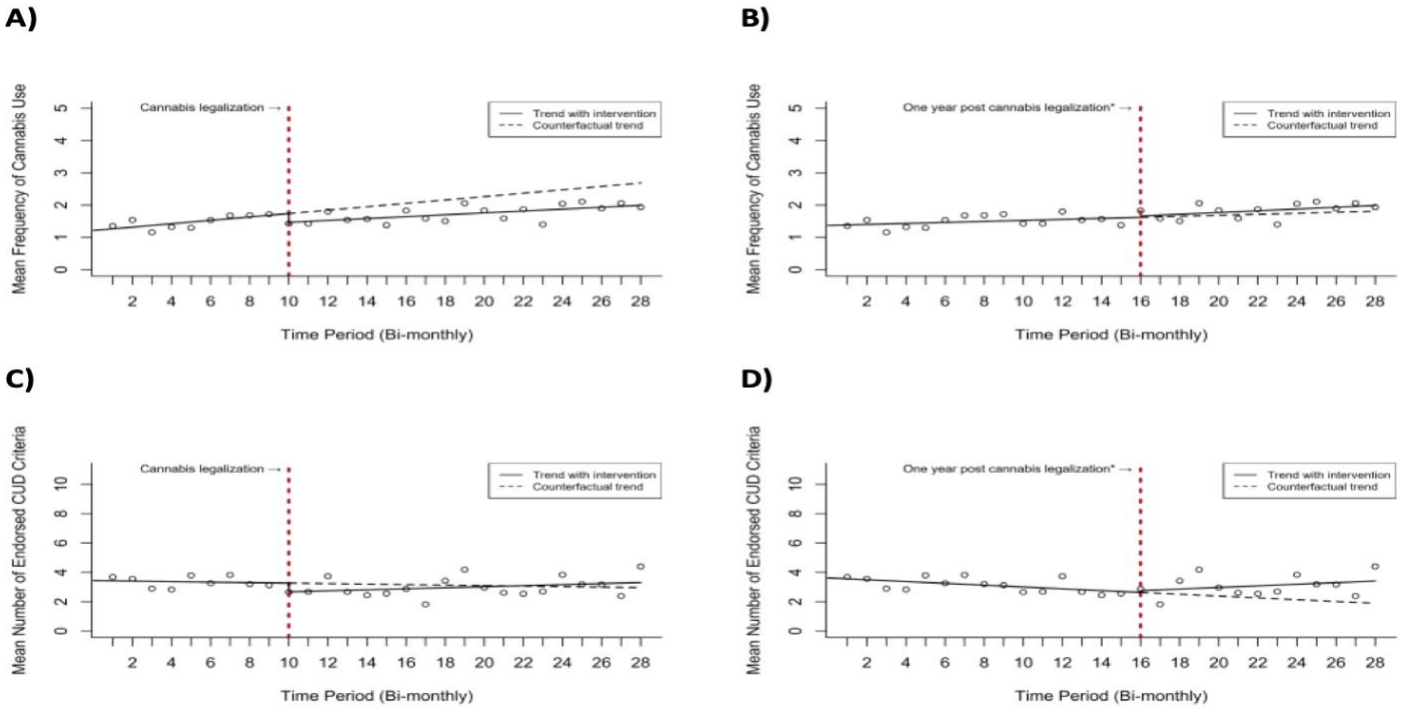
Table 3. *Segmented Regression Results Examining Associations between Recreational Cannabis Legalization and Cannabis Use Outcomes Stratified by Sex*

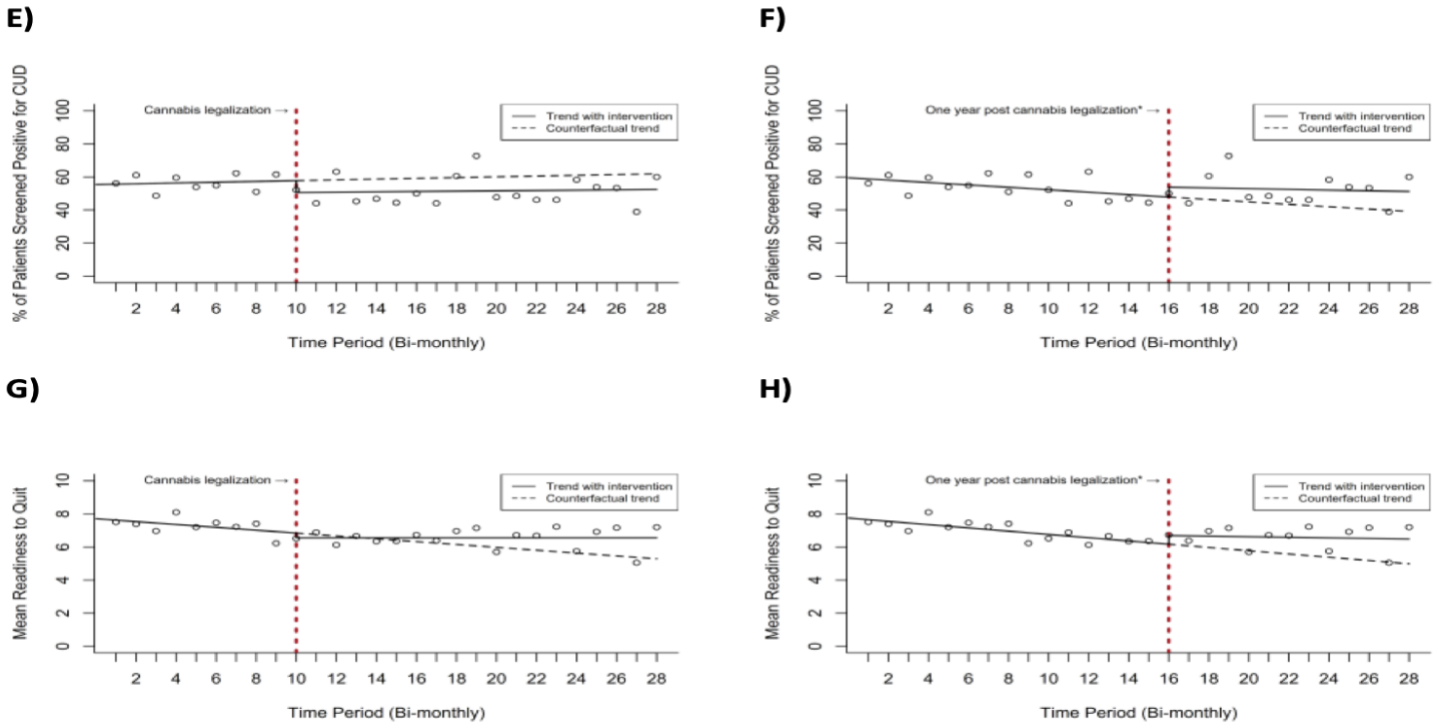
	Cannabis Legalization Breakpoint (Oct 17, 2018)							Edibles Legalization Breakpoint (Oct 17, 2019)						
	DW	*p*	*B*	*SE*	*t*	*p*	BF	DW	*p*	*B*	*SE*	*t*	*p*	BF
Frequency of cannabis use														
Males	2.45	.529						2.30	.846					
Intercept			1.21	0.13	9.04	< .001				1.37	0.11	12.99	< .001	
Slope			0.05	0.02	2.20	.038	0.47			0.02	0.01	1.36	.187	2.10
Level change			-0.27	0.16	-1.73	.097	1.19			0.04	0.15	0.27	.786	5.10
Slope change			-0.02	0.03	-0.93	.361	3.43			0.01	0.02	0.62	.542	4.37
Females [a]	1.80	.243						1.94	.424					
Intercept			0.99	0.27	3.71	.001				0.89	0.20	4.52	< .001	
Slope			0.00	0.05	-0.05	.961	5.29			0.02	0.02	0.94	.358	3.41
Level change			0.12	0.31	0.38	.711	4.93			-0.24	0.29	-0.85	.406	3.70
Slope change			0.02	0.05	0.34	.740	5.00			0.02	0.04	0.53	.601	4.60
Severity of cannabis use														
Males	2.04	.614						2.07	.666					
Intercept			3.44	0.43	8.03	< .001				3.62	0.32	11.38	< .001	
Slope			-0.02	0.08	-0.22	.826	5.16			-0.06	0.04	-1.77	.090	1.12
Level change			-0.60	0.50	-1.19	.246	2.61			0.12	0.44	0.28	.783	5.09
Slope change			0.05	0.08	0.65	.520	4.28			0.12	0.06	2.08	.048	0.61
Females	2.11	.761						2.11	.740					
Intercept			3.45	0.91	3.79	.001				3.68	0.68	5.39	< .001	
Slope			-0.04	0.16	-0.23	.822	5.16			-0.10	0.08	-0.27	.218	2.38
Level change			-0.93	1.07	-0.87	.391	3.61			0.36	0.95	0.38	.707	4.92
Slope change			0.12	0.17	0.70	.489	4.14			0.20	0.12	1.65	.111	1.35
Proportion of CUD +ve														
Males	2.29	.866						2.32	.799					
Intercept			0.22	0.23	0.93	.361				0.39	0.17	2.21	.037	
Slope			0.01	0.04	0.23	.819	5.15			-0.03	0.02	-1.54	.138	1.63
Level change			-0.29	0.27	-1.06	.298	3.01			0.24	0.24	0.98	.337	3.28
Slope change			-0.01	0.04	-0.13	.901	5.25			0.02	0.03	0.69	.500	4.18
Females [b]	2.29	.881						2.36	.734					
Intercept			0.14	0.40	0.34	.737				0.18	0.30	0.59	.558	
Slope			-0.05	0.07	-0.69	.497	4.10			-0.06	0.03	-1.81	.083	1.01
Level change			-0.35	0.48	-0.73	.476	4.00			0.24	0.42	0.57	.572	4.41
Slope change			0.10	0.08	1.25	.224	2.38			0.12	0.06	2.17	.041	0.50

Readiness to quit													
Males [c]	2.90	.050						2.88	.057				
Intercept			7.71	0.41	18.89	< .001				7.75	0.30	25.55	< .001	
Slope			-0.09	0.07	-1.19	.245	2.60			-0.10	0.03	-2.96	.007	0.07
Level change			-0.29	0.48	-0.61	.549	4.40			0.53	0.42	1.24	.255	2.44
Slope change			0.09	0.08	1.14	.267	2.77			0.08	0.05	1.53	.140	1.65
Females	1.85	.310						1.86	.317				
Intercept			6.23	0.72	8.61	< .001				6.86	0.54	12.66	< .001	
Slope			0.19	0.13	1.46	.159	1.84			0.06	0.06	0.93	.362	3.43
Level change			-0.76	0.85	-0.90	.376	3.52			-1.08	0.75	-1.43	.166	1.90
Slope change			-0.20	0.14	-1.45	.161	1.86			0.02	0.10	0.25	.805	5.13

Note. DW = Durbin-Watson test; BF = Bayes Factor. [a] Since the Breuch-Pagan test for the OLS regression model failed for homoscedasticity, we present the results using WLS regression. [b] Since the proportion of CUD positive screened corresponding to time point 28 was an extreme outlier, the analyses were performed using the proportions of 1 to 27-time points. [c] Since the *p* value of the Durbin-Watson test was exactly .05, we also ran this analysis using Prais-Winsten regression. Results did not meaningfully differ across the two approaches, so here we present the results using OLS regression.

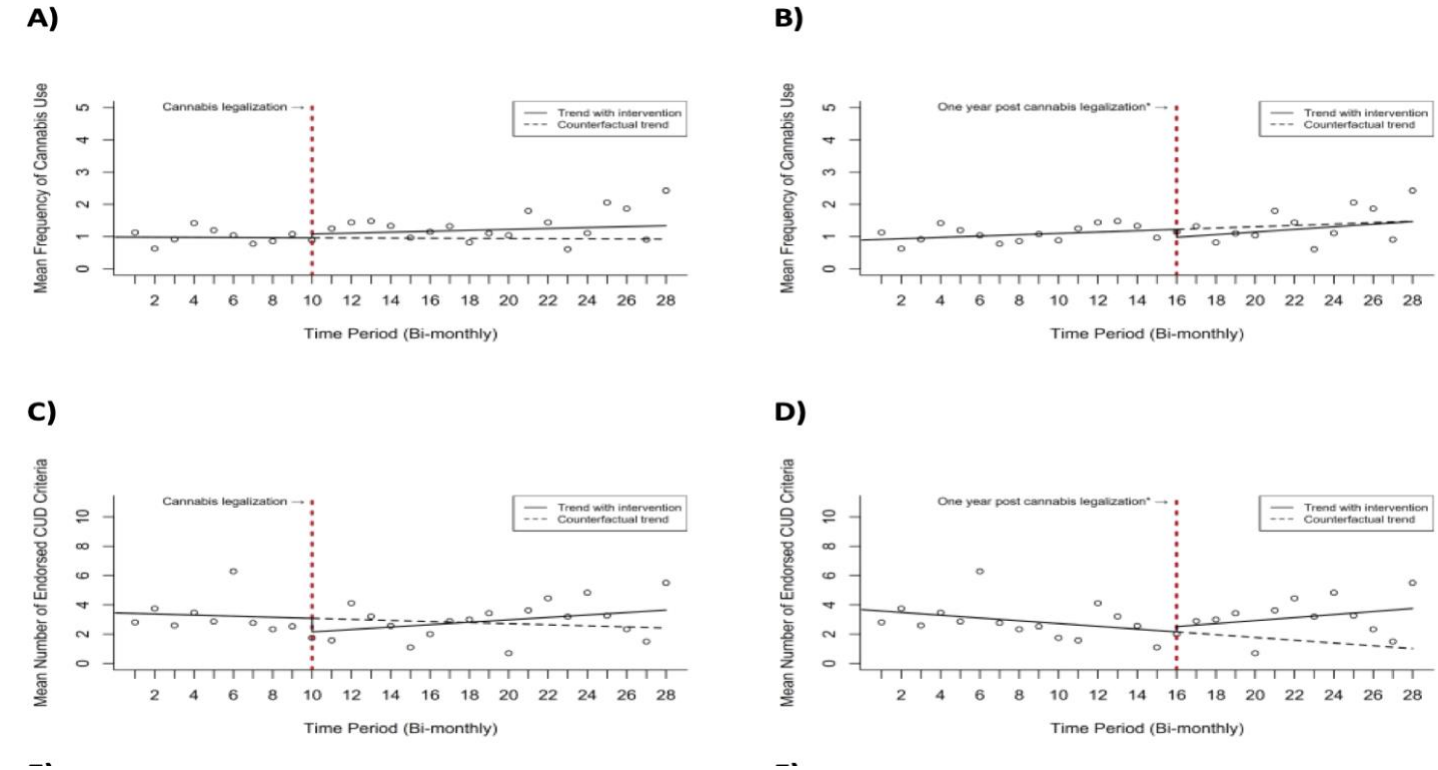
Figure 2. *Trends for Each Outcome With and Without Legalization Occurring Among Males*

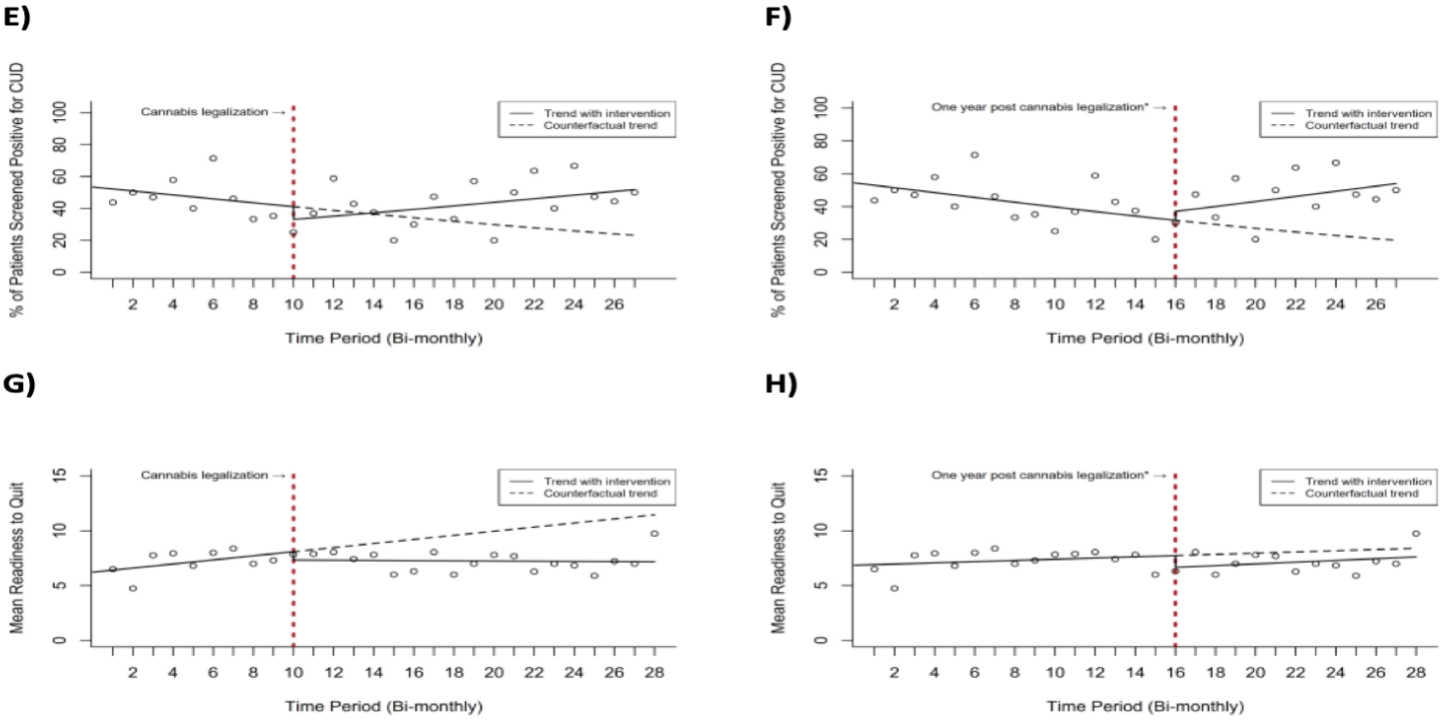




Note. *1-year lagged legalization break point coincides with the expanding commercialization of cannabis in Ontario including legalization of edibles, concentrates and topicals. Panel A-B: Frequency of cannabis use; Panel C-D: Severity of CUD symptoms; Panle E-F: Proportion of CUD +ve screened; Panel G-H: Readiness to quit using cannabis.

Figure 3. *Trends for Each Outcome With and Without Legalization Occurring Among Females*





Note. *1-yr lagged legalization break point coincides with the expanding commercialization of cannabis in Ontario including legalization of edibles, concentrates and topicals. Panel A-B: Frequency of cannabis use; Panel C-D: Severity of CUD symptoms; Panel E-F: Proportion of CUD +ve screened; Panel G-H: Readiness to quit using cannabis.

DISCUSSION

In contrast to research showing an increase in cannabis use following legalization in Canada among the general population (e.g., Athanassiou et al., 2023; Fischer et al., 2021; Hall et al., 2023; Turna et al., 2021), our current investigation suggests this may not be the case among individuals entering treatment for SUD. Indeed, we found no evidence to suggest legalization was associated with either immediate or gradual increases in the frequency of cannabis use post-cannabis or post-edibles legalization. These findings are consistent, however, with other work showing no change in cannabis use patterns following legalization in a sample of youth seeking substance use services (Hawke & Henderson, 2021) and a sample of patients treated for opioid use disorder (Rosic et al., 2021). Moreover, our findings are also consistent with research showing that increases in cannabis use, at least within a community sample, may be restricted to individuals who did not use cannabis prior to legalization (Turna et al., 2021). Together, these results suggest that the changes associated with legalization (e.g., increased access to and awareness of cannabis) may have less of an impact on subpopulations who were already using cannabis at elevated rates prior to legalization, such as individuals with SUD.

While there was no evidence of an overall increase in cannabis use, there was evidence of an increase in CUD symptom severity post-edibles legalization among the subsample who used cannabis; however, this did not translate into an increase in the proportion of individuals who screened positive for CUD. Notably, the increasing CUD severity trend only emerged using the edibles legalization date, one year after recreational cannabis legalization, as the intervention breakpoint, but not using the initial date of legalization. Although the policy change took effect across Canada on October 17, 2018, legalization was not necessarily a discrete event, but rather an unfolding process with substantial variability across different provincial and territorial jurisdictions (Myran et al., 2019; Myran, Staykov, et al., 2022). In Ontario, access to legal cannabis remained quite limited in the

first year following legalization and was largely restricted to online sales. Thus, this trend of increasing CUD symptom severity post-edibles legalization may be due in part to the availability of more potent cannabis products, as well as to the expanding commercial landscape more broadly. Our findings are consistent with other research showing that increases in cannabis-related harms tend to coincide more with cannabis commercialization, rather than legalization with strict retail controls (Kim et al., 2023; Myran, Pugliese, et al., 2022). This suggests that greater access and availability of cannabis products is likely contributing to harmful effects, rather than the policy change itself. Additionally, a clinical implication of our findings is the need to adapt programs and services to address increasing CUD severity over time.

Among the subsample of patients who used cannabis, we found no evidence that legalization was associated with any changes in readiness to quit. However, there was evidence of a global decrease in motivation to quit over the entire study period, independent of legalization. Research has demonstrated reduced perceptions of the harmfulness of cannabis use over time (Hasin & Walsh, 2021), and these shifting perceptions may make people less motivated to change their behaviour. Furthermore, this decrease in motivation to reduce cannabis use may reflect changes in attitudes and increased social acceptance that were occurring even before the actual policy change took effect.

Finally, we found some evidence of sex differences in terms of trends in CUD severity, the proportion of those who screened positive for CUD, and readiness to quit using cannabis. Results indicated a trend of increasing CUD severity post-edibles legalization for males, mirroring the results of the total sample; however, this trend was not significant for females. Examination of the pattern of results shows that these trends were similar for both males and females, but the comparatively small sample of females likely made it difficult to detect an effect. As a result, we are hesitant to conclude that these results reflect any kind of meaningful sex difference in the impacts of legalization on CUD severity. We also found marginal evidence of an increase in the proportion of females who screened positive for CUD following post-edibles legalization. With respect to readiness to quit, there was a significant overall decrease for males, like the total sample, but not for females. The female trend over time, while nonsignificant, was in the opposite direction, which suggests that this may reflect a true sex difference as opposed to simply a lack of statistical power.

Strengths and Limitations

This investigation included several strengths, including applying an ITS design with existing clinical data to study a natural experiment, a moderate sample size and time frame, and the examination of multiple outcomes. However, its limitations require consideration. First, the modest number of bi-monthly data points pre- and post- legalization meant the studies could likely only detect relatively large effects (Bernal et al., 2017). Therefore, it is important to stress, the absence of observing any early effects of legalization on the cannabis use outcomes understudy does not preclude the potential presence of longer-term effects that should be the focus of ongoing study. In addition, the sample sizes for the stratified analyses were relatively small, particularly for the female subgroup. As a result, analyses with the female subgroup may have been underpowered, contributing to the null findings. Second, the reference period for reporting cannabis use and CUD symptom severity changed from the past year to the past 90 days during the pre-legalization period and may have introduced variability in the responses that cannot be fully attributable to the legalization breakpoints. That said, we expect both reference periods are susceptible to the same recency bias, in that respondents are likely to rely heavily on recent events or behaviours to answer the questions. In this case, we would expect responses to be similar regardless of the reference period. In fact, our supplementary, segmented regression analyses indicated that there was no change in either of the outcomes following the change in reference period. Although we cannot be sure the change in reference period did not affect the results, our supplementary results provide some reassurance. Although time consuming, future research should employ a timeline follow back method (Sobell & Sobell, 1992), when feasible, to limit recency bias concerns. Third, there were differences in the demographic and substance use characteristics of participants who entered the

treatment program pre- and post-legalization, which also could have contributed to the null effects. Finally, the study analyzed trends in a single clinical setting that is similar to many others, but whether these results are provincially or nationally generalizable is an open question.

Conclusion

This study provides evidence that legalization has not (yet) affected the frequency of cannabis use, the proportion of those who screen positive for CUD or readiness to change cannabis use within a sample of individuals entering treatment for SUD. There was, however, evidence of increasing severity of CUD symptoms post-edibles legalization among those who used cannabis, coinciding with increased commercialization. These early findings point to some potentially important changes that may only continue with time. Thus, it will be important to continue to monitor trends in cannabis use, CUD severity and readiness to quit cannabis within this clinical population.

.

REFERENCES

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (5th ed.)*. American Psychiatric Publishing Inc. https://doi/book/10.1176/appi.books.9780890425596

Athanassiou, M., Dumais, A., Zouaoui, I., & Potvin, S. (2023). The clouded debate: A systematic review of comparative longitudinal studies examining the impact of recreational cannabis legalization on key public health outcomes. *Frontiers in Psychiatry*, *13,* 1060656. https://doi.org/10.3389/fpsyt.2022.1060656

Bernal, J. L., Cummins, S., & Gasparrini, A. (2017). Interrupted time series regression for the evaluation of public health interventions: A tutorial. *International Journal of Epidemiology*, *46*(1), 348–355. https://doi.org/10.1093/ije/dyw098

Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica*, 47(5), 1287–1294. https://doi.org/10.2307/1911963

Calakos, K. C., Bhatt, S., Foster, D. W., & Cosgrove, K. P. (2017). Mechanisms underlying sex differences in cannabis use. *Current Addiction Reports*, *4*(4), 439–453. https://doi.org/10.1007/s40429-017-0174-7

Cannabis Act, S.C. 2018, c. 16 (2018). https://laws-lois.justice.gc.ca/eng/acts/C-24.5/

Chung, T., Maisto, S. A., Mihalo, A., Martin, C. S., Cornelius, J. R., & Clark, D. B. (2011). Brief assessment of readiness to change tobacco use in treated youth. *Journal of Substance Abuse Treatment*, *41*(2), 137–147. https://doi.org/10.1016/j.jsat.2011.02.010

Cuttler, C., Mischley, L. K., & Sexton, M. (2016). Sex differences in cannabis use and effects: A cross-sectional survey of cannabis users. *Cannabis and Cannabinoid Research*, *1*(1), 166–175. https://doi.org/10.1089/can.2016.0010

Dienes, Z. (2016). How Bayes factors change scientific practice. *Journal of Mathematical Psychology*, *72*, 78–89. https://doi.org/10.1016/j.jmp.2015.10.003

Durbin, J., & Watson, G. S. (1992). Testing for serial correlation in least squares regression. I. In S. Kotz & N. L. Johnson (Eds.), *Breakthroughs in Statistics: Methodology and Distribution* (pp. 237–259). Springer. https://doi.org/10.1007/978-1-4612-4380-9_20

Fischer, B., Lee, A., Robinson, T., & Hall, W. (2021). An overview of select cannabis use and supply indicators pre- and post-legalization in Canada. *Substance Abuse Treatment, Prevention, and Policy*, *16*(1), 77. https://doi.org/10.1186/s13011-021-00405-7

Government of Canada. (2022, October 20). *Taking stock of progress: Cannabis legalization and regulation in Canada*. https://www.canada.ca/content/dam/hc-sc/documents/programs/engaging-cannabis-legalization-regulation-canada-taking-stock-progress/document/pdf-lr-engagement-paper-en.pdf

Hajizadeh, M. (2016). Legalizing and regulating marijuana in Canada: Review of potential economic, social, and health impacts. *International Journal of Health Policy and Management*, *5*(8), 453–456. https://doi.org/10.15171/ijhpm.2016.63

Hall, W., Stjepanović, D., Dawson, D., & Leung, J. (2023). The implementation and public health impacts of cannabis legalization in Canada: A

systematic review. *Addiction*, 1–11. https://doi.org/10.1111/add.16274

Hango, D., & LaRochelle-Côté, S. (2018). Association between the frequency of cannabis use and selected social indicators. In *Insights on Canadian Society*. Statistics Canada. https://books-scholarsportal-info.proxy.lib.uwaterloo.ca/en/read?id=/ebooks/ebooks0/gibson_cppc/2015-08-25/1/11070475

Hasin, D. S., O'Brien, C. P., Auriacombe, M., Borges, G., Bucholz, K., Budney, A., Compton, W. M., Crowley, T., Ling, W., Petry, N. M., Schuckit, M., & Grant, B. F. (2013). DSM-5 criteria for substance use disorders: Recommendations and rationale. *American Journal of Psychiatry*, *170*(8), 834–851. https://doi.org/10.1176/appi.ajp.2013.12060782

Hasin, D., & Walsh, C. (2021). Cannabis use, cannabis use disorder, and comorbid psychiatric illness: A narrative review. *Journal of Clinical Medicine*, *10*(1), Article 1. https://doi.org/10.3390/jcm10010015

Hawke, L. D., & Henderson, J. (2021). Legalization of cannabis use in Canada: Impacts on the cannabis use profiles of youth seeking services for substance use. *Journal of Substance Abuse Treatment*, *126*, 108340. https://doi.org/10.1016/j.jsat.2021.108340

Health Canada. (2024, January 12). *Canadian Cannabis Survey 2023: Summary* [Surveys]. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/research-data/canadian-cannabis-survey-2023-summary.html

Kim, C., Chum, A., Nielsen, A., MacMaster, F., Rittenbach, K., Allin, S., O'Campo, P., Kirst, M., & Hamilton, H. (2023). Cannabis legalization and cannabis-related hospitalizations in Ontario, Canada. *The Canadian Journal of Psychiatry*, *68*(1), 67–70. https://doi.org/10.1177/07067437221114785

Levitt, E. E., Syan, S. K., Sousa, S., Costello, M. J., Rush, B., Samokhvalov, A. V., McCabe, R. E., Kelly, J., & MacKillop, J. (2021). Optimizing screening for depression, anxiety disorders, and post-traumatic stress disorder in inpatient addiction treatment: A preliminary investigation. *Addictive Behaviors*, *112*, 106649. https://doi.org/10.1016/j.addbeh.2020.106649

Lev-Ran, S., Le Foll, B., McKenzie, K., George, T. P., & Rehm, J. (2013). Cannabis use and cannabis use disorders among individuals with mental illness. *Comprehensive Psychiatry*, *54*(6), 589-598. https://doi.org/10.1016/j.comppsych.2012.12.021

Lev-Ran, S., Le Strat, Y., Imtiaz, S., Rehm, J., & Le Foll, B. (2013). Gender differences in prevalence of substance use disorders among individuals with lifetime exposure to substances: Results from a large representative sample. *The American Journal on Addictions*, *22*(1), 7–13. https://doi.org/10.1111/j.1521-0391.2013.00321.x

Maisto, S. A., Krenek, M., Chung, T., Martin, C. S., Clark, D., & Cornelius, J. (2011). A comparison of the concurrent and predictive validity of three measures of readiness to change alcohol use in a clinical sample of adolescents. *Psychological Assessment*, *23*, 983–994. https://doi.org/10.1037/a0024136

Myran, D. T., Brown, C. R. L., & Tanuseputro, P. (2019). Access to cannabis retail stores across Canada 6 months following legalization: A descriptive study. *CMAJ Open*, *7*(3), E454–E461. https://10.9778/cmajo.20190012

Myran, D. T., Pugliese, M., Tanuseputro, P., Cantor, N., Rhodes, E., & Taljaard, M. (2022). The association between recreational cannabis legalization, commercialization and cannabis-attributable emergency department visits in Ontario, Canada: An interrupted time-series analysis. *Addiction (Abingdon, England)*, *117*(7), 1952–1960. https://doi.org/10.1111/add.15834

Myran, D. T., Staykov, E., Cantor, N., Taljaard, M., Quach, B. I., Hawken, S., & Tanuseputro, P. (2022). How has access to legal cannabis changed over time? An analysis of the cannabis retail market in Canada 2 years following the legalisation of recreational cannabis. *Drug and Alcohol Review*, *41*(2), 377–385. https://doi.org/10.1111/dar.13351

National Institute on Drug Abuse. (2012). *Resource guide: Screening for drug use in general medical settings*. https://nida.nih.gov/sites/default/files/pdf/nmassist.pdf

Nigatu, Y. T., Elton-Marshall, T., Adlaf, E. M., Ialomiteanu, A. R., Mann, R. E., & Hamilton,

H. A. (2020). *CAMH Monitor e-Report: Substance use, mental health and well-being among ontario adults, 1977–2019*. Centre for Addiction and Mental Health. http://www.camh.ca/camh-monitor

Ollech, D. (2021). *seastests: Seasonality tests*. R package version 0.15.4, https://CRAN.R-project.org/package=seastests

Ollech, D., and Webel, K. (2020). *A random forest-based approach to identifying the most informative seasonality tests*. Deutsche Bundesbank discussion paper no. 55/2020. http://dx.doi.org/10.2139/ssrn.3721055

Owram, K. (2019, April 01). Ontario's first pot shops open their doors today, but the actual number ready is pretty underwhelming. *Financial Post*. https://financialpost.com/cannabis/an-underwhelming-pot-shop-rollout-for-ontario-cannabis-weekly

Prais, S. J., & Winsten, C. B. (1954). *Trend estimators and serial correlation*. Cowles Commission discussion paper Chicago.

R Core Team. (2024). *R: A language and environment for statistical computing* [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Rosic, T., Sanger, N., Panesar, B., Foster, G., Marsh, D. C., Rieb, L., Thabane, L., Worster, A., & Samaan, Z. (2021). Cannabis use in patients treated for opioid use disorder pre- and post-recreational cannabis legalization in Canada. *Substance Abuse Treatment, Prevention, and Policy*, *16*(1), 34. https://doi.org/10.1186/s13011-021-00372-z

Secades-Villa, R., Garcia-Rodríguez, O., Jin, C. J., Wang, S., & Blanco, C. (2015). Probability and predictors of the cannabis gateway effect: A national study. *International Journal of Drug Policy*, *26*(2), 135–142. https://doi.org/10.1016/j.drugpo.2014.07.011

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*(3-4), 591–611. https://doi.org/10.1093/biomet/52.3-4.591

Sobell, L. C., & Sobell, M. B. (1992). Timeline follow-back: A technique for assessing self-reported alcohol consumption. In R. Z. Litten & J. P. Allen (Eds.), *Measuring alcohol consumption: Psychosocial and biochemical methods* (pp. 41–72). https://doi.org/10.1007/978-1-4612-0357-5_3

Subbaraman, M. S., & Kerr, W. C. (2015). Simultaneous versus concurrent use of alcohol and cannabis in the National Alcohol Survey. *Alcohol: Clinical and Experimental Research*, *39*(5), 872–879. https://doi.org/10.1111/acer.12698

Svrakic, D. M., Lustman, P. J., Mallya, A., Lynn, T. A., Finney, R., & Svrakic, N. M. (2012). Legalization, decriminalization and medicinal use of cannabis: A scientific and public health perspective. *Missouri Medicine*, *109*(2), 90–98.

Turna, J., Belisario, K., Balodis, I., Van Ameringen, M., Busse, J., & MacKillop, J. (2021). Cannabis use and misuse in the year following recreational cannabis legalization in Canada: A longitudinal observational cohort study of community adults in Ontario. *Drug and Alcohol Dependence*, *225*, 108781. https://doi.org/10.1016/j.drugalcdep.2021.108781

Walker, M., Carpino, M., Lightfoot, D., Rossi, E., Tang, M., Mann, R., Saarela, O., & Cusimano, M. D. (2023). The effect of recreational cannabis legalization and commercialization on substance use, mental health, and injury: A systematic review. *Public Health*, *221*, 87–96. https://doi.org/10.1016/j.puhe.2023.06.012

Windle, S. B., Wade, K., Filion, K. B., Kimmelman, J., Thombs, B. D., & Eisenberg, M. J. (2019). Potential harms from legalization of recreational cannabis use in Canada. *Canadian Journal of Public Health*, *110*(2), 222–226. https://doi.org/10.17269/s41997-018-00173-1

Wittchen, H.-U., Fröhlich, C., Behrendt, S., Günther, A., Rehm, J., Zimmermann, P., Lieb, R., & Perkonigg, A. (2007). Cannabis use and cannabis use disorders and their relationship to mental disorders: A 10-year prospective-longitudinal community study in adolescents. *Drug and Alcohol Dependence*, *88*, S60–S70. https://doi.org/10.1016/j.drugalcdep.2006.12.013

Xiao, H., Augusto, O., & Wagenaar, B. H. (2021). Reflection on modern methods: A common error in the segmented regression parameterization of interrupted time-series analyses. *International Journal of Epidemiology*, *50*(3), 1011–1015. https://doi.org/10.1093/ije/dyaa148

Funding and Acknowledgements: This research was funded in part by the Canadian Centre on Substance Use and Addiction (CCSA) using funds provided by Health Canada in support of cannabis research. The views expressed herein do not necessarily represent the views of CCSA or its funders. JM's contributions were partially supported by the Peter Boris Chair for Addictions Research. Homewood Research Institute (HRI) is an independent charitable organization funded through a variety of sources including Homewood Health, community stakeholders, corporations, and private foundations. Homewood Health provides unrestricted charitable donations to HRI. JM is a senior scientist and principal in BEAM Diagnostics, Inc. and a consultant to Clairvoyant Therapeutics, Inc. The authors declare no competing interests.