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Evaluating the impact of Canadian cannabis legalization on cannabis use outcomes in emerging adults: Comparisons to a US control sample via a natural experiment

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ABSTRACT

Background: Recreational cannabis legalization marked a significant policy shift in Canada, but has been difficult to evaluate because of the absence of a control group. Although it is unfeasible to evaluate legalization using a randomized controlled trial design, sophisticated statistical techniques can employ quasi-experimental designs using natural experiments. This study evaluates the impact of cannabis legalization in a longitudinal cohort of Canadian emerging adults by comparing changes in cannabis use frequency and related consequences over time to changes in a similar cohort in a United States jurisdiction where no policy change took place.

Methods: Two samples of emerging adults from Hamilton, Ontario, and Memphis, Tennessee, were followed longitudinally in 4-month intervals from March 16, 2018 to March 11, 2020, with three pre-legalization and four post-legalization assessments. Doubly robust difference-in-difference (DiD) estimation was used to assess whether cannabis legalization impacted cannabis use frequency or cannabis-related consequences in the Canadian sample over time. The impact of cannabis legalization on alcohol use and alcohol-related consequences was also assessed as a control form of substance use for which no policy change took place. Cohort differences were adjusted within DiD estimation using propensity score balancing.

Results: Against a general trend of decreasing use over time, the DiD estimation revealed significantly greater cannabis use frequency approximately 6-months post legalization (ATT (95% CI): 0.2245 (0.0154, 0.4336)) and approximately one year post legalization (ATT (95% CI):0.3091 (0.0473, 0.5709)) in the Canadian sample compared to the American sample. Cannabis-related consequences were also greater in the Canadian sample at both of these time points (ATT (95% CI): 0.0.7610 (0.0797, 1.4423)), (ATT (95% CI): 1.0396 (0.1864, 1.8928)). These higher levels reflected less steep declines over time (i.e., attenuated 'aging out'). Alcohol changes showed no impact of legalization at any time point, as expected.

Conclusions: Findings suggest that cannabis legalization was associated with smaller reductions in cannabis use frequency and adverse consequences than expected in the Canadian sample compared to the American control sample. Although the magnitude of these impacts was small, these findings suggest the start of diverging cannabis trajectories. Given that effects of legalization are hypothesized to be long-term rather than immediate, further monitoring of the impacts of cannabis legalization on developmental trends in cannabis use and related consequences is warranted.

Introduction

Recreational cannabis legalization in Canada in October 2018 represented a substantial change in Canadian drug policy. The aims of legalization were to protect public health and safety, disrupt the criminal cannabis market, and restrict youth access to cannabis (Government

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of Canada, 2021). However, inherent increases in access and normalization of cannabis that follow legalization raise concern about increasing population-level patterns of use. As such, a key priority with such a policy change is continuous population surveillance of cannabis-related behaviours. A primary indicator of interest is frequency of cannabis use, as high-frequency use is of significant concern for numerous public health reasons, including potential impacts on physical and mental health (Lubman et al., 2015; Volkow et al., 2016) and risk for development of cannabis use disorder (Gunn et al., 2020)

A limitation to Canada's implementation of cannabis legalization is the lack of robust data on population-level cannabis use patterns that can be leveraged to evaluate potential impacts the policy may have over time. Previous research examining the impacts of Canadian cannabis legalization among adults has yielded mixed findings, with some literature suggesting increases in cannabis use, while others find no significant changes (Imtiaz et al., 2023a; Rotermann, 2021a; Rubin-Kahana et al., 2022a); however, most studies have been cross-sectional in nature. In fact, a 2023 systematic review of studies which evaluated recreational cannabis legalization policies included 32 US-based studies, but no Canadian studies met methodological inclusion criteria for robust evaluation of cannabis legalization, namely to have longitudinal data and to include a comparison group (Athanassiou et al., 2023a). The Government of Canada implemented cannabis-focused surveys aimed at monitoring cannabis use behaviours in the population in 2017, including the Canadian Cannabis Survey and the National Cannabis Survey (Government of Canada, 2024a; Statistics Canada, 2024), but both surveys are repeat cross-sectional in nature. Although these surveys report increases in cannabis use frequency since legalization (Government of Canada, 2024b; Rotermann, 2021b), the cross-sectional nature of these data make it challenging to attribute these shifts to the policy change specifically.

In a previous study, the current authors found that Canadian legalization did not appear to increase cannabis use frequency or related consequences among a sample of high-risk emerging adults (Doggett et al., 2023). Emerging adults are a priority subgroup to examine impacts of legalization because they tend to have the greatest prevalence of substance use compared to other age groups, including cannabis use (Government of Canada, 2024a) and are also particularly vulnerable to cannabis-related harms due to the combination of higher frequency use with their developmental life stage (Hall et al., 2020). Emerging adults also have relatively predictable patterns of substance use in that they tend to reduce or "age-out" of use as they get older (Cristiano & Sharif-Razi, 2019a; Tucker et al., 2021). While our previous research found that legalization did not prevent this aging-out process, we were unable to assess whether legalization may have otherwise affected it (e.g., stunted or delayed it). As such, to extend findings of previous work, the purpose of the present study was to evaluate the impact of cannabis legalization by comparing changes in cannabis use frequency and related consequences in the Canadian sample to a similar cohort during the same time period from a jurisdiction in the United States where recreational cannabis was neither legalized nor decriminalized. This type of natural experiment design, which leverages longitudinal data and a counterfactual comparator has been highlighted as a key priority for the evaluation of policy changes (Craig et al., 2012), including specifically for cannabis legalization (Athanassiou et al., 2023b), but, to our knowledge, no existing study has evaluated Canadian cannabis legalization using this approach.

Methods

Design and participants

This study used data from two co-existing longitudinal studies on substance use behaviours among emerging adults in Hamilton, Ontario, Canada and Memphis, Tennessee, United States. Federal legalization of cannabis for recreational purposes in Canada occurred on October 17th, 2018, while no such federal or state policies surrounding cannabis changed in Memphis, which serves as the control sample in this study. Data collection time points were organized into 4-month periods to surround Canadian legalization (with a longer baseline period due to rolling enrollment). Since reporting of cannabis use was past-month retrospective, post-legalization was defined as any time on or past November 17, 2018. This includes three pre-legalization time points (April 17, 2017 – March 16, 2018; March 17, 2018 – July 16, 2018, July 17, 2018 – Nov 16, 2018) and four post-legalization time points (Nov 17, 2018 – March 16, 2019; March 17, 2019 – July 16, 2019; July 17, 2019 – Nov 16, 2019; Nov 17, 2019 – March 11, 2020).

Enrollment criteria for the Hamilton sample was 19.5–23 years of age (i.e., at least 6 months older than legal drinking age in this jurisdiction), 2 or more instances of heavy episodic drinking (HED) in the past month or 1 or more instances of HED plus concurrent cannabis use at least weekly (reflecting risky substance use in general), fluency in written English, and absence of current or past psychosis. Age and substance use criteria for the Memphis sample differed slightly, due to a higher legal age of drinking; participants were required to be 21.5–24.9 years of age at enrollment (i.e., similar to the Canadian sample, a minimum of 6 months older than the legal drinking age) and needed to report 2 or more past-month instances of HED (with no alternate cannabis criteria, as this study was not originally designed with the intention of evaluating cannabis legalization). Substance use inclusion criteria was designed to recruit a higher-risk subsample of emerging adults already engaged in substance use. It is hypothesized that observable shifts in substance use behaviours caused by legalization would be most detectable in this sample given the higher-risk profiles (and high-prevalence of co-occurring substance use behaviours (Government of Canada, 2023) as well as greater substance use rates among the emerging adult age cohort in general (Government of Canada, 2023). Informed consent was attained for participation, and both studies received ethical approval from their respective review boards (Hamilton project #2193, Memphis project #4320).

Participants were excluded if they did not have at least 1 pre- and post-legalization data collection wave, with the post-legalization wave occurring on or before March 11th 2020 (WHO declaration of the global SARS-COV-2 pandemic), with the goal to limit the potentially confounding impacts of the pandemic. In total, 1102 (94 %) participants met these requirements; 638 participants in Hamilton and 464 participants in Memphis.

Difference-in-difference methodology

This study leverages difference-in-difference (DiD) methodology to examine how within-individual cannabis trajectories may have been impacted by cannabis legalization through comparison to a US control group where cannabis was not legalized. DiD is an approach used to estimate causal effects of an intervention or treatment in situations where there are available counterfactual data for those who were not exposed to the intervention or treatment of interest (Wing et al., 2018). In practice, this approach is a way to evaluate the effect of an intervention when the gold-standard randomized controlled trial (RCT) approach is not feasible, and DiD is especially useful to evaluate natural experiments. While much of the DiD literature uses "treated" and "control" to describe groups mimicking RCT terminology, it is notable that cannabis legalization is better defined as an exposure (to the policy change) rather than a treatment, so terminology throughout the remainder of this section is adjusted appropriately.

For illustrative purposes, this section provides an explanation of DiD for the conventional case of one exposed group, two time periods, and no covariate conditioning. In practice, the utility of DiD can, and often is, expanded to allow for multiple exposure groups, multiple time periods, or conditioning on observed covariates to account for inherent differences between exposed and unexposed samples. Readers interested in a fulsome explanation of expanded DiD approaches, including those

leveraged in this study, are directed to Callaway and Sant'Anna (2021).

In the foundational two-group, two-time point design of DiD, the expected difference between post-intervention and pre-intervention outcomes in the exposed group is given by:

$$E[Y_t - Y_{t-1}|D = 1]$$

Where Y_t is the mean outcome post-exposure, Y_{t-1} is the mean outcome pre-exposure, and $D = 1$ indicates exposure. Similarly, the expected difference in the non-exposed group ($D = 0$) is given by:

$$E[Y_t - Y_{t-1}|D = 0]$$

Taking the difference between the above terms (which are themselves differences, hence the method name "difference-in-difference") yields the main parameter of interest for this approach, the average treatment (exposure) effect on the treated (exposed) (ATT):

$$ATT = E[Y_t - Y_{t-1}|D = 1] - E[Y_t - Y_{t-1}|D = 0]$$

If the exposure has no differential effect on the exposed group (compared to the non-exposed control), the ATT is expected to be not significantly different from zero. A significantly positive ATT indicates greater outcome values in the exposed group post-exposure (compared to the unexposed), while a significantly negative ATT would indicate lesser outcome values in the exposed group post-exposure (compared to the unexposed).

The conclusion that a significant ATT is caused by the exposure of interest hinges on the parallel trends assumption, which posits that the expected outcomes of the exposed group had they not been exposed (an unobserved counterfactual) is equal to the observed outcomes in the unexposed group. Where $Y_t(0)$ represents untreated outcomes in either the exposed or unexposed group this assumption is given by:

$$E[Y_t(0) - Y_{t-1}(0)|D = 1] = E[Y_t(0) - Y_{t-1}(0)|D = 0]$$

Based on this assumption, if the exposed group trend diverges from the non-exposed trend, the exposure of interest is said to have had an effect on those exposed.

Measures

Outcomes

Cannabis use was assessed using the Alcohol, Smoking, Substance Involvement Screening Test (ASSIST), where frequency of use is reported as: "none," "monthly," "weekly," "daily," or "multiple times daily" (WHO ASSIST Working Group, 2002). Experiences of cannabis-related consequences was measured using the Brief Marijuana Consequences Questionnaire (B-MACQ), which is a 21-item summed inventory of problems experienced as a result of recent (past 4 months) cannabis use (Simons et al., 2012). For the purpose of counterfactual comparison to alcohol, average drinks per week was assessed through the Daily Drinking Questionnaire (DDQ) (Collins et al., 1985), and alcohol-related consequences was assessed through the 24-item brief young adult alcohol consequences questionnaire (B-YAACQ) (Kahler et al., 2008).

Conditioning covariates

Several conditioning variables at baseline were included to account for statistically significant differences between the samples, including those present due to sampling differences (described in Section 1.1), and are presented in Table 1. Conditioning variables included age, race (White; Black; Other), sex assigned at birth (female, male), subjective income level (not enough, enough but need to cut back, enough but no extras, enough for extras) (Najdzionek et al., 2023), education (≥ Bachelors degree, < Bachelors degree), cannabis use frequency, and average drinks per week.

Table 1
Unadjusted Demographic Characteristics of Hamilton and Memphis Samples at Baseline.

	Hamilton $N = 638$	Memphis $N = 464$	Significance
Age, mean (SD)	21.44 (1.18)	22.6 (1.01)	<0.001
Sex assigned at birth, n (%)			
Female	353 (55.3 %)	282 (60.8 %)	0.081
Male	285 (44.7 %)	182 (39.2 %)	
Ethnicity, n (%)			
White	442 (69.3 %)	214 (46.1 %)	<0.001
Black	12 (1.9 %)	183 (39.4 %)	
Other	184 (28.8 %)	67 (14.4 %)	
Education, n (%)			
≥ Bachelors degree	443 (69.4 %)	315 (67.9 %)	0.630
< Bachelors degree	193 (30.3 %)	149 (27.8 %)	
Subjective income, n (%)			
Not enough for bills (despite cutting back)	24 (3.8 %)	27 (5.8 %)	0.031
Enough for bills (had to cut back)	140 (21.9 %)	146 (31.5 %)	
Enough for bills (no extras)	219 (34.3 %)	136 (29.3 %)	
Enough for extras	255 (40.0 %)	155 (33.34 %)	
Drinks per week, Mean (SD)	12.65 (10.39)	17.3 (15.18)	<0.001
B-YAACQ[1] Score (24 item), Mean (SD)	6.20 (4.16)	6.49 (4.64)	0.193
Cannabis frequency by categories, n (%)			
No Use	247 (38.7 %)	221 (47.6 %)	<0.001
Monthly Use	204 (32.0 %)	95 (20.5 %)	
Weekly Use	101 (15.8 %)	63 (13.6 %)	
Daily Use	51 (8.0 %)	29 (6.3 %)	
Daily +	35 (5.5 %)	56 (12.1 %)	
B-MACQ[2] Score (21-item), Mean (SD)	4.05 (4.46)	4.37(4.10)	0.947

[1] Young Adult Alcohol Consequences Questionnaire (Brief).
[2] Marijuana Consequences Questionnaire (Brief).

Illustrating covariate balance

This study leverages doubly robust estimation integrated into the *did* package (described in detail in Sant'Anna and Zhao (2020a)), which derives ATTs using weights re-calculated at each time point, although estimated weights are not extractable. As such, to illustrate covariate balancing and demonstrate feasibility of balancing based on the chosen covariates, we externally calculated propensity score weights utilizing the *matchit* package. Improvements in standardized mean differences (SMDs) after adjustment are illustrated in Fig. 1. Samples are generally considered balanced if SMDs are less than 0.25 (Harder et al., 2010).

Analysis

This study extends the conventional dichotomous pre-post time comparisons described in Section 1.3 to compare multiple time periods (Callaway & Sant'Anna, 2021). While time periods could have been aggregated into single pre- and post-legalization measures, policy changes are generally hypothesized to have longer rather than shorter-term impacts on behaviour change. As such, it was important to assess not only if change was present, but also when change occurred relative to legalization. We assessed the potential impact of legalization on the Hamilton sample by calculating the ATT at each post-legalization time point, and leveraged an unbalanced panel design which allowed for

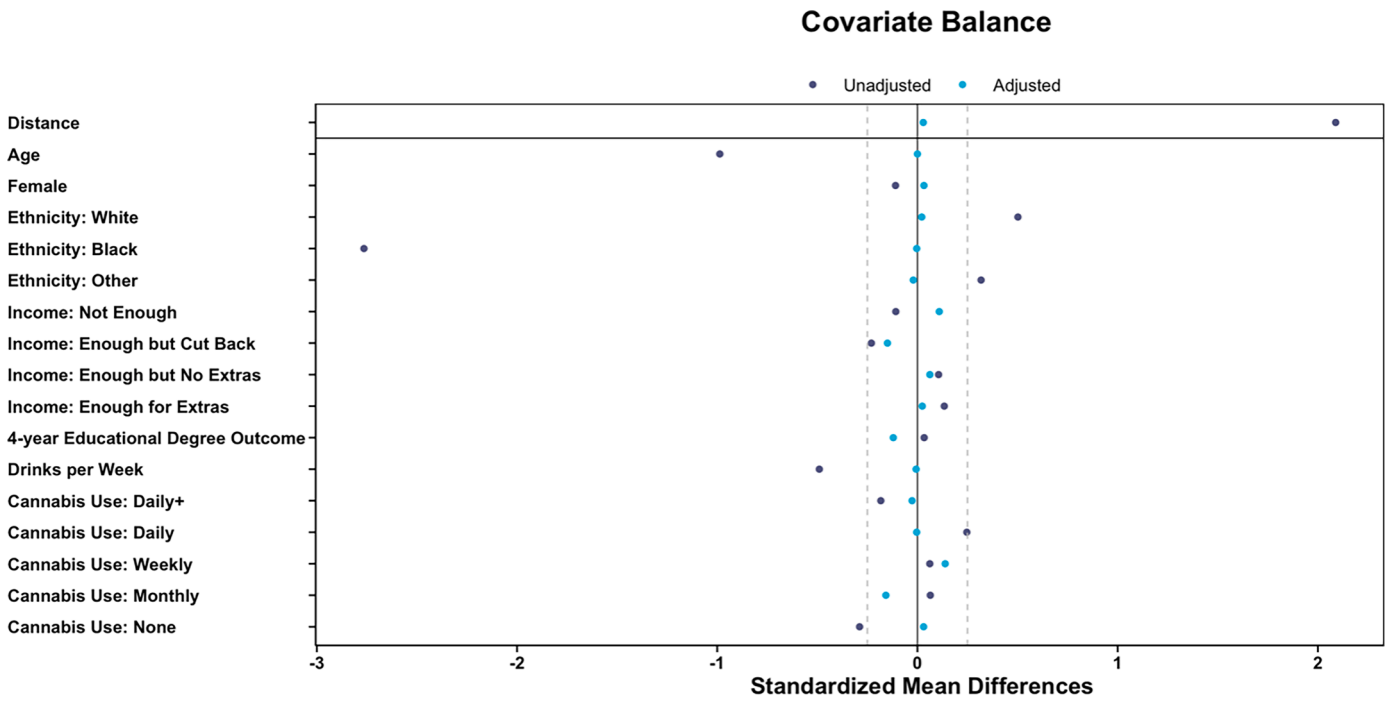

Fig. 1. Love Plot showing standardized mean differences between Hamilton and Memphis Samples by covariate before and after adjusting on propensity score. Dotted lines represent 0.25 and −0.25 SMD based on recommendations from Harder et al. (2010).

missingness to be present (participants needed to have at least 1 pre- and 1 post- time point).

An additional extension to the methods described in Section 1.3 was the conditioning on observed covariates. Although the parallel trends assumption had strong theoretical foundation in this study given that research has established clear aging-out type trends for substance use among emerging adults (Acuff et al., 2023; Bird et al., 2024; Cristiano & Sharif-Razi, 2019b), the demographic differences between the Hamilton and Memphis samples (presented in Table 1) necessitated balancing on these differences. Samples were balanced using built-in functionality of the *did* package (used for all analyses) to condition outcome likelihood at each time point (Callaway & Sant'Anna, 2022) based on all measures listed in Section 1.2.2. Wald $\chi 2$ testing re-affirmed the that the parallel assumptions held for all analyses in the pre-legalization period, after conditioning. Notably, propensity score balancing only adjusts for observed differences between the samples; confounding unobserved individual characteristics as well as confounding events in either jurisdiction may impact results of DiD.

The estimation approach used for analyses was doubly robust (Callaway & Sant'Anna, 2022; Sant'Anna & Zhao, 2020b). An additional analysis was performed to examine whether cannabis legalization may have shifted behaviours in advance of the policy change by setting an anticipation period of one time point; results of this analysis are available in Supplemental Materials.

Results

Descriptive unweighted trends in all outcomes in Hamilton and Memphis samples are presented in Fig. 2. ATTs are presented graphically in Fig. 3, for cannabis use frequency, cannabis-related consequences, and the two counterfactual alcohol use measures. As the exposure (cannabis legalization) in this study only occurred in Hamilton, ATTs can be interpreted as the impact of legalization in Hamilton in the units of the measured outcome. A non-significant ATT is indicative of no impact of cannabis legalization in the Hamilton sample (i.e., substance use behaviours in the post-legalization period were not significantly different between Hamilton and Memphis). A significant ATT post-legalization in the positive direction would indicate higher substance use-related outcomes in Hamilton compared to Memphis (and vice versa for a negative direction).

Fig. 3 presents ATT estimates and 95 % confidence intervals for each outcome. Neither alcohol measure (drinks per week and B-YAACQ score) revealed significant ATTs. However, DiD revealed a significantly greater cannabis use frequency post-legalization at time period 5 (March-July 2019) (ATT (95% CI): 0.2245 (0.0154, 0.4336)), and time period 7 (Nov 2019 – March 2020) (ATT (95% CI):0.3091 (0.0473, 0.5709)) for the Hamilton sample. DiD also indicated significantly greater B-MACQ scores at time period 5 (ATT (95% CI): 0.0.7610 (0.0797, 1.4423) and time period 7 (ATT (95% CI): 1.0396 (0.1864, 1.8928)) for the Hamilton sample. An additional analysis examining whether recreational cannabis legalization may have had an anticipation period (i.e., impacted behaviour in the time point immediately prior to the policy change) is available in Supplemental Materials. In this analysis, DiD demonstrated greater cannabis use frequency for the Hamilton sample only at post 6 (July-November 2019) (ATT (95% CI): 0.3087 (0.0653, 0.5521)), and no other time points or measures revealed significant differences.

Discussion

This is the first study evaluating the impacts of Canadian cannabis legalization using a natural experiment control group comparison, to our knowledge. Given the emerging adult samples of this study, it would be expected that substance use behaviours would on average decline over time, consistent with expected "aging out" trajectories among this age cohort (Cristiano & Sharif-Razi, 2019a). Descriptive trends illustrated that the Canadian sample's trajectories in cannabis use and related consequences appeared flatter compared to the steadily decreasing trends in the American control group. After controlling for sample differences and using difference-in-difference analyses to robustly examine the impacts of legalization, converging evidence revealed that cannabis use and related consequences were significantly greater in emerging adults in Canada compared to the US at two of the four post-legalization time points, suggesting modest but nonetheless

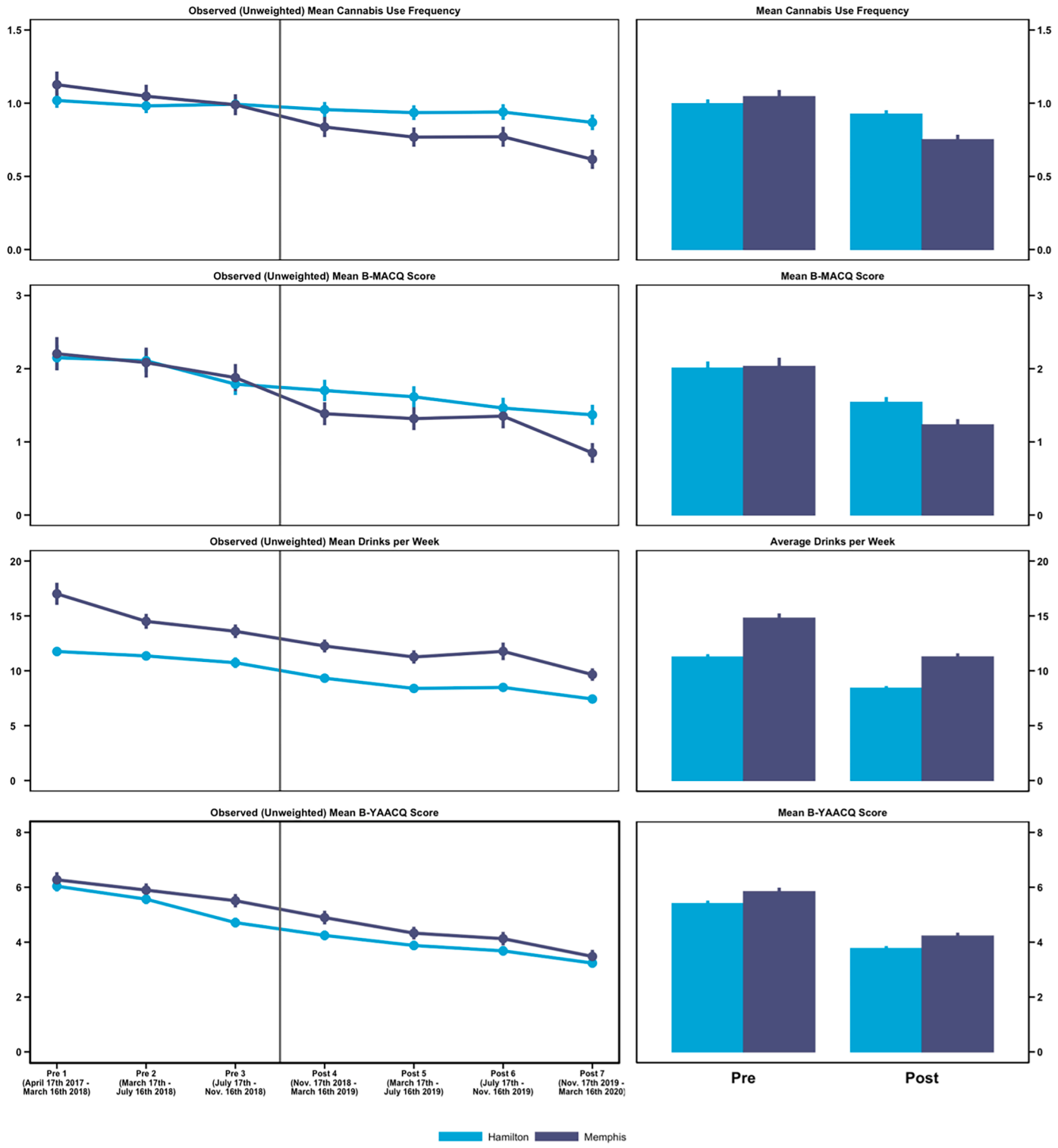

Fig. 2. Unadjusted trends of each outcome measure across time in Hamilton and Memphis Samples.
Grey line between Pre 3 and Post 4 marks the date of cannabis legalization.
Bar graphs show average values across pre and post time points.
Vertical lines represent standard error.

detectable impacts of legalization. Conversely, there were no observed impacts of cannabis legalization on the counterfactual alcohol-related measures.

As emerging adults age, they tend age-out of substance use behaviours (Cristiano & Sharif-Razi, 2019a; Tucker et al., 2021) and one of the benefits of leveraging a longitudinal sample is the ability to observe whether the aging out process has occurred, and at what rate. In previous work we examined whether cannabis legalization may have influenced the aging out process, but found that despite legalization, the Canadian sample of emerging adults still on average significantly reduced their cannabis use frequency and related consequences as they got older (Doggett et al., 2023). Although it was clear that legalization

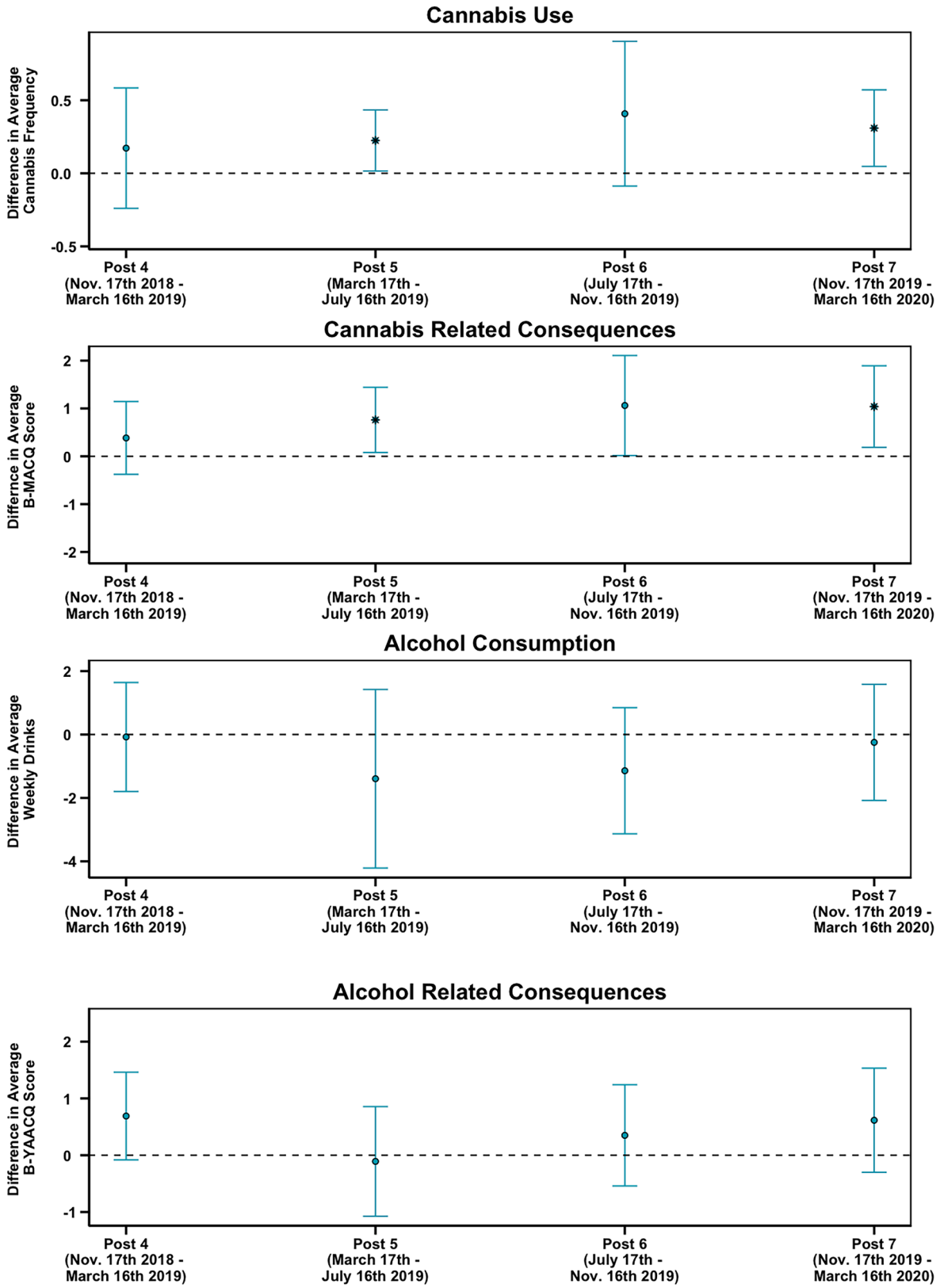

Fig. 3. Average treatment effect on the treated at each time point.
Average Treatment Effects on Treated (ATTs) represent the average effect of legalization (through comparison to pre-legalization) between the Hamilton and Memphis samples, in the units of the measured outcome indicated on the y-axes.
Points represent ATT estimates and lines represent their respective 95 % confidence intervals; significant differences between Hamilton and Memphis samples are apparent when confidence bars do not cross zero (indicated by the horizontal dotted line) and are also identified with *.

did not prevent aging out overall, the addition of a control group further contextualizes our current understanding of how legalization may have impacted emerging adults. While legalization does not appear to have prevented aging out in this cohort, it does appear to have stunted it, as decreases in cannabis use and related consequences were expected to be greater than actually observed based on the American cohort. Confidence that these are non-spurious findings is strengthened by the lack of impact of legalization on alcohol-related outcomes.

A recent systematic review of studies which evaluated cannabis legalization using control group comparisons included 32 US-based studies, and findings indicated there were moderate increases in cannabis use among adult populations in states which legalized recreational cannabis, but no impact among adolescents or young adults (Athanassiou et al., 2023a). Outside of previous work in the present sample (Doggett et al., 2023), as well as some work examining impacts in youth (Zuckermann et al., 2021), there have been few evaluations of Canadian legalization longitudinally studying within-person changes over time. Repeat-cross-sectional trends from the Canadian Cannabis Survey suggest an increase in past 12-month cannabis use from 2018 to 2023 overall, as well as specifically among those over 25, but not emerging adults aged 20–24, and little changes to frequency of use (Government of Canada, 2024a). These data are not necessarily inconsistent with the present study, given that the altered aging out trajectories we observed would not be apparent in the absence of longitudinal control group data. Another Canadian repeat cross-sectional study found that cannabis use frequency and consequences have increased among adults post-legalization; this study's long period of surveillance illustrated that cannabis use has generally trended upwards since 2001 (Imtiaz et al., 2023b), and is somewhat consistent with US trends over similar time frame (Carliner et al., 2017). This type of surveillance of cannabis use behaviours over longer time periods illustrates the variability in trends wave-by-wave, and contextualize that the findings of the present study, although small in magnitude, may hint at flattened patterns of aging-out trajectories that could grow more clinically important over time.

It is notable that the findings of the present work that cannabis-related trends were impacted by legalization should not be interpreted as evidence of policy failure. Canada's approach to cannabis legalization has been comparatively stricter than many US state-based policies (Rubin-Kahana et al., 2022b), including what is essentially complete prohibition on cannabis advertising and promotion (Government of Canada, n.d.). Nevertheless, results of this study do suggest that cannabis legalization has impacted cannabis trajectories of emerging adults. While cannabis was already highly accessible in Canada pre-legalization (Wadsworth et al., 2022), cannabis access certainly increased with legalization (as expected and intended with the legal market). These changes to access could be a plausible mechanism to explain the shift in cannabis trajectories in this study given the context that this was an Ontario sample. Although storefront rollout was slow in Ontario and the current high density of storefronts (Ontario Cannabis Store, 2023) would not have impacted this study period, the province had quickly implemented a comprehensive online ordering system for cannabis post-legalization (Government of Ontario, 2018). Availability of novel products may have also influenced use patterns in this sample in the latter two post-legalization time points when Ontario permitted the sale of highly palatable forms of cannabis like confectionery and chocolate (in contrast to Quebec for example, where such products remain prohibited (Gouvernement du Québec, 2024)). In addition to increased access, more upstream mechanisms hypothesized to influence cannabis trajectories post-legalization include shifts in societal perceptions that can accompany this type of policy change. There is evidence to suggest that the current aging-out processes for young adult cannabis use is being stunted compared to what was typical in the past, driven by i) continued normalization of recreational cannabis use in general and ii) alterations in the typical time frame it takes for young people to reach certain societal milestones of adulthood (e.g., employment, marriage, children, etc.) (Asbridge et al., 2016; Carliner et al., 2017; Cristiano & Sharif-Razi, 2019a; Parker et al., 2002). Since liberalization of cannabis policies is a change that can contribute to the former, the findings of the present study may reflect expedited changes related to the normalization of cannabis use. This is somewhat supported by government surveillance of cannabis attitudes in Canada, which reveal that although risk perceptions appear to be increasing, so is perceived social acceptability of recreational cannabis use (Government of Canada, 2018, 2022). However, these interpretations of mechanisms are necessarily conjecture and direct investigations of the specific consequences of legalization as a policy that led to behavioral changes are needed (e.g., access, quality, perceived norms). Moreover, future research should prioritize cross-verification of these findings by leveraging other Canadian and control samples in order to increase confidence that impacts on cannabis trajectories observed in this study can be attributed to the legalization policy change and not other unmeasured confounding at individual or jurisdiction levels.

The findings of this study, which reveal a stunted aging-out process among emerging adults' post-legalization, raise important public health concerns. Although the observed difference was small, this shift warrants attention if it signals future cannabis use trends for the post-legalization landscape, as emerging adults are at the highest risk for cannabis use disorder (Qadeer et al., 2019). Given that Canada may be moving toward further liberalizing existing cannabis regulations (Government of Canada, 2024c), this study underscores the need for ongoing, longitudinal monitoring of cannabis use behaviors among Canadians.

Strengths and limitations

This study has several strengths, including the use of robust statistical methodology which leveraged longitudinal data and a control group comparison. Both elements allowed for methodologically high-quality evaluation of Canadian cannabis legalization which has not been possible in previous work. However, this study is also not without limitations; the first is that while sophisticated methods were used to balance the characteristics between the Hamilton sample and the Memphis control group, it is not possible to balance samples on unmeasured characteristics. As such, it is possible that unmeasured differences between the samples (e.g., remaining differences between characteristics of individuals, or the occurrence of a confounding event in either location) over time could be contributing to the observed divergence in trends. Next, neither the exposed or control samples were intended to be representative of their respective catchment areas, but were originally recruited based on high-risk substance use patterns, and are most comparable to individuals with similar characteristics (i.e., emerging adults reporting regular heavy episodic drinking). Although these findings inform on the impacts of Canadian legalization, their generalizability might be limited when applied to other jurisdictions, ages, or cohorts with other substance use profiles. Lastly the self-report nature of these data could be influenced by normalization of cannabis use (i.e., greater acceptance of cannabis post-legalization may lead to people being more willing to report cannabis use), although notably cannabis was fairly normalized in Canada prior to legalization (Asbridge et al., 2016; Duff & Erickson, 2014). These limitations highlight the need for future studies to examine legalization using other data from other sample and control jurisdictions.

Conclusions

This study leveraged a comparable American sample to conduct a robust statistical evaluation of the impacts of Canadian cannabis legalization in a sample of high-risk emerging adults in Canada. The findings illustrated that cannabis legalization had a modest negative impact on emerging adults within the first 16 months post-legalization, such that cannabis use frequency and related consequences were greater than

expected based on comparison to the 'natural experiment' control group. Given the generally longer-term impact of policy changes, although the differences were small in magnitude, these findings may indicate the beginning of a divergence in trends post-legalization, namely, higher rates of persistence of cannabis use in emerging adults. Further monitoring of cannabis trajectories using longitudinal samples and contextualization in relation to other non-legalization control groups is a high priority to understand the impact of legalizing cannabis in Canada and around the world.

Ethics approval

The authors declare that they have obtained ethics approval from an appropriately constituted ethics committee/institutional review board where the research entailed animal or human participation.

Both studies received ethical approval from their respective review boards (Hamilton project #2193, Memphis project #4320).

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CRediT authorship contribution statement

Amanda Doggett: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Kyla L. Belisario:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **André J. McDonald:** Writing – review & editing, Conceptualization. **Mahmood Gohari:** Writing – review & editing, Methodology. **Scott T. Leatherdale:** Writing – review & editing. **James G. Murphy:** Writing – review & editing, Resources, Funding acquisition, Conceptualization. **James MacKillop:** Writing – review & editing, Writing – original draft, Supervision, Resources, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: JM is a principal in Beam Diagnostics, Inc. and a consultant to Clairvoyant Therapeutics, Inc. All other authors report no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.drugpo.2024.104686.

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