THESIS

IDENTIFYING RISK AND PROTECTIVE FACTORS FOR CANNABIS HANGOVERS

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ABSTRACT

IDENTIFYING RISK AND PROTECTIVE FACTORS FOR CANNABIS HANGOVERS

Objective: An understudied topic in the cannabis field is the cannabis hangover. Cannabis hangovers are defined as unwanted consequences of cannabis use occurring either the next-day or same day after the acute effects have worn off. Cannabis hangovers have been described by people who use cannabis in self-report social media posts; however, there are inconsistent findings in the current literature. The inconsistency in the current literature may be largely due to low validity and the limited range of symptoms investigated. The present study sought to identify the prevalence and severity of cannabis hangover symptoms, explore facets of cannabis use (e.g., quantity, frequency, route of administration, tolerance) as predictors, and exploring the associations between protective behavioral strategies (PBS) and cannabis hangover occurrence and severity. Method: 1211 adult college students who reported using cannabis at least once in their lifetime were recruited from the psychology research pool at Colorado State University over 2 semesters. Participants completed a survey on their cannabis use patterns, cannabis hangover experiences, and protective behavioral strategies (PBS) for cannabis use, along with general information questionnaires (e.g., demographics). Results: Overall, the study results provide evidence for heterogeneity in both the endorsement of cannabis hangover symptoms and the severity ratings. 91.4% of the sample reported at least one cannabis hangover symptom with a mean total number of symptoms of 7.5 (SD=6.07). The average mean severity across symptoms was 4.73 (SD=1.69). Each predictor was significantly associated with the likelihood of at least one cannabis hangover symptom. Tolerance and average PBS frequency were the most

robust predictors of cannabis hangover symptom occurrence such that tolerance significantly predicted a higher likelihood of endorsing 29 symptoms and average PBS frequency significantly predicted a greater likelihood of not endorsing 19 symptoms. Only flower use, tolerance and average PBS frequency significantly predicted the rate of total number of cannabis hangover symptoms, whereby flower use and tolerance predicted a higher rate of total number of cannabis hangover symptoms and average PBS frequency predicted a lower rate. None of the predictors were significantly associated with cannabis hangover severity ratings. Conclusion: This study describes a high prevalence rate and moderate severity of cannabis hangovers, with tolerance and protective behavioral strategies emerging as key predictors of symptom occurrence and total symptom count. The results suggest that interventions aimed at lowering tolerance and promoting PBS use may be more effective in reducing the occurrence of cannabis hangovers than simply focusing on changing patterns of use. Future research should use longitudinal designs to investigate causal relationships and explore potential confounding variables, such as contextual factors, to better understand cannabis hangover symptom occurrence and severity.

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Introduction

In this introduction, I will start by broadly reviewing cannabis use in the United States. I will then briefly review cannabis dependence focusing on two symptoms of dependence, withdrawal and tolerance, that have been implicated in the occurrence and severity of cannabis hangovers. After reviewing the current literature on the acute effects of cannabis, I will discuss cannabis hangovers in detail. Lastly, I will discuss harm reduction and protective behavioral strategies (PBS) with attention paid to the importance of PBS in decreasing the unwanted consequences of cannabis use (e.g., cannabis hangovers).

Cannabis Use

Cannabis use is prevalent, with 18.7% of people aged 12 or older reporting past year use (Substance Abuse and Mental Health Service Administration, 2023). Cannabis is a Schedule 1 substance under the Controlled Substance Act; therefore, cannabis is federally illegal to own, consume, or sell. However, cannabis is legal for recreational and medical use in 21 states and the District of Columbia, legal for medical use only in 23 states, and remains illegal in 6 states as of 2023. Presently, cannabis is decriminalized for low-level cannabis possession in 31 states and the District of Columbia. Though public opinion of cannabis is becoming increasingly favorable (Carliner et al., 2017) and there are reported benefits (Webb & Webb, 2014), there are also known consequences associated with its use (Hall & Solowij, 1998). Regardless, cannabis has a long-standing history of human consumption for its psychoactive properties.

There are four main routes of administration: inhalation (e.g., cannabis flower and concentrates), oral (e.g., edibles and tinctures) and topical (e.g., lotion and oil) and ‘other routes” (e.g., suppositories, intranasal delivery). Inhalation can be further classified into consumption of

smoked vs. vaporized cannabis products, resulting in a total of five main consumption types (i.e., flower, concentrate, oral, topical and 'other'). Cannabinoids are chemical compounds that interact with the body's endocannabinoid system, which plays a role in regulating psychomotor coordination and executive functions such as decision-making, learning and memory (Earleywine, 2005). Though there are over 100 cannabinoids found in cannabis, delta-9 tetrahydrocannabinol (THC) and cannabidiol are two of the most well-known cannabinoids. THC, the main psychoactive component of cannabis, activates cannabinoid 1 (CB1) receptors in the brain, which are a major component of the endogenous cannabinoid system and are more concentrated in regions whose functions are known to be impacted by cannabis (Earleywine, 2005). Regular cannabis use results in the downregulation of CB1 receptors and is associated with neurobiological changes within the hippocampus and prefrontal cortex (Lorenzetti et al., 2016). Within four weeks of abstinence CB1 receptor density begins to return to normal levels (Hirvonen et al., 2012). THC is fat soluble and is stored and released into the bloodstream (Grotenhermen, 2003). Since THC is fat soluble, it has a relatively long half-life and can be detected in urine anywhere from one day to more than a month after use (Huestis et al., 1996).

Changes in the cannabis market have occurred due to shifts in the legalization landscape. These changes have impacted cannabis products and cannabis related consequences. THC potency of cannabis has increased markedly since legalization (Englund et al., 2017), and higher potency cannabis is correlated with more severe symptoms than lower potency cannabis (Craft et al., 2022; Freeman & Winstock, 2015; Rigucci et al., 2016). The prevalence of cannabis use disorder (CUD) has risen from 1.8% in 2010 to 5.8% in 2022 among individuals 12 years old or older (Substance Abuse and Mental Health Service Administration, 2010 & 2022). The evolving

cannabis market highlights a need for updated studies that broadly capture the full spectrum of cannabis use and associated consequences.

Dependence

Cannabis dependence occurs when an individual engages in a problematic pattern of cannabis use despite its negative impact on their life and health. For individuals who use cannabis, an estimated 8.9% become dependent on cannabis at some point in their life (Lopez-Quintero et al., 2011). Higher frequency of cannabis use and use of cannabis products with high THC potency are associated with increased likelihood of cannabis dependency (Curran et al., 2019; Freeman & Winstock, 2015). Cannabis dependence is often associated with a cannabis use disorder, which is characterized by a problematic pattern of cannabis use that leads to clinically significant impairment or distress. The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) outlines criteria for diagnosing a cannabis use disorder. Symptoms include using more cannabis than intended, difficulty controlling or cutting down on use, spending significant amount of time obtaining or using cannabis, and continued use despite experiencing negative consequences. Cannabis dependence frequently includes symptoms of tolerance and cannabis withdrawal (Nocon et al., 2006).

Withdrawal

Cannabis withdrawal, also known as cannabis withdrawal syndrome, consists of symptoms that may occur when an individual who uses cannabis regularly stops or significantly reduces their use. The DSM-5 lists the following symptoms: A) cessation of heavy and prolonged cannabis use, and B) three or more of the following within several days after cessation: 1) irritability, 2) nervousness, 3) sleep difficulty, 4) decreased appetite, 5) physical symptoms and discomfort. Typically, withdrawal symptoms occur 24-48 hours after cessation,

peaking within 2-6 days and lasting 1-2 weeks with abstinence; however, the duration and severity may vary across symptoms and individuals (Budney et al., 2004; Connor et al., 2022; Hesse & Thylstrup, 2013; Kouri & Pope Jr., 2000).

Cannabis withdrawal syndrome is correlated with the downregulation of CB1 receptors from habitual use (D'Souza et al., 2016). Cannabis withdrawal syndrome is generally milder compared to withdrawal symptoms associated with other illicit drugs. However, cannabis withdrawal symptoms increase the likelihood of relapse and may negatively impact wellbeing and daily functioning (Connor et al., 2022). Not everyone who uses cannabis will experience withdrawal symptoms. An estimated 47% of individuals who use cannabis regularly will experience cannabis withdrawal and certain factors such as level of cannabis use, severity of cannabis dependence, and the presence of tolerance influence the likelihood (Bahji et al., 2020; Levin et al., 2010).

Tolerance

Cannabis tolerance occurs when an individual's response to cannabis changes over time with repeated use leading to a decrease in the drug's acute effects. These changes often motivate the individual to increase the quantity and/or frequency of their cannabis use to achieve the desired effects. The pharmacodynamic model of cannabis tolerance states that tolerance is primarily due to the downregulation of CB1 receptors (Ramaekers et al., 2020). A recent systematic review found that individuals who use cannabis regularly (i.e., a pattern of daily or weekly cannabis use), have a reduced sensitivity to THC compared to individuals who only use cannabis occasionally (Colizzi & Bhattacharyya, 2018). Previous studies assessing the neuropsychological and physiological effects of tolerance suggest that individuals who use cannabis regularly develop a tolerance to the effects of THC on certain cognitive measures, but

not on subjective-effect ratings, psychomotor function and physiological measures (Hart et al., 2010; Ramaekers et al., 2020).

Acute Effects of Cannabis Use

During intoxication, cannabis can produce a range of acute cognitive, psychological and physiological changes. THC is the primary psychoactive compound in the cannabis plant. Smoking cannabis results in psychoactive effects that onset quickly and peak effects occur roughly 30 minutes after inhalation and subside within approximately 4 hours (Grotenhermen, 2003). When ingested orally, the psychoactive effect is delayed due to absorption in the stomach, reaching peak effects within approximately 90 minutes and lasting up to 6 hours (Grotenhermen, 2003). The delayed onset of acute effects following oral ingestion may result in accidental over-intoxication and subsequent stronger and longer lasting effects (Reboussin et al., 2019). Case reports describe marijuana-induced psychosis following edible use (Bui et al., 2015; Hudak et al., 2015). Furthermore, social media self-reports suggest that edible use may be associated with the occurrence and severity of cannabis hangovers.

Cognitive impairments in working memory, attention, concentration, decision-making, impulsivity and inhibition are evident during acute intoxication (Hart et al., 2001; Heishman et al., 1997; McDonald et al., 2003; Miller et al., 1977; Ramaekers, Kauert, et al., 2006; Ramaekers, Moeller, et al., 2006; Vadhan et al., 2007). Multiple studies examining the acute effects of cannabis have found differences in cognitive impairment among individuals who chronically use cannabis compared to individuals who use cannabis less frequently. Crean et al. (2011) found that impairment in concentration and attention was more significant in individuals who engaged in less frequent use. Interestingly, Kelleher et al. (2004) found that individuals who engaged in heavy cannabis use had slower information processing when abstinent, which

returned to normal during acute intoxication. These effects are consistent with physiological tolerance and dependence on cannabis though anecdotally individuals who use cannabis would likely attribute these neurocognitive effects to a cannabis hangover.

Acute intoxication from cannabis can cause a range of both positive and negative psychological effects. A euphoric effect, characterized by heightened mood and laughter, as well as increased anxiety, panic, paranoia and psychosis have been observed (Ashton, 2001). Reports on the subjective experiences of cannabis commonly include both positive effects (e.g., increased mood, sensory alteration, insight/thinking more deeply, relaxation) and negative effects (e.g., paranoia, depression, hallucinations, anxiety), in addition to slowed time perception and increased appetite (Green et al., 2003). Subjective effects have been found to be correlated with the level of intoxication where a lower level of intoxication is associated with decreased sleep latency, increased sociability and increased appetite; meanwhile higher levels of intoxication is associated with sensations of floating, drowsiness, altered time perception, impaired memory, paranoia, difficulty falling asleep and hallucinations (Tart, 1971).

Acute cannabis intoxication causes physiological effects including a dose-related tachycardia with a heart beating up to 160 beats per minute, and postural hypotension where a drop in blood pressure occurs upon standing from a sitting or lying position (Ashton, 2001; Heishman et al., 1997). Research on the impact of cannabis on sleep has produced mixed findings. A recent review of the literature highlights evidence that suggests a short-term benefit on sleep such as a decrease in sleep onset latency, as well as deficits including decrease in rapid eye movement sleep and diminished sleep quality (Babson et al., 2017). Considering the subjective reports of increased appetite following cannabis use, it is not surprising that cannabis

has been shown to be effective in stimulating appetite in certain patient populations who struggle with appetite suppression (Aquino, 2005).

The acute effects of cannabis are relatively well understood. The current literature suggests that dose and THC potency of cannabis consumed as well as tolerance and/or dependence to cannabis influences the presence of certain acute effects (Crean et al., 2011; Kelleher et al., 2004; Tart, 1971). While there are known chronic consequences of cannabis use (Filbey et al., 2014; Volkow et al., 2014), the chronic effects are beyond the scope of the current study. The current study aims to better understand the unwanted consequences of cannabis that occur following acute intoxication.

Hangovers

Alcohol hangovers are a well-studied consequence of alcohol use and have been reported by a large percentage of people who use alcohol (Smith & Barnes, 1983). Symptoms of an alcohol hangover include headache, fatigue, nausea, vomiting, dizziness, sensitivity to light and sound, and cognitive impairment. The symptoms are known to develop when an individual's blood alcohol concentration (BAC) approaches zero after a single drinking episode, in contrast to the onset of alcohol withdrawal symptoms which occurs after an individual maintains a stable level of alcohol consumption through continuous drinking (van Schrojenstein Lantman et al., 2016; Verster et al., 2020). Recent research investigating the cause of alcohol hangovers has determined that the rate at which the body metabolizes ethanol is a significant predictor of next day hangover severity (Mackus et al., 2020). Furthermore, the role of acetaldehyde in eliciting an inflammatory response to alcohol has been identified as a contributing factor to the occurrence of alcohol hangovers (van de Loo et al., 2020). In addition to the health impact, alcohol hangovers affect daily life such as causing absences from work or school (Pittler et al., 2005). Due to the

negative impact of alcohol hangovers on health and daily life, an individual may be motivated to engage in behaviors that reduce the likelihood and severity of symptoms.

A cannabis hangover refers to the unwanted consequences following cannabis use either the next day or the same day after the high has worn off. Cannabis hangover symptoms have been reported by users on social media sites and there are numerous websites, including popular ones such as Leafly (Lland, 2023), healthline (Vandergriendt, 2019) and MedicalNewsToday (PharmD, 2024), that publish articles about cannabis hangover symptoms, and prevention and treatment strategies. Even though cannabis hangovers are described in the popular media, the current literature does not fully capture the phenomenon. There have been a limited number of experimental studies that have primarily relied on cognitive and safety-sensitive tasks to measure the next day effects of cannabis use. Results have not been consistent across these studies. Some studies found evidence for impairment on driving/flying simulator tasks (Leirer et al., 1991; Yesavage, 1985), while others did not (Brands et al., 2019; Leirer et al., 1989; Rafaelsen et al., 1973; Ronen et al., 2008). Additionally, some studies have found evidence for impairment on cognitive tasks (Chait, 1990; Chait et al., 1985; Fant, 1998; Heishman et al., 1990; Pope et al., 1995), while others did not (G. Barnett et al., 1985; Chait & Perry, 1994). In a systematic review, McCartney et al. (2023) reviewed twenty studies (n=458) involving 345 performance tests that assessed “next day” performance (8-24 hours after THC administration). Sixteen studies, including nine that used randomized, double-blind, placebo-controlled designs, did not find any “next day” effects of cannabis. Only five studies, encompassing just 12 performance tests (i.e., learning, memory, perception, working memory, divided attention and simulated flying), found evidence for “next day” impairment 8-12 hours after using cannabis. Notably, none of these five studies used randomized, double-blind, placebo-controlled designs. Almost half of the

performance tests (N=121/345) were unable to produce clear results due to insufficient information. Interestingly, 3 performance tests (i.e., information processing and simulated driving) found positive "next day" effects among individuals who regularly use cannabis 48 hours after consumption. One of the studies that found "next day" impairment, also observed higher elation and positive mood the morning after smoking cannabis compared to the placebo group, though this is thought to be due to the frustration experienced from receiving inactive cannabis (Chait et al., 1985).

It is important to note that many of these studies have methodological concerns including a lack of randomized double-blind study designs in more than half of the studies, small sample sizes and a severe underrepresentation of participants who are not male (McCartney et al., 2023). In addition to limitations in study design, these studies also fail to represent the current cannabis market. Due to the nature of the experimental design, these studies relied on cannabis provided by federal agencies (ex: National Institute of Drug Abuse) with relatively low THC levels (2.1-12.5%) and most studies administered a single limited/unknown dose of THC (e.g., "five puffs") either orally or via a cannabis cigarette. Though these studies showed that intoxication occurred, the low dose (marked by low potency and quantity), limited modes of consumption and focus on impairment on cognitive and safety-sensitive tasks may have limited their ability to fully capture the cannabis hangover. These limitations highlight an important need for further studies that have improved methodologies and ecological validity. An important addition to the present literature is a study that investigated cannabis use for sleep aid among college students using daily dairies (Goodhines et al., 2019). The authors noted next-day daytime fatigue as a potential adverse short-term consequence of cannabis sleep aid use, despite its indicated benefits for sleep.

Though there is literature on the biological mechanisms underlying the acute and chronic effects of cannabis, cannabis hangovers are a relatively unexplored phenomenon. One could hypothesize that cannabis withdrawal and cannabis hangovers have overlapping biological mechanisms due to their overlapping symptoms (e.g., decreased appetite, fatigue, anxious feelings). Conducting studies aimed at identifying the biological mechanisms of cannabis hangover symptoms is an important future direction. However, prior to conducting time- and resource- intensive research, the cannabis hangover phenomenon needs to be more thoroughly described. Identifying cannabis hangover symptoms and their relation to cannabis use patterns is an important foundational step.

Cannabis hangovers are unwanted consequences of cannabis use that individuals try to avoid. In fact, many people who use cannabis report using strategies to prevent and/or treat their cannabis hangover symptoms (McFarland et al., 2023). Using PBS to reduce the negative consequences of cannabis use is an effective intervention/prevention approach and may be relevant for the cannabis hangover (Bravo et al., 2017; Prince et al., 2019).

Harm Reduction

Harm reduction is a term used to describe interventions that aim to reduce the negative consequences of behaviors (Marlatt, 1996). Within the substance use field, the goal of harm reduction is to minimize the risks associated with substance use beyond abstinence-only approaches (Logan & Marlatt, 2010). Harm reduction emphasizes approaches towards safer substance use. These approaches can include both individual approaches (e.g., reducing frequency of use) and community-level efforts (e.g., needle exchange programs). Although complete abstinence from substance use is effective in reducing the harms from substance use, evidence suggests that abstinence focused approaches may not be effective, feasible or necessary

for everyone (McGrath, 2003). Substance use interventions that target improved well-being and improved functioning more broadly may be more useful for a wider proportion of the population (Witkiewitz & Tucker, 2020). Protective behavioral strategies (PBS) are a set of harm reduction strategies that individuals can use to reduce the frequency of substance use and/or severity of negative consequences.

Protective Behavioral Strategies

Modern PBS research was initially focused on alcohol use. PBS were first talked about as self-control techniques (Carey & Maisto, 1985) and were then referred to as drinking control strategies (Sugarman & Carey, 2007). Some of these strategies are directed towards avoiding or limiting alcohol consumption while others focus on behaviors that help an individual stay safe while drinking. There is evidence to support PBS as a mechanism of change in brief motivational interventions aimed at reducing alcohol use and/or alcohol-related problems in college students (N. P. Barnett et al., 2007; Murphy et al., 2012). When investigating the relationship between PBS, alcohol consumption and alcohol-related consequences among college students, Martens et al. (2004) found that less PBS use was associated with more alcohol-related consequences. The literature shows consistent evidence to support that individuals who use PBS while drinking are able to reduce or avoid negative consequences of alcohol use (Bravo et al., 2015, 2016; Pearson, 2013).

More recently, there has been a focus on the development and evaluation of protective behavioral strategies for cannabis use. An important development is the creation of the Protective Behavioral Strategies for Marijuana (PBSM) scale (Pedersen et al., 2016). The PBSM includes a range of strategies aimed at limiting and/or managing cannabis consumption, preventing impaired driving and related legal issues, and minimizing potential interpersonal and work

issues. The implementation of cannabis PBS in cannabis use interventions has proven to be effective, as evidenced by a web-based intervention, eCHECKUP TO GO, designed for college students to reduce the harms associated with heavy cannabis use (Riggs et al., 2018). Current literature indicates that individuals who have a greater use of PBS for cannabis tend to report lower cannabis use frequencies and fewer cannabis-related negative consequences (Bravo et al., 2017; Prince et al., 2019). This suggests that PBS may be a mechanism that individuals use to self-regulate their cannabis use and reduce their risk of experiencing consequences associated with cannabis use.

Preliminary Study

My colleagues and I conducted a preliminary study that sought to describe the prevalence of cannabis hangover symptoms and explore whether cannabis quantity, frequency, and/or route of administration differentially predict cannabis hangover symptoms (McFarland et al., 2023). 451 adult college students and/or community members were recruited from Prolific and Washington State University's psychology research pool. To capture a wide range of cannabis use frequency while excluding those who may have only used cannabis a few times, participants who reported 11+ lifetime uses sessions were eligible to participate. Participants were asked to complete a self-report questionnaire via Qualtrics and were asked questions about their cannabis use, cannabis hangover symptoms, and some demographic information. Cannabis hangover symptoms were measured using a Cannabis Hangover Symptom Questionnaire with 35 symptoms and a 4-point Likert scale ranging from 1 (almost never) to 4 (almost every time) to measure symptom frequency. Among the participants, 97% (n=438/451) reported experiencing at least one cannabis hangover symptom. Mean number of total symptoms experienced was 9.51 (SD=6.3). The most commonly experienced symptoms included: tired (n=320), dry mouth

(n=316), brain fog (n=218), grogginess (n=214) and decreased motivation (n=207). The least commonly experienced symptoms were: hyperhidrosis (i.e., excessive sweating) (n=23), muscle soreness (n=29), feeling bloated (n=35), difficulty imagining or being creative (n=37) and aversion to cannabis (n=44). The most robust predictors of the total number of cannabis hangover symptoms reported were average THC potency in concentrates and lifetime frequency. Endorsed strategies to prevent and/or reduce cannabis hangover symptoms included, but were not limited to staying hydrated (n=209), adjusting eating habits (n=66), using at a certain time of the day (n=45), getting sleep (n=30) not using when there are obligations or responsibilities later in the day/the next day (n=28) and adjusting the quantity consumed (n=24). These findings suggest that a significant proportion of individuals who use cannabis are reporting the presence of certain cannabis hangover symptoms. Cannabis use measures, such as frequency and potency, may predict the likelihood of experiencing cannabis hangover symptoms. Additionally, some individuals are reporting the use of protective strategies to prevent and/or treat cannabis hangover symptoms.

Current Study

The current study built upon the preliminary study by further examining the prevalence of cannabis hangover symptoms in a college student sample in Colorado, investigating tolerance and PBS as individual predictors of cannabis hangover occurrence and severity, and exploring the subjective severity of cannabis hangover symptoms. Among college students in 2020, annual prevalence of cannabis use is up to 44% (Schulenberg et al., 2021). College students often invest significant financial resources into obtaining a college degree (Barrow & Malamud, 2015). Arria et al. (2015) observed that among college students, cannabis use negatively impacted academic outcomes, both directly and indirectly through poorer class attendance. Though it is uncertain

whether cannabis hangovers contribute to the negative impact of cannabis use on academic outcomes, I speculate that cannabis hangover symptoms (e.g., fatigue, lack of motivation, brain fog) would negatively affect academic performance. I utilized a descriptive cross-sectional design to survey a large representative sample of students who use Colorado State University's psychology research pool.

Hypotheses

Aim 1 of this study was to describe the prevalence and severity of cannabis hangover symptoms. Aim 2 was to identify cannabis use factors (e.g., quantity, route of administration, frequency, tolerance) that most strongly predict cannabis hangovers and cannabis hangover severity. Aim 3 was to assess the relationship between PBS and cannabis hangovers. To address these aims, several hypotheses were tested.

Aim 1:

1. Hypothesis 1: There will be heterogeneity among cannabis hangover symptom endorsement and severity rating.

Aim 2:

2. Hypothesis 2: Higher typical dose (quantity x THC potency) will positively predict the severity and likelihood of cannabis hangovers.
3. Hypothesis 3: Frequency of cannabis use will negatively predict the severity and likelihood of cannabis hangovers.
4. Hypothesis 4: Among cannabis consumption types, edibles will most strongly predict the severity and likelihood of cannabis hangovers.
5. Hypothesis 5: Self-reported tolerance will negatively predict the severity and likelihood of cannabis hangovers.

Aim 3:

6. Hypothesis 6: PBS will negatively predict the severity and likelihood of cannabis hangovers.

Methods

Participants and Procedure

Participants. 1211 undergraduate college students from Colorado State University were recruited as a part of a study on cannabis hangovers. Sociodemographic information and survey measures on study constructs were collected from participants who consented to take part in the study for course credit.

Procedure. The study was accepted by the Colorado Multi-Institutional Review Board at Colorado State University (Protocol ID: 4212). In accordance with APA guidelines, individuals were provided information about the study's purpose, potential benefits and risks of participation. Participants were recruited with the option of gaining course credit for their participation. Participation was voluntary.

The measures of this study were: Screening survey (see appendix A), demographic questionnaire (see appendix B), Timeline Follow Back (TLFB; see appendix C), Cannabis Tolerance (items modified from the DSM-5 Checklist: DSM5; see appendix D) 17-item Protective Behavioral Strategies for Marijuana Scale (PBSM-17; see appendix E), and Cannabis Hangover Symptom Questionnaire (CHSQ; see appendix F).

Measures

Screening Survey. Participants were asked if they are 18 or older and if they have ever used cannabis in their lifetime (see appendix A).

Demographic Questionnaire. Participants answered questions regarding their age, race, ethnicity, sex assigned at birth, gender identity and health status (see appendix B).

Timeline Follow Back (TLFB). The Timeline Follow Back gathers information regarding substance use patterns. Participants were asked to self-report the quantity, which days they used, and amount of time spent using (Sobell & Sobell, 1992). For this study, only cannabis use patterns from the last 30 days were collected. This included days and time periods of use, quantity of cannabis used, and route of administration (see appendix C).

Cannabis Tolerance (items modified from the DSM-5 Checklist: DSM5). This two-item cannabis tolerance measure was adapted specifically for cannabis from criteria 10 in the DSM-5 criteria for diagnosing and classifying substance use disorders. Participants indicated 1) whether in the past 12 months they have required increasingly higher doses of cannabis to achieve the desired effect, and 2) if in the past 12 months they got much less of an effect by using the same amount of cannabis in the past by answering either Yes (1) or No (0) (see appendix D).

17-item version of the Protective Behavioral Strategies for Marijuana Scale (PBSM-17). The PBSM-17 (Pedersen et al., 2017) is a 17-item protective behavioral strategies (PBS) scale specifically for cannabis use. Participants were presented with 17 PBS (e.g., avoid using marijuana before school or work, limit use to weekends) and then indicated how often they use each strategy on a 6-point Likert scale ranging from 1 (never) to 6 (always) (see appendix E).

Cannabis Hangover Symptom Questionnaire (CHSQ). The CHSQ is an inventory of 35 potential cannabis hangover symptoms. The symptoms are divided into three domains: physical (17), cognitive (11) and affective (7). Participants were asked to indicate whether they have ever experienced each symptom following cannabis use by answering either Yes (1) or No (0). If they answer “Yes” for any symptom they were then prompted to report how bothersome

each symptom was on a 10-point linear numeric scale ranging from 1 (not bothersome at all) to 10 (very bothersome) (see appendix F).

Analysis Plan

Demographic Variables. The descriptive statistics for demographic variables for sex, race, ethnicity, and sexual orientation were reported and described.

Cannabis hangover symptom data was handled in five ways: 1) dichotomized to "any" (1) vs. none (0) with each cannabis hangover symptom as a binary outcome, 2) total symptom count for each participant was calculated for use in regression models, 3) total symptom count for each symptom was calculated across the entire sample for descriptive purposes, 4) symptom severity was averaged for each participant across all endorsed symptoms for use in regression models, and 5) symptom severity was also averaged for each symptom, across the entire sample for descriptive purposes.

Prior to fitting regression models, the predictor and outcome variables distribution were assessed to detect potential outliers or overdispersion.

While in my thesis I conducted many statistical tests, increasing the likelihood of a Type I error, I did not apply a correction for multiple comparisons. Though alpha corrections protect against Type I errors, they increase the risk of Type II errors. Rothman (1990) argues against the use of multiple comparison corrections to lessen errors of interpretation when working with data that are derived from actual observations. Additionally, Perneger (1998) argues that the Bonferroni correction is flawed due to its focus on the null hypothesis significance testing which is often irrelevant to researchers. Another weakness of alpha corrections is the increased likelihood of missing important findings that are deemed non-significant (Perneger, 1998). To address the use of multiple comparisons, this thesis follows recommendations by Cumming

(2011, 2014) by not solely relying on null hypothesis significance testing, but to also interpreting effect sizes, confidence intervals and accumulation of evidence to draw conclusions from the data.

Hypothesis 1: Prevalence rate of experiencing at least one cannabis hangover symptom was calculated. To describe the rate of endorsement for each symptom, the total count of each symptom across the sample was calculated and ranked ordered for data visualization. Additionally, mean and standard deviation of the total symptom count across participants was calculated. To describe the severity of each symptom, the mean and standard deviation of the severity rating for each symptom was calculated and rank ordered for data visualization.

Hypothesis 2: To test hypothesis 2, the predictor variable was the typical dose (quantity x THC potency) across consumption types[1]. Typical dose for each consumption type was calculated via the following steps: 1) multiplying the average quantity of cannabis consumed by the average percentage of THC, 2) if needed, the value was then converted into milligrams[2], and 3) the average of each typical dose across all consumption types was then computed. Typical dose was defined as the average milligrams of THC consumed for each participant. The variable "typical dose" contained extreme values and overdispersion; therefore, a log transformation was applied. This approach was applied to mitigate the potential bias caused by outliers and overdispersion in the regression models.

A series of logistic regressions were used to examine the relationship between the predictor variable and each binary outcome variable for each hangover symptom. For each regression model, the odds ratios (OR) are reported. ORs represent the odds of experiencing a

[1] Topicals and 'other' routes of administration were not reported in the sample, therefore the analysis was limited to flower, concentrates, and edibles.
[2] Edibles was measured in milligrams, so no conversion was necessary.

specific hangover symptom associated with a one-unit increase in the predictor variable. The ORs are calculated from the exponentiating the regression coefficients. An OR greater than 1 indicates a higher rate of the outcome, while an OR less than 1 indicates a lower rate. 95% confidence intervals (CI) are provided for each OR. The CIs are a range within which the true odds ratio is expected to lie with a 95% confidence. An OR is considered statistically significant if its CI does not include 1.0. Additionally, the p-value is provided to indicate statistical significance of the predictors in each logistic regression model for completeness.

Next, a series of quasi-Poisson (QP) count regressions were used to predict the total number of symptoms experienced for each outcome. For each count regression model, the incidence rate ratio (IRR) was calculated by exponentiating the coefficient from a QP regression coefficient. The IRR represents the rate of which the number of hangover symptoms changes with an additional one-unit in the predictor variable. An IRR greater than 1 indicates a higher rate of the outcome, while an IRR less than 1 indicates a lower rate. The CI for the IRR provides a range within which the true IRR is likely to fall. If the CI does not include 1.0, the IRR is considered statistically significant. The p-value is provided to indicate statistical significance for completeness.

Based on the normal distribution of symptom severity, an ordinary least squares (OLS) regression was used to predict cannabis hangover severity. For each OLS regression model, the coefficients are estimated using the ordinary least squares method, which minimizes the sum of squared differences between observed and predicted values. The coefficients represent the predicted change in the outcome variable for each additional unit in the predictor variable. The coefficient indicates that an additional unit of the predictor is associated with a predicted slope-unit change in the outcome variable. CIs for the coefficients provide a range within which the

true parameter is likely to fall. If the CI does not include zero, the coefficient is considered statistically significant. The p-value is provided to indicate statistical significance for completeness.

Hypothesis 3: Frequency of cannabis use was treated as a continuous predictor variable. 30-day frequency of cannabis was used to maintain consistency with how the current literature measures cannabis frequency. 30-day frequency was calculated by counting the number of days an individual used cannabis at least once, regardless of consumption type and within day frequency. See hypothesis 2 for analysis plan; outcome variables are the same.

Hypothesis 4: Consumption types were treated as categorical predictor variables and were dummy coded. Use of edibles was treated as a binary predictor variable, whereby endorsing edible use was indicated as a 1, and no edible use was indicated as a 0. See hypothesis 2 for analysis plan; outcome variables are the same.

Hypothesis 5: Cannabis tolerance was treated as a binary predictor variable, whereby endorsing at least one item indicating tolerance on a two-item scale was indicated as a 1 and not endorsing either item indicating tolerance was indicated as a 0. See hypothesis 2 for analysis plan; outcome variables are the same.

Hypothesis 6: Average PBS use frequency score was calculated for each participant and was treated as the predictor variable. See hypothesis 2 for analysis plan; outcome variables are the same.

Results

The aims of the study were to: 1) describe the prevalence and severity of cannabis hangover symptoms, 2) to identify cannabis use factors (e.g., quantity, route of administration, frequency, tolerance) that most strongly predict cannabis hangovers and cannabis hangover severity, and 3) assess the relationship between PBS and cannabis hangovers.

A majority of the participants in this sample identified as white (n=1028; 85%), non-Hispanic (n=843; 70%), heterosexual (n=844; 70%), assigned female at birth (n=804; 66%) and 18-24 years old (n=993; 82%). Mean age was 19 years old (SD=1.87), with a minimum age of 18 years old and maximum age of 43 years old. Table 13 in Appendix G present a demographic table for sex, race, ethnicity, sexual orientation, gender and age.

I found support for hypothesis 1 as there was heterogeneity among cannabis hangover symptom endorsement and severity ratings. In addition, the prevalence rate of experiencing at least one cannabis hangover symptom was 91.4% (n=1107/1211). The most commonly endorsed symptoms included: tired (n=794; 66%), dry mouth (n=629; 52%), grogginess (n=521; 43%), decreased motivation (n=407; 34%), and difficulty focusing (n=398; 33%). The least commonly endorsed symptoms included: hyperhidrosis (n=39; 3%), muscle soreness (n=52; 4%), aversion to cannabis (n=78; 6%), difficulty imagining or being creative (n=81; 7%), and bloated (n=90 7%). See figure 1. The mean number of symptoms endorsed was 7.5 (SD=6.07). Severity was measured on a scale of 1 (not bothersome at all) to 10 (very bothersome). Symptoms with the highest severity rating included: increased anxiety (mean=7.08, SD=2.24), paranoia (mean=6.97, SD=2.36), difficulty talking to people (mean=6.43, SD=2.43), heart racing (mean=6.05, SD=2.61), and difficulty completing normal tasks (mean=5.99, SD=2.3). Symptoms with the

lowest severity rating included: red eyes (mean=3.84, SD=2.62), no appetite (mean=4.07, SD=2.38), dry eyes (mean=4.11, SD=2.16), muscle soreness (mean=4.62, SD=2.3), and headache (mean=4.65, SD=2.09). See table 14 in Appendix G. The average mean severity across symptoms was 4.73 (SD=1.69).

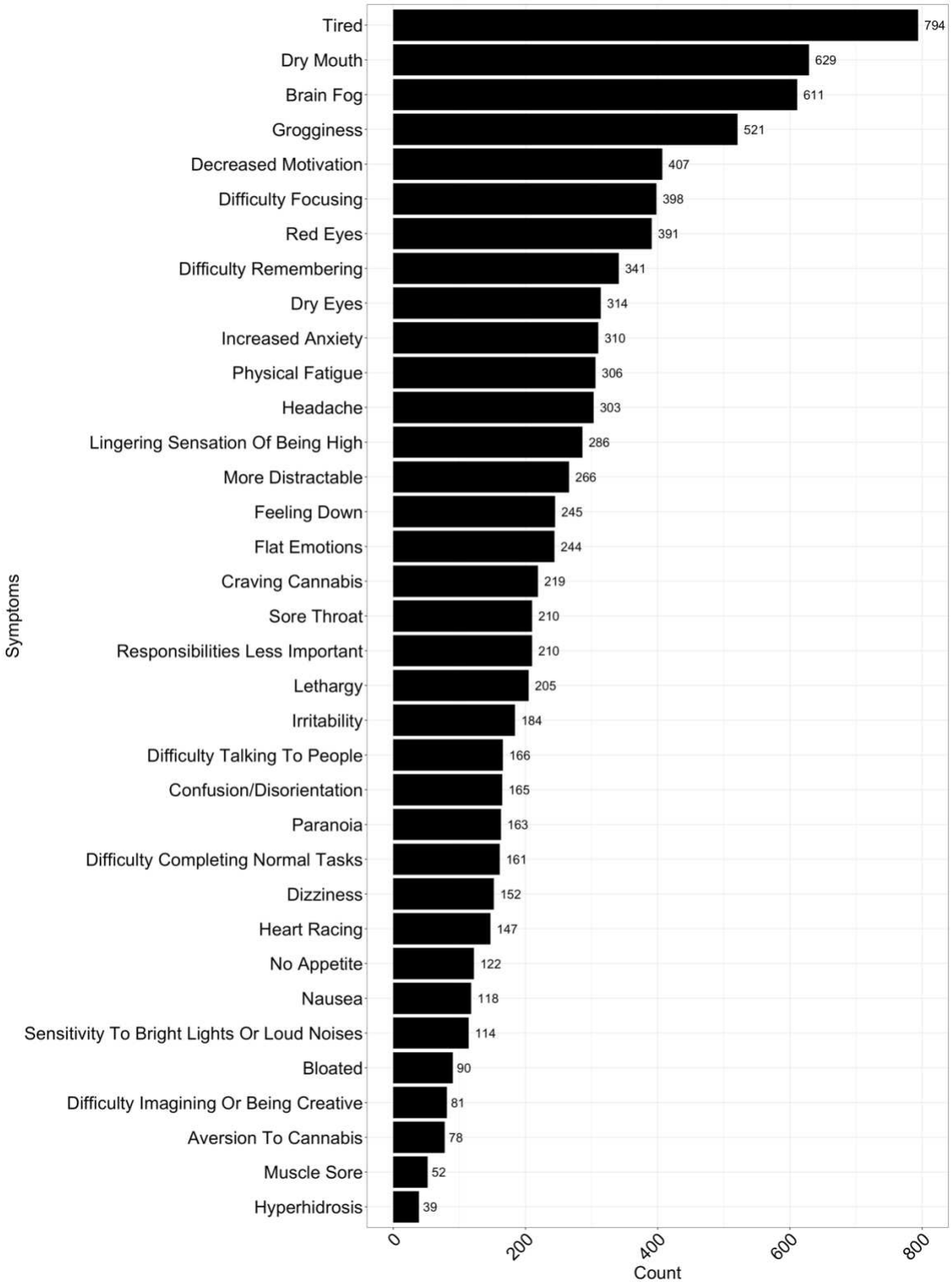

Figure 1

Total Count for Each Cannabis Hangover Symptom

Note: Bar graph 1 presents results of the total count for each cannabis hangover symptom.

As described above, there were a total of 3 types of regression models to account for the three outcome variables: logistic regression, count regression and OLS regression. Figures 2 to 6 present bar graphs to visualize a series of logistic regression results. Additionally, tables 15 to 19 in Appendix G present these logistic regression results with provided ORs and CIs. Tables 1 to 12 present a series of count regression and OLS regression results. Lastly, table 20 in Appendix G provides descriptive statistics for the cannabis use measures that were reported by participants. Among the 657 participants who endorsed past month use, the average 30-day frequency was 2.91 days (SD=6.19) with a mean typical dose of 127.56 mg of THC (SD=229.16 mg). Among consumption types, 236 participants reported edible use, 449 reported flower use, and 375 participants reported using concentrates.

I found minimal support for hypothesis 2, as the typical dose (i.e., average mg of THC across all consumption types) significantly and positively predicted the likelihood of one cannabis hangover symptom. Typical dose significantly and positively predicted craving cannabis (OR=1.25, CI [1.11–1.39], $p<.05$), such that a one additional mg of average THC dose predicted a 25% higher likelihood of craving cannabis. Typical dose did not significantly predict the likelihood of the remaining 34 cannabis hangover symptoms. See figure 2 and table 15 in Appendix G. Additionally, typical dose did not significantly predict total number of cannabis hangover symptoms or severity of cannabis hangovers. See tables 1 and 2.

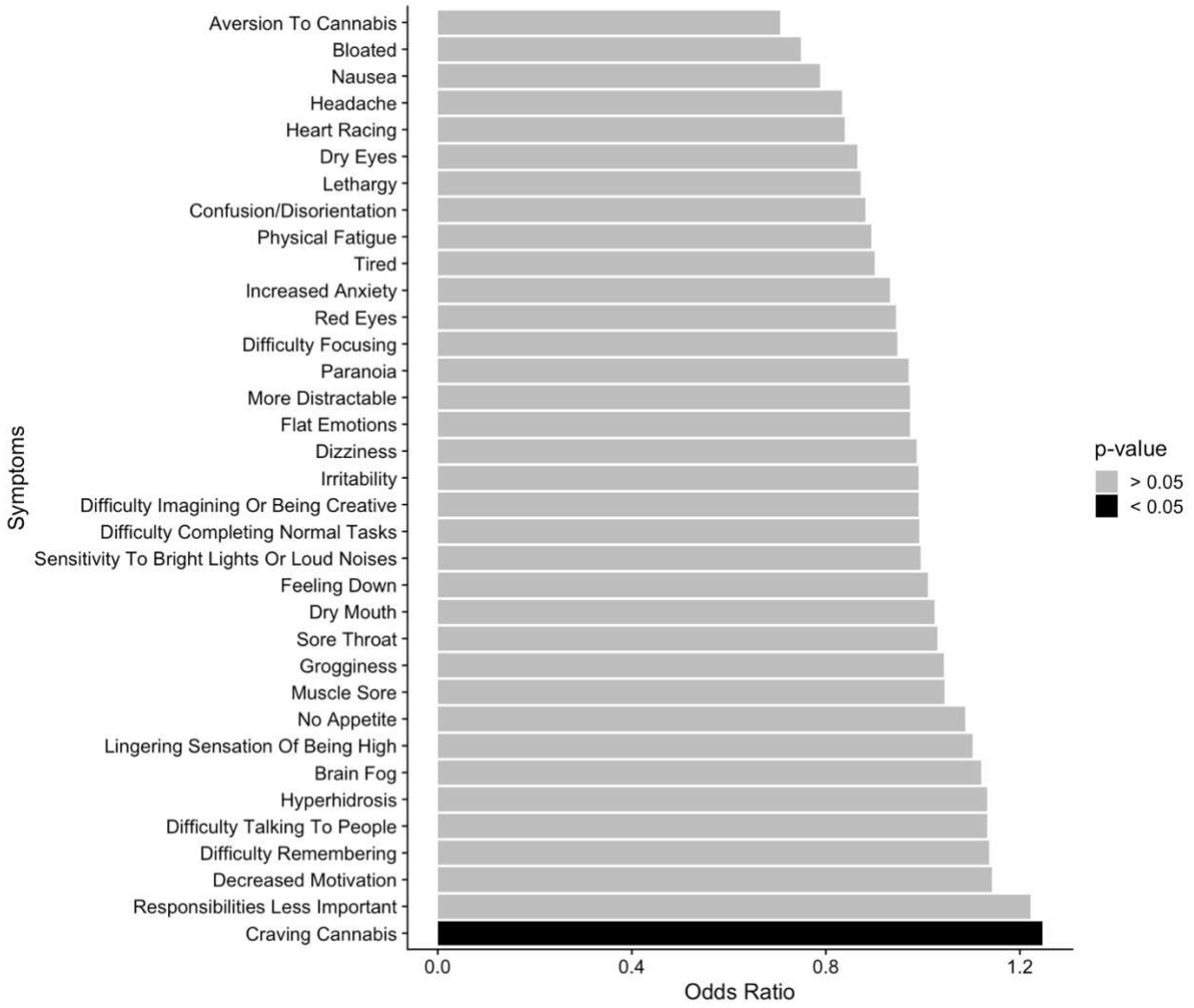

Figure 2

Logistic Regression Models for Typical Dose

Note: Figure 2 presents ORs from 35 logistic regression models. Bars in gray are not significant (p>0.05); bars in black are significant (p<0.05).

Table 1

Count Regression for Typical Dose Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	8.72	6.64 – 11.35	**<0.001**
Typical Dose	0.99	0.93 – 1.06	0.876

Note: CI = 95% confidence intervals, p = p-value.

Table 2

OLS Regression for Typical Dose Predicting Symptom Severity

Predictors	*Estimates*	*CI*	*p*
(Intercept)	4.23	3.66 – 4.79	**<0.001**
Typical Dose	0.07	-0.07 – 0.21	0.350

Note: CI = 95% confidence intervals, p = p-value.

I did not find support for hypothesis 3, as the 30-day frequency of cannabis use did not negatively predict the severity and likelihood of cannabis hangovers. Quite the reverse, 30-day frequency significantly and positively predicted six cannabis hangover symptoms: craving cannabis, grogginess, difficulty remembering, lingering sensation of being high, irritability, and more distractable such that one additional day of cannabis use predicted a 3-4% (OR=1.03–1.04) higher likelihood of these symptoms. 30-day frequency did not significantly predict the remaining 29 symptoms. See figure 3 and table 16 in Appendix G. Additionally, 30-day frequency did not significantly predict the total number of cannabis hangover symptoms or severity of cannabis hangovers. See tables 3 and 4.

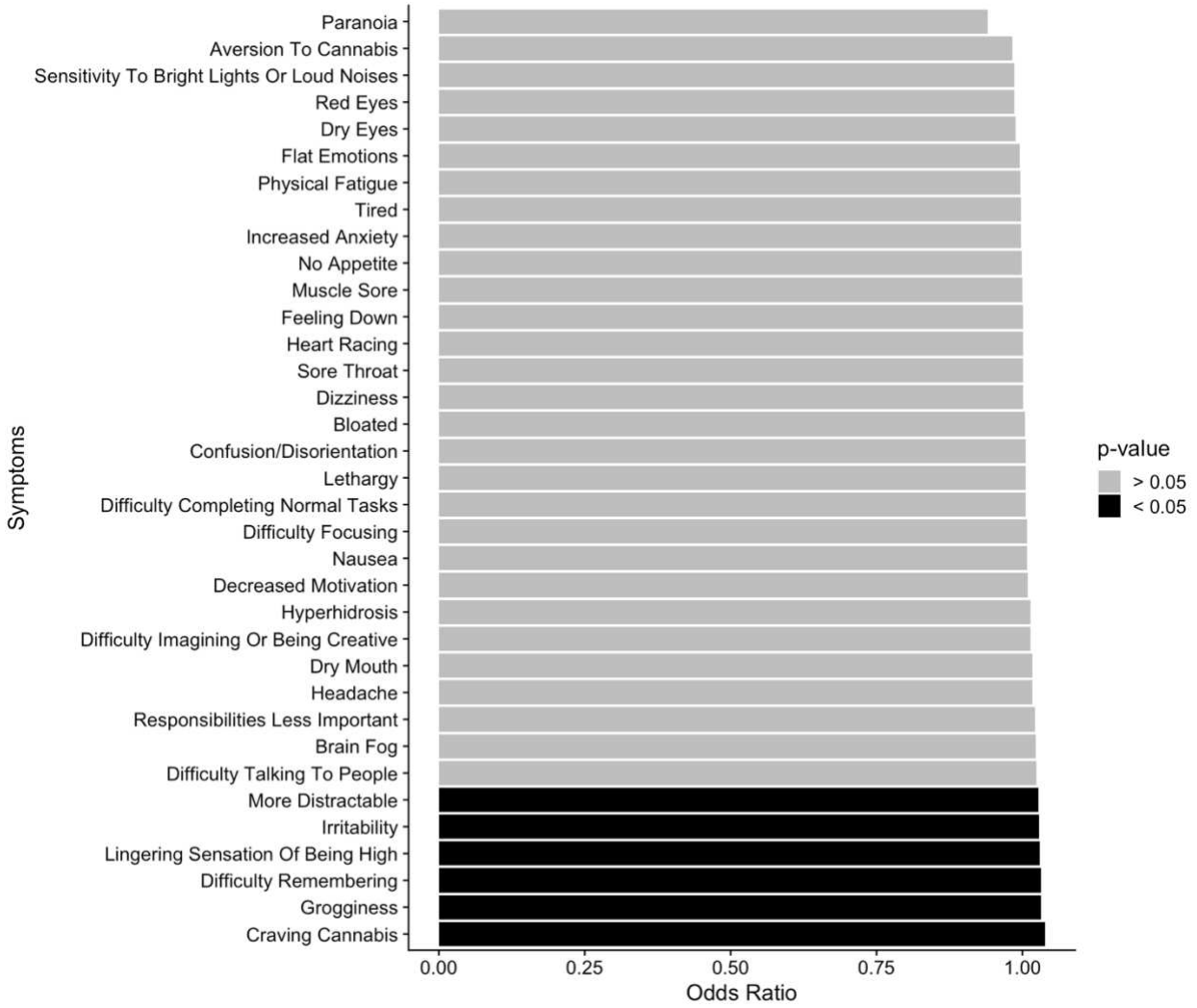

Figure 3

Logistic Regression Models for 30-day Frequency

Note: Figure 3 presents ORs from 35 logistic regression models. Bars in gray are not significant (p>0.05); bars in black are significant (p<0.05).

Table 3

Count Regression for 30-Day Frequency Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	7.82	7.31 – 8.35	**<0.001**
30-Day Frequency	1.01	1.00 – 1.02	0.156

Note: CI = 95% confidence intervals, p = p-value.

Table 4

OLS Regression for 30-Day Frequency Predicting Symptom Severity

Predictors	*Estimates*	*CI*	*p*
(Intercept)	4.62	4.48 – 4.77	**<0.001**
30-Day Frequency	0.00	-0.02 – 0.02	0.949

Note: CI = 95% confidence intervals, p = p-value.

I found some support for hypothesis 4 as the use of edibles, regardless of the use of other consumption types (i.e., not controlling for other consumption types), significantly and positively predicted the likelihood of two cannabis hangover symptoms: dizziness and no appetite. Using edibles predicted a 104% (OR=2.04) higher likelihood of experiencing dizziness and 76% (OR=1.76) higher likelihood of experiencing no appetite compared to not using edibles. I also found evidence against hypothesis 4, as the use of edibles also significantly and negatively predicted the likelihood of headache and craving cannabis. Such that using edibles predicted a 161% (OR=0.62) greater likelihood of not endorsing a headache and a 159% (OR=0.63) greater likelihood of not endorsing craving cannabis compared to not using edibles. Edibles did not significantly predict the remaining 31 cannabis hangover symptoms. See figure 4 and table 17 in Appendix G.

I did not find additional support for hypothesis 4. Edibles, regardless of the use of other consumption types, did not predict the total number of cannabis hangover symptoms or severity of cannabis hangovers. See tables 5 and 6. However, the use of flower, regardless of the use of other consumption types, significantly and positively predicted the total number of cannabis hangover symptoms (IRR=1.26, CI [1.11-1.44], p<.001) such that using flower predicted a 26% higher rate of total number of cannabis hangover symptoms. See table 7. Concentrates did not significantly predict the total number of cannabis hangover symptoms. See table 8.

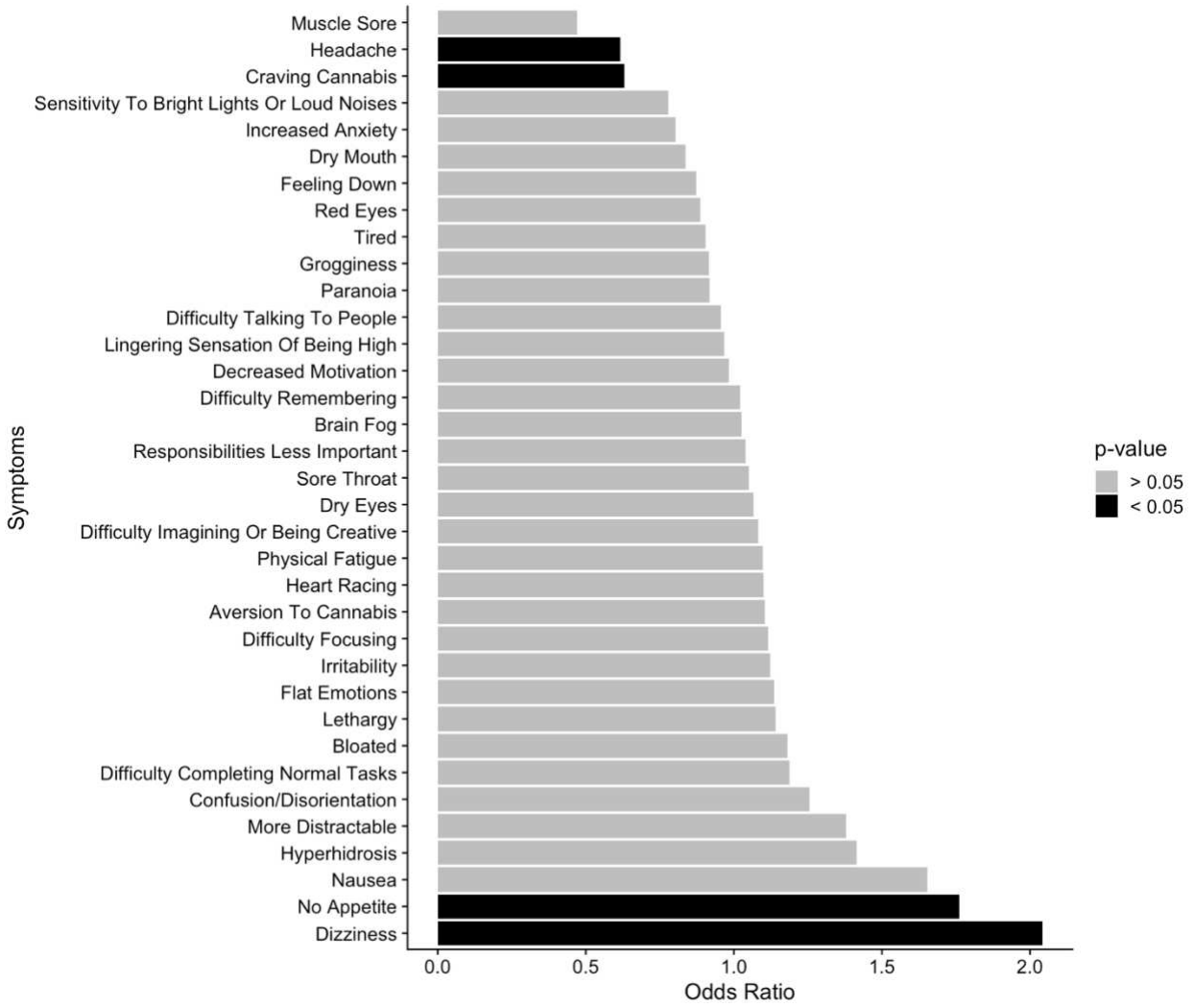

Figure 4

Logistic Regression Models for Edible Use

Note: Figure 4 presents ORs from 35 logistic regression models. Bars in gray are not significant (p>0.05); bars in black are significant (p<0.05).

Table 5

Count Regression for Edible Use Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	7.95	7.37 – 8.56	**<0.001**
Flower Use	1.01	0.89 – 1.14	0.895

Note: CI = 95% confidence intervals, p = p-value.

Table 6

OLS Regression for Edible Use Predicting Symptom Severity

Predictors	*Estimates*	*CI*	*p*
(Intercept)	4.58	4.42 – 4.75	**<0.001**
Edible Use	0.11	-0.16 – 0.38	0.422

Note: CI = 95% confidence intervals, p = p-value

Table 7

Count Regression for Flower Use Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	6.77	6.02 – 7.57	**<0.001**
Flower Use	1.26	1.11 – 1.44	**0.001**

Note: CI = 95% confidence intervals, p = p-value.

Table 8

Count Regression for Concentrate Use Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	7.43	6.75 – 8.16	**<0.001**
Concentrate Use	1.13	1.00 – 1.28	0.051

Note: CI = 95% confidence intervals, p = p-value.

I did not find support for hypothesis 5 as cannabis tolerance did not significantly and negatively predict the severity and likelihood of cannabis hangovers. On the contrary, tolerance significantly and positively predicted the severity and likelihood of cannabis hangovers. Starting with the largest effect, tolerance to cannabis significantly and positively predicted the likelihood of craving cannabis, such that having tolerance to cannabis predicted a 356% (OR=4.56) higher likelihood of craving cannabis compared to not having tolerance to cannabis. Six cannabis hangover symptoms had significant ORs indicating a 113%-197% (OR=2.13-2.97) higher likelihood of occurrence in individuals with cannabis tolerance compared to those without tolerance. These symptoms, in order of greatest to least effect, included difficulty imagining or being creative, difficulty remembering, irritability, bloating, hyperhidrosis (i.e., excessive sweating), and felt like responsibilities are less important. Next, 21 cannabis hangover symptoms

had significant OR's indicating a 32%-99% (OR=1.32-1.99) higher likelihood of occurrence in individuals with cannabis tolerance compared to those without tolerance. These symptoms, in order of greatest to least effect, included flat emotions, tired, muscle soreness, lethargy, more distractable, lingering sensation of being high, feeling down, difficulty completing normal tasks, decreased motivation, brain fog, sore throat, difficulty talking to people, difficulty focusing, confusion/disorientation, nausea, physical fatigue, dizziness, grogginess, red eyes, headache, dry mouth. Tolerance did not significantly predict the likelihood of six cannabis hangover symptoms. See figure 5 and table 18 in Appendix G.

Additionally, I found that cannabis tolerance significantly and positively predicted the total number of cannabis hangover symptoms (IRR=1.43, CI [1.30-1.56], $p<.001$), such that tolerance to cannabis predicted a 43% higher rate of total number of cannabis hangover symptoms compared to no tolerance. See table 9. Tolerance to cannabis did not significantly predict the severity of cannabis hangovers. See table 10.

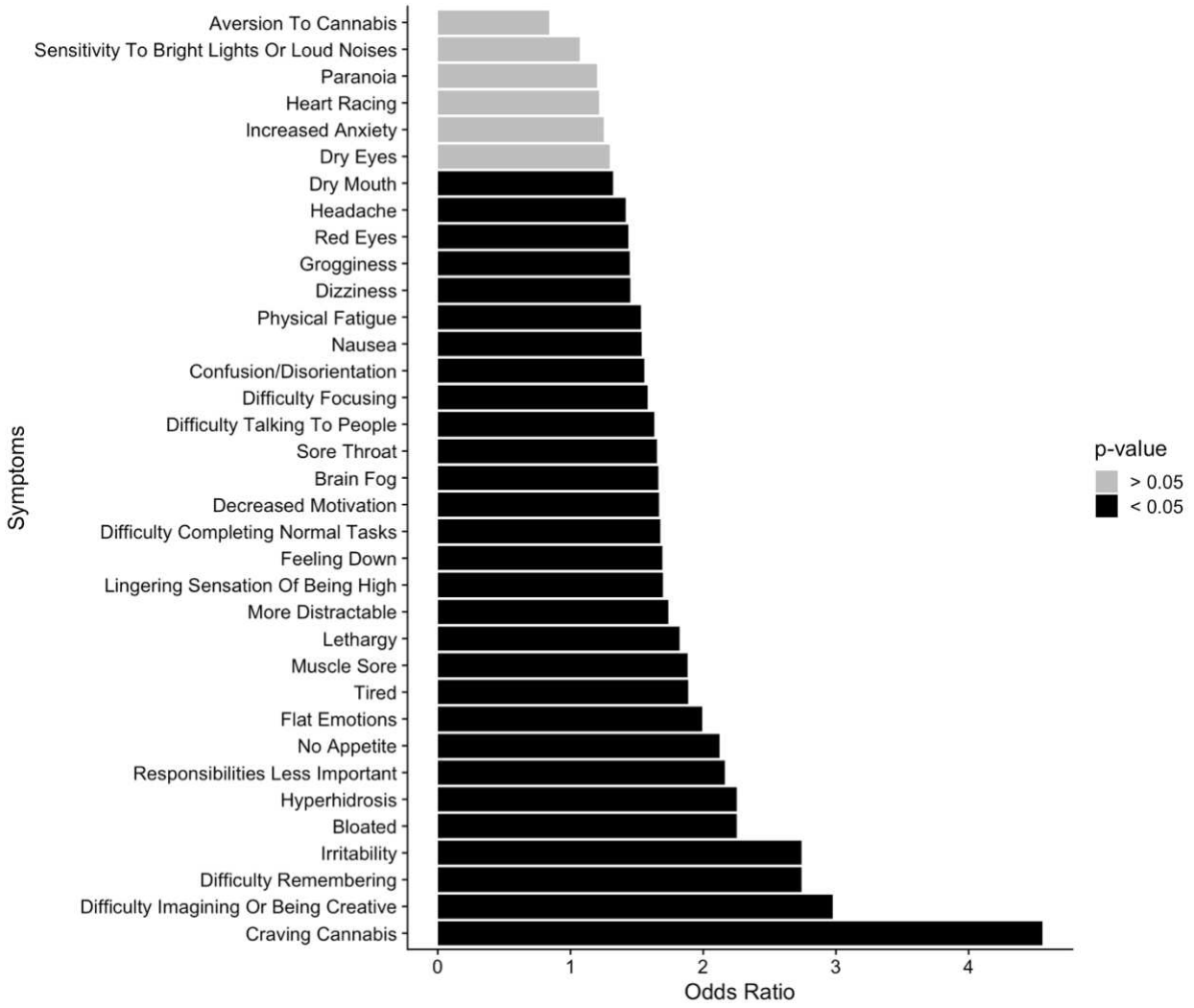

Figure 5

Logistic Regression Models for Tolerance

Note: Figure 5 presents ORs from 35 logistic regression models. Bars in gray are not significant (p>0.05); bars in black are significant (p<0.05).

Table 9

Count Regression for Tolerance Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	6.64	6.27 – 7.03	**<0.001**
Tolerance	1.43	1.30 – 1.56	**<0.001**

Note: CI = 95% confidence intervals, p = p-value.

Table 10

OLS Regression for Tolerance Predicting Symptom Severity

Predictors	*Estimates*	*CI*	*p*
(Intercept)	4.69	4.57 – 4.82	**<0.001**
Tolerance	0.11	-0.11 – 0.33	0.317

Note: CI = 95% confidence intervals, p = p-value

I found support for hypothesis 6 as average PBS frequency significantly and negatively predicted the likelihood of cannabis hangover symptoms. As described above, PBS frequency was measured on a 6-point Likert scale ranging from 1 (never) to 6 (always). Starting with the largest effect, average PBS frequency significantly and negatively predicted the likelihood of craving cannabis, such that an additional 1 unit in PBS frequency predicted an 85% (OR=0.54) greater likelihood of not endorsing craving cannabis. Next, 18 cannabis hangover symptoms had significant ORs indicating a 11-59% (OR=0.63-0.90) greater likelihood of those symptoms not being endorsed for each additional 1 unit in PBS frequency. Those symptoms, from greatest to least effect, included hyperhidrosis, difficulty imagining or being creative, difficulty remembering, felt like responsibilities are less important, irritability, no appetite, difficulty talking to people, flat emotions, feeling down, decreased motivation, lingering sensation of being high, lethargy, sore throat, tired, brain fog, difficulty focusing, grogginess and dry mouth. Average PBS frequency did not significantly predict the remaining 16 symptoms. See figure 6 and table 19 in Appendix G.

I found additional support for hypothesis 6 as average PBS frequency significantly and negatively predicted the total number of cannabis hangover symptoms (IRR=0.91, CI [0.87-0.94], p<.001), such that higher use of PBS predicted a 9% lower rate in total number of cannabis hangover symptoms. See table 11. Average PBS frequency did not significantly predict cannabis hangover severity. See table 12.

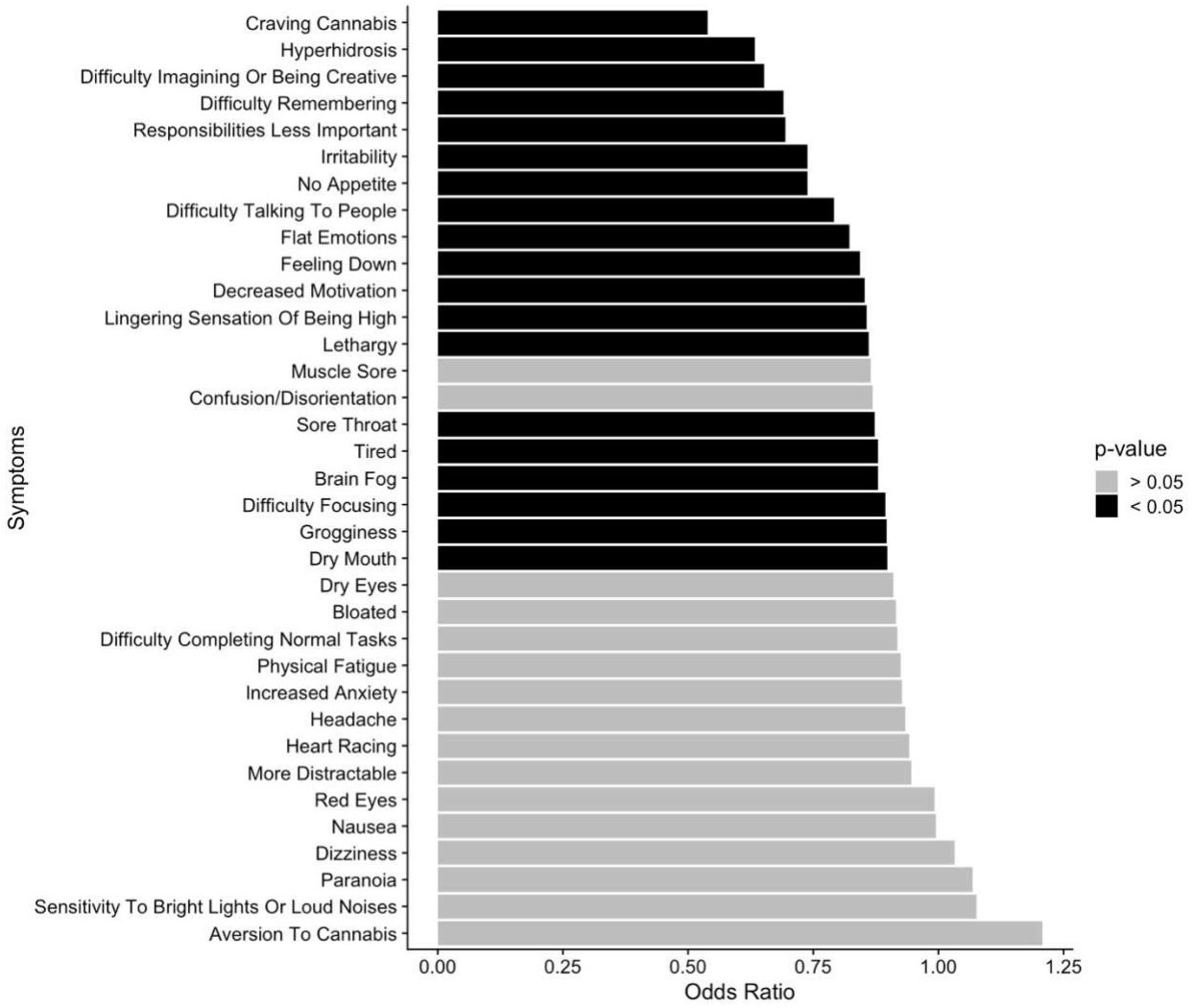

Figure 6

Logistic Regression Models for Average PBS Frequency

Note: Figure 6 presents ORs from 35 logistic regression models. Bars in gray are not significant (p>0.05); bars in black are significant (p<0.05).

Table 11

Count Regression for Average PBS Frequency Predicting Total Number of Symptoms

Predictors	*Incidence Rate Ratios*	*CI*	*p*
(Intercept)	11.67	9.79 – 13.85	**<0.001**
Average PBS Freq	0.91	0.87 – 0.94	**<0.001**

Note: CI = 95% confidence intervals, p = p-value.

Table 12

OLS Regression for Average PBS Frequency Predicting Symptom Severity

Predictors	*Estimates*	*CI*	*p*
(Intercept)	4.78	4.34 – 5.21	**<0.001**
Average PBS Freq	0.01	-0.10 – 0.08	0.834

Note: CI = 95% confidence intervals, p = p-value

Discussion

Cannabis hangover is an understudied topic within the current cannabis literature. Cannabis hangovers are defined as unwanted consequences of cannabis use occurring either the next-day or same day after the acute effects have worn off. The study aimed to provide further understanding of cannabis hangovers by examining the prevalence of cannabis hangover symptoms among a college student sample at Colorado State University, exploring facets of cannabis use (e.g., quantity, frequency, route of administration, tolerance) as predictors, and exploring the associations between protective behavioral strategies (PBS) and cannabis hangover occurrence and severity. Cannabis hangovers were measured using an inventory of 35 potential cannabis hangover symptoms.

In this study, I found evidence to suggest that cannabis hangovers are common among individuals who use cannabis, whereby 91.4% of the sample reported at least one cannabis hangover symptom with a mean total number of symptoms of 7.5 (SD=6.07). These findings were consistent with the preliminary study (McFarland et al., 2023), whereby 97% of the sample reported at least one cannabis hangover symptom with a mean total number of symptoms of 9.51 (SD=6.3). Additionally, I posited and found heterogeneity in both the endorsement of cannabis hangover symptoms and the severity ratings, suggesting that some symptoms are more common and/or are more severe. The five most common symptoms were not ranked among the most severe. The five most severe symptoms indicate that affective symptoms (e.g., paranoia, increased anxiety) and those impacting daily or social functioning (e.g., difficulty completing tasks, difficulty interacting with others) are the most bothersome. Interventions targeting the most severe symptoms could be more effective for motivating change and reducing

consequences of cannabis use, whereas commonly endorsed symptoms may be less impactful if they are not also endorsed as severe.

I found that all predictors predicted the likelihood of experiencing at least 1 cannabis hangover symptom. Cannabis use measures (i.e., 30-day frequency, use of edibles, and typical dose) significantly predicted the likelihood of between 1 to 6 symptoms, whereby all cannabis use measures predicted an overall higher likelihood of experiencing significant symptoms, except for edibles which predicted both a higher likelihood of endorsing some symptoms and a greater likelihood of not endorsing other symptoms. In contrast, average PBS frequency and cannabis tolerance significantly predicted the likelihood of 19 and 29 symptoms respectively, whereby average PBS frequency predicted an overall greater likelihood of not endorsing symptoms and cannabis tolerance predicted an overall higher likelihood of endorsing symptoms. Most cannabis use measures did not significantly predict the total number of symptoms endorsed. Flower was the only cannabis use measure that significantly predicted the total number of symptoms, whereby using flower was had a positive association with symptom count. Average PBS frequency had a significant and negative associated with the total number of symptoms. Tolerance had a significant and positive association with the total number of symptoms.

Overall, cannabis use measures were not the most robust predictors of hangover symptoms. This suggests that cannabis hangovers are not solely a result of cannabis use patterns or types of consumption. Instead, results suggest that tolerance and PBS were the most robust predictors of both cannabis hangover symptoms and the total number of symptoms. Current literature indicates that while cannabis use indicators such as quantity and frequency are moderately associated with consequences, no single indicator explains most of the variance in

cannabis-related consequences. Additionally, an article examining the limitations of current cannabis literature poses that frequency of use does not necessarily indicate problematic use (Temple et al., 2011). The article goes on to suggest that confounding factors such as the social and physical context of use, motivations for use, and subjective effects of intoxication may be more relevant. Identifying other factors that may have strong associations with consequences of cannabis use could provide additional targets of intervention for reducing those consequences. For cannabis hangovers, these findings indicate that tolerance and PBS frequency may be more effective than cannabis use measures at explaining individual differences in the occurrence of hangover symptoms.

I found that tolerance was associated with a higher likelihood of endorsing 29 of the 35 cannabis hangover symptoms, as well a higher rate of the total number of cannabis hangover symptoms. This is the opposite direction of association that I hypothesized, as I expected tolerance to reduce cannabis hangover symptoms. While tolerance decreases sensitivity to the acute effects of cannabis (Colizzi & Bhattacharyya, 2018; Ramaekers et al., 2020), these findings suggest that tolerance is associated with a higher likelihood of experiencing cannabis hangovers. Research suggests that the presence of cannabis dependence and tolerance is associated with an increase in the likelihood of experiencing cannabis withdrawal (Bahji et al., 2020; Levin et al., 2010). Interestingly, some of the hangover symptoms that have a significant and positive association with tolerance overlap with cannabis dependence (e.g., craving cannabis – strongest effect) and withdrawal (e.g., irritability, nausea, physical fatigue, headache). It is possible that cannabis hangovers, withdrawal, and dependence may be associated or even overlap to some degree. Overall, these findings suggest a need to further examine the role of tolerance and its association with consequences of cannabis use.

I found that average PBS frequency was associated with a higher likelihood of not endorsing 19 of the 35 cannabis hangover symptoms and a lower rate of the total number of cannabis hangover symptoms. These results suggest that PBS may be an effective intervention or prevention method to reduce the likelihood of experiencing hangover symptoms. These findings are consistent with previous research that found an association between PBS use and reduction in the negative consequences of cannabis use (Bravo et al., 2017; Prince et al., 2019). Clinically, PBS appears to have important implications in reducing consequences of cannabis use, including hangovers.

Contrary to my hypotheses, I found that none of the predictors were associated with cannabis hangover severity. This finding is surprising given that the average symptom severity in the sample was 4.53 (SD=1.69), suggesting that cannabis hangover symptoms are moderately bothersome. Additionally, research indicates that cannabis use measures (e.g., high THC potency, higher frequency of use, modes of consumption) are associated with increased severity of dependence (Freeman & Winstock, 2015), increased negative cannabis-related consequences (Gunn et al., 2020; Manning et al., 2019; Pearson et al., 2017) and adverse acute effects (Ramaekers, Moeller, et al., 2006). Furthermore, studies suggest that PBS use is negatively associated with negative cannabis-related consequences (Prince et al., 2019; Richards et al., 2022). As described above, confounding factors such as social and physical contexts, motivations for use and subjective effects of intoxication may be associated with cannabis hangover outcomes (i.e., severity). The clinical implications of the subjective severity of hangovers, including its potential to increase motivation for change, combined with the finding that symptoms were, on average, moderately severe, warrant further investigation into indicators of hangover severity.

A strength of this study is the use of advanced statistical techniques (i.e., QP regression) to handle overdispersion of count data that often occurs in substance use research. Although negative binomial regressions are commonly used for count data, research suggests that these models may not be robust to all distributional characteristics of count data (Baggio et al., 2018). More specifically, negative binomial regressions are not robust against outliers, which are commonly found in substance use data. Instead, QP regressions were found to be a valid model for handling situations with outliers and confounding variables. Additionally, as described above, a multiple comparison correction (i.e., an alpha correction) was not applied to avoid the increased likelihood of Type II error and misinterpretation of the data (Perneger, 1998; Rothman, 1990). Bonferroni corrections are overly conservative and risk missing important findings. In fact, Rothman (1990, p.43) argues, "A policy of not making adjustments for multiple comparisons is preferable because it will lead to fewer errors of interpretation when the data under evaluation are not random numbers but actual observations on nature." Further, Perneger (1998) explains that "the Bonferroni method is concerned with the general null hypothesis, which is rarely of interest or use to researchers", "the main weakness [of the Bonferroni correction] is that the interpretation of a finding depends on the number of other tests performed", and "the likelihood of type II errors is also increased, so that truly important differences are deemed non-significant" (p. 1236). Instead, recommendations by Cumming (2011, 2014) were followed by emphasizing effect sizes, confidence intervals and accumulation of evidence to draw interferences from the data. There are a number of advantages to analyzing data using effect sizes, confidence intervals, and accumulation of evidence instead of relying on null hypothesis significance testing to draw conclusions from data (Cumming, 2011, 2014). These advantages include (a) presenting increased information about the magnitude of the effect

and about the precision of estimates presented, (b) exchanging dichotomous decision making for a focus on estimation, (c) avoiding the limitations of relying p- values, e.g., Type I and Type II errors, and (d) ease of integrating findings with other research using meta-analytic strategies.

Another strength of this study is the extension of the current literature on next-day effects of cannabis use (i.e., cannabis hangovers) by incorporating a cannabis hangover symptom questionnaire that captures a wider range of possible symptoms. This expands upon previous studies, which primarily focused on performance on cognitive tests to assess next-day effects (McCartney et al., 2023). Additionally, the study built upon the preliminary study (McFarland et al., 2023) by including PBS and tolerance as predictors, which emerged as the most robust indicators of cannabis hangover symptoms.

While this study expands our current knowledge about cannabis hangovers, the study relied on cross-sectional data, limiting the ability to infer causality. Additionally, there may be other factors (e.g., motivations of use, contextual factors, use of other substances, etc.) that were not included in this thesis project that account for some of the variance in the occurrence and severity of cannabis hangovers. Particularly, alcohol use may be a variable of interest that was not included in this thesis. Alcohol and cannabis co-use is prevalent in college student population (citation). Co-use of alcohol and cannabis is associated with more negative consequences (citation). Symptoms associated with an alcohol hangover overlap with cannabis hangover (e.g., headache, fatigue, nausea, dizziness, sensitivity to light and sound). Role of alcohol…

The sample of this study consisted solely of college undergraduates at Colorado State University and was primarily white (n=1028; 85%), non-Hispanic (n=843; 70%), heterosexual (n=844; 70%), assigned female at birth (AFAB) (n=804; 66%), and 18-24 years old (n=993;

82%), limiting the generalizability of the findings. In 2022, the undergraduate enrollment in the United States was predominately AFAB (58%), white (51%), and non-Hispanic (79%) (National Center for Education Statistics, 2023). While the study's findings may be applicable to U.S. colleges, there is an overrepresentation of white and AFAB students. Research has found that individuals assigned male at birth report using cannabis more frequently and in higher quantities (Cuttler et al., 2016). Additionally, cannabis use is greater among adults who identify as black, native-American and mixed-race (Wu et al., 2016), and those with sexual minority identities (Gonzales, 2020). This suggests that the findings of this thesis may not be generalizable to men, and racial and sexual minority groups. Furthermore, the age range of the sample, primarily young adults, may have impacted the results of the study. The current alcohol literature has found that the severity and frequency of alcohol hangovers decreases with age (Tolstrup et al., 2013; Verster et al., 2021). Similarly, it is possible that young adults may experience a higher frequency and severity of cannabis hangovers. Therefore, the findings of this study are limited to a young adult college population.

The study's inclusion criteria required participants to have used cannabis at least once in their lifetime, allowing a wide range of cannabis use frequencies. However, only cannabis use within the past 30 days was measured to minimize retrospective recall bias. As a result, 45.7% of the sample reported lifetime cannabis use but not past 30-day cannabis use, resulting in a larger sample for analyses that excluded cannabis use measures such as frequency, typical dose and consumption type. Significant effects were found for tolerance and PBS, which were likely influenced by the larger sample size for those analyses. These findings should be interpreted with consideration of the varying sub-sample sizes, as p-values are influenced by sample size.

Recently, leaders in the cannabis field have proposed establishing standardized units of cannabis, such that 5 milligrams (mg) of THC equates to one unit of cannabis (Freeman & Lorenzetti, 2020). The proposed unit of cannabis (i.e., 5 mg of THC) was not used in this thesis project due to concerns about its interpretability, lack of consistency within the current cannabis literature, and loss of information when rounding exact values to the nearest 5 mg. For this thesis project, the mean typical dose was calculated across consumption types using mg of THC consumed. This provided a standardized dose metric across modes of consumption. The advantage of using a standardized dose is that it allows for a systematic analysis of THC's effects on outcome variables, while factoring in both quantity and THC potency. However, this approach has faced criticism due to the challenges of establishing a standardized dose based on the dose of THC, as the pharmacokinetics of cannabis can vary significantly by route of administration (Jugl et al., 2021). As a result, the same dose of THC may result in different experiences depending on the mode of consumption.

While cannabis hangovers are a negative consequence associated with cannabis use, they may not necessarily be harmful. Similar to alcohol hangovers, which deter further alcohol consumption and can act as a protective factor against the development of an alcohol use disorder, cannabis hangovers may serve a similar protective role, particularly for individuals who use cannabis recreationally. There are not many salient short-term consequences of cannabis use that are possible targets of intervention and prevention efforts. As a short-term consequences of cannabis use, cannabis hangovers may provide an opportunity for motivational interviewing, encouraging individuals to change their cannabis use patterns and use PBS strategies to reduce their likelihood of experiencing a cannabis hangover. The resulting behavior change could indirectly lower the risk of developing a cannabis use disorder. For individuals who use cannabis

for medical reasons avoiding hangovers is important, as they may interfere with the therapeutic benefits of cannabis.

Some of the reported symptoms may commonly occur among individuals who do not use cannabis (e.g., tired, grogginess, etc.). Individuals may experience these symptoms due to a variety of factors (e.g., sleep quality, presence of health concerns, stress, alcohol use). While these symptoms may be common, the instructions for the Cannabis Hangover Symptom Questionnaire clearly state: "The following set of questions ask about your experiences following cannabis use, either on the same day after the high has fully worn off or the following day." Therefore, it is assumed that participants are not reporting general symptoms but those specifically related to their cannabis use.

Future studies could benefit from a longitudinal design, such as ecological momentary assessment (EMA), to provide stronger evidence for the directionality and causal relationships between predictors (i.e., cannabis use measures, PBS) and cannabis hangover outcomes. Through repeated measures across time, longitudinal designs can infer processes of cannabis hangovers and allow for within-person analysis. Longitudinal designs with a multivariate focus can help identify confounding variables (e.g., contextual factors, motivations for use, subjective experience of acute effects, alcohol use) and negative consequences of cannabis hangovers (e.g., academic and occupational performance, social functioning), as well as disentangle the direction of causality in their associations with cannabis hangovers. Furthermore, longitudinal designs may help differentiate and clarify the association between cannabis hangover symptoms and cannabis withdrawal.

While there is existing literature on the biological mechanisms related to the acute and chronic effects of cannabis, the biological mechanism of cannabis hangover remains unexplored. Future research should investigate the biological basis of cannabis hangovers, specifically mechanisms underlying symptoms. One hypothesis could be that cannabis withdrawal and cannabis hangovers share overlapping biological mechanisms due to their shared symptomology (e.g., decreased appetite, fatigue, and anxious feelings). Another hypothesis could be that craving cannabis, a symptom that occurs in both cannabis dependence and cannabis hangovers, may have a unified biological mechanism. Exploring the biological basis of these overlapping symptoms could offer insights into the physiological processes underlying cannabis hangovers, withdrawal and dependence, potentially leading to targeted interventions for individuals who experience these symptoms.

Conclusion

Overall, results suggest that cannabis hangovers are a common consequence of cannabis use with moderate severity. This thesis project has provided evidence on the prevalence and severity of cannabis hangovers, as well as their associations with various predictors, within an undergraduate sample. Findings indicate that while cannabis use measures may predict certain cannabis hangover symptoms, tolerance and protective behavioral strategies (PBS) are more robust predictors of both the occurrence and total number of cannabis hangover symptoms. These results suggest that interventions aimed at lowering tolerance and promoting PBS use may be more effective in reducing the occurrence and total number of cannabis hangovers than purely focusing on changing patterns of use. Although several predictors were examined, this study did not identify a significant predictor for cannabis hangover severity. This suggests that there may be confounding variables, such as contextual factors, that better explain cannabis hangover severity. Furthermore, the study highlights potential overlap between symptoms of cannabis hangover, cannabis dependence, and cannabis withdrawal, signifying a need for future research to clarify these associations. As cannabis use continues to be prevalent, it is important to identify and target factors that contribute to cannabis hangovers with the overall aim of reducing cannabis-related consequences.

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Appendix

Appendix A

Screener:

Are you 18 years old or older?

0. No
1. Yes

Have you ever used cannabis?

0. No
1. Yes

Appendix B

Demographic Questionnaire:

Note: This survey is completely anonymous. Your responses will be anonymous and will be kept secure. This information will not be used for a discriminatory purpose.

What is your age in years?

How do you define your Race? Select all that apply:

1. Asian - Eastern
2. Asian – Indian
3. African American
4. Native American
5. White / Caucasian
6. Another_____
7. I prefer not to say

How do you define your Ethnicity?

1. Hispanic or Latinx
2. Not Hispanic or Latinx
3. Another _____
4. Do not wish to respond

How do you define your Sexual Orientation/Preference? Select all that apply:

1. Aromantic
2. Asexual
3. Bisexual
4. Fluid
5. Gay
6. Lesbian
7. Pansexual
8. Queer
9. Questioning or unsure
10. Same-gender-loving
11. Straight (heterosexual)
12. Stud
13. Another _____
14. I prefer not to say

How do you define your Gender Identity? Select all that apply:

1. Man
2. Woman
3. Agender

4. Androgynous
5. Demiboy
6. Demigirl
7. Gender Fluid
8. Gender Non-Binary
9. Gender Non-Conforming
10. Gender Fluid
11. Gender Non-Binary
12. Gender Non-Conforming
13. Genderless
14. Genderqueer
15. Third Gender
16. Trans Man
17. Trans Woman
18. Transgender
19. Transperson
20. Two Spirit
21. Other _____
22. I prefer not to say

What was the sex assigned to you at birth?

1. Male
2. Female
3. Intersex
4. Another _____
5. Do not wish to respond

What is the legal status of cannabis where you live?

1. Recreational and medical use is legal
2. Only medical use is legal
3. Fully illegal
4. Don't know/I'm not sure
5. Do not wish to respond

Do you identify yourself as having any of the following health concerns? Select all that apply:

0. I do not have any health concerns
1. Disability
2. Chronic illness
3. Chronic pain
4. Vision and/or hearing loss
5. Mental health disorder *(for example: post-traumatic stress disorder, substance use disorder)*
6. Attention deficit hyperactivity disorder (ADHD)
7. Diabetes
8. Heart disease
9. Cancer

10. Arthritis
11. Asthma
12. Hypertension
13. Kidney disease
14. Epilepsy
15. Multiple sclerosis
16. Other _____
17. Other _____
18. Other _____
19. Other _____
20. Other _____
21. I prefer not to say

Do you use cannabis medically to help with your health concern(s)?

0. No
1. Yes
2. I prefer not to say

Appendix C

Timeline Follow Back Sample:
In the space provided, please describe your cannabis use over the past four weeks. If you did not use on a day/time, leave that space blank. If you did, list the type and amount used according to the legend. The amount used should be your best approximation. The example shows someone who did not use from 6am-12pm, had about half of a gram of flower from 12pm-6pm, 20 milligrams of edibles from 6pm-12am, and did not use from 12am-6am.

Legend: F = Flower, C = Concentrates, E = Edible, T = Topical, O = Other
Estimate Flower and Concentrates in grams (g), Edibles and Topicals in milligrams (mg)

Example			
6am-12pm	12pm-6pm	6pm-12am	12am-6am
	F.5g	E20mg	

Sunday			
6am-12pm	12pm-6pm	6pm-12am	12am-6am

Monday				Tuesday				Wednesday			
6am-12pm	12pm-6pm	6pm-12am	12am-6am	6am-12pm	12pm-6pm	6pm-12am	12am-6am	6am-12pm	12pm-6pm	6pm-12am	12am-6am

Thursday				Friday				Saturday			
6am-12pm	12pm-6pm	6pm-12am	12am-6am	6am-12pm	12pm-6pm	6pm-12am	12am-6am	6am-12pm	12pm-6pm	6pm-12am	12am-6am

Appendix D

Cannabis Tolerance (items modified from the DSM-5 Checklist: DSM5):

In the past 12 months, I found I needed greater amounts of cannabis than I use to in order to feel intoxicated or to get a desired effect

0. No
1. Yes

In the past 12 months, I got much less of an effect by using the same amount of cannabis as in the past.

0. No
1. Yes

Appendix E

17-item version of the Protective Behavioral Strategies for Marijuana Scale (PBSM-17: Pedersen et al., 2017):

	Please indicate the degree to which you engage in the following behaviors when using marijuana/cannabis.	Never	Rarely	Occasionally	Sometimes	Usually	Always
1	Use marijuana only among trusted peers	1	2	3	4	5	6
2	Avoid use while spending time with family	1	2	3	4	5	6
3	Avoid using marijuana before work or school	1	2	3	4	5	6
4	Avoid using marijuana to cope with emotions such as sadness or depression	1	2	3	4	5	6
5	Limit use to weekends	1	2	3	4	5	6
6	Only purchase marijuana from a trusted source	1	2	3	4	5	6
7	Avoid using marijuana habitually (that is, every day or multiple times a week)	1	2	3	4	5	6
8	Use a little and then wait to see how you feel before using more	1	2	3	4	5	6
9	Avoid mixing marijuana with other drugs	1	2	3	4	5	6
10	Avoid using marijuana in public places	1	2	3	4	5	6
11	Take periodic breaks if it feels like you are using marijuana too frequently	1	2	3	4	5	6
12	Buy less marijuana at a time so you smoke less	1	2	3	4	5	6
13	Have a set amount of "times" you take a hit (e.g., passing on a shared joint if you have already hit that limit)	1	2	3	4	5	6
14	Avoid methods of using marijuana that can make you more intoxicated than you would like (e.g., using large bongs, volcano, 'edibles,' etc.)	1	2	3	4	5	6
15	Only use one time during a day/night	1	2	3	4	5	6
16	Limit the amount of marijuana you smoke in one sitting	1	2	3	4	5	6
17	Avoid using marijuana before engaging in physical activity (i.e., exercise, hiking)	1	2	3	4	5	6

Source: Pedersen, E. R., Huang, W., Dvorak, R. D., Prince, M., Hummer, J. F., & Marijuana Outcomes Study Team. (2017). The Protective Behavioral Strategies for Marijuana Scale: Further examination using Item Response Theory. *Psychology of Addictive Behaviors, 31,* 548-559.

Further reading: Pedersen, E. R., Hummer, J. F., Rinker, D. V., Traylor, Z. K., & Neighbors, C. (2016). Measuring protective behavioral strategies for marijuana use among young adults. *Journal of Studies on Alcohol and Drugs*, *77,* 441–450.

Appendix F

Cannabis Hangover Symptom Questionnaire (CHSQ):

The following set of questions ask about your experiences following cannabis use, either on the same day after the high has fully worn off or the following day.

*Note: This is **not** asking about your experience immediately after using cannabis, but rather how you feel after the high/acute effects of cannabis has fully worn off.*

Symptom Severity:
When you were experiencing this effect, how much did it bother you?

1 ---------- 10
Not bothersome at all Very bothersome

Physical Prevalence:
Please select all effects that you have experienced at least once following cannabis use, either on the same day after the high has worn off or the following day.

1. Headache
2. Tired
3. Dry eyes
4. Dry mouth
5. Sore throat
6. Lethargy
7. Physical fatigue
8. Muscle soreness
9. Nausea
10. Sensitivity to bright lights or loud noises
11. Lingering sensation of being high
12. Dizziness
13. Heart racing
14. Hyperhidrosis (excessive sweating)
15. Feeling bloated
16. No appetite
17. Red eyes
18. None of the above

Cognitive Prevalence:
Please select all effects that you have experienced at least once following cannabis use, either on the same day after the high has worn off or the following day.

1. Grogginess
2. Brain fog
3. Difficulty focusing
4. Decreased motivation

5. Felt like responsibilities are less important
6. Difficulty remembering
7. Difficulty imagining or being creative
8. Confusion/disorientation
9. Difficulty talking to people
10. More distractable
11. Difficulty completing normal tasks
12. None of the above

Affective Prevalence:

Please select all effects that you have experienced at least once following cannabis use, either on the same day after the high has worn off or the following day.

1. Feeling "down"
2. Increased anxiety
3. Craving weed
4. Aversion to weed
5. Flat emotions
6. Irritability
7. Paranoia
8. None of the above

Other Prevalence:

If you have experienced any other negative effects following cannabis use, either on the same day after the high has worn off or the following day, please list them below:

1. Other _____
2. Other _____
3. Other _____
4. Other _____
5. Other _____

Appendix G

Results Tables:

Table 13

Demographic Information

Characteristics	n (%)	Characteristics	n (%)
Sex		Gender	
Female	804 (66%)	Man	357 (30%)
Male	384 (32%)	Woman	786 (65%)
Intersex	1 (<1%)	Agender	3 (<1%)
Race		Androgynous	4 (<1%)
Asian-Eastern	39 (3%)	Demiboy	4 (<1%)
Asian-Indian	11 (<1%)	Demigirl	3 (<1%)
African American	51 (4%)	Gender Fluid	7 (<1%)
Native American	19 (2%)	Gender nonbinary	12 (<1%)
White	1028 (85%)	Gender nonconforming	4 (<1%)
Another	16 (1%)	Genderless	2 (<1%)
Ethnicity		Genderqueer	11 (<1%)
Hispanic	195 (16%)	Third gender	1 (<1%)
Non-Hispanic	843 (70%)	Transman	3 (<1%)
Sexual Orientation		Transwoman	1 (<1%)
Aromantic	7 (<1%)	Transgender	5 (<1%)
Asexual	27 (2%)	Two-Spirit	1 (<1%)
Bisexual	196 (16%)	Another	2 (<1%)
Fluid	11 (<1%)	Age	
Gay	13 (1%)	18-24	993 (82%)
Lesbian	42 (3%)	25-34	8 (<1%)
Pansexual	40 (3%)	35-44	2 (<1%)
Queer	49 (4%)		
Questioning or unsure	30 (2%)		
Same-gender-loving	3 (<1%)		
Heterosexual	844 (70%)		
Stud	10 (<1%)		
Another	9 (<1%)		

Table 14:

Mean Severity of Cannabis Hangover Symptoms

Symptoms	Mean	SD
Increased anxiety	7.08	2.24
Paranoia	6.97	2.36
Difficulty talking to people	6.43	2.43
Heart racing	6.05	2.61
Difficulty completing normal tasks	5.99	2.30
Decreased motivation	5.87	2.43
Difficulty focusing	5.74	2.31
Feeling down	5.69	2.37
Nausea	5.56	2.84
Difficulty remembering	5.56	2.43
Bloated	5.54	2.44
Responsibilities less important	5.51	2.50
Brain fog	5.36	2.29
Irritability	5.34	2.35
Confusion/disorientation	5.29	2.41
Difficulty imagining or being creative	5.22	2.58
Lethargy	5.21	2.15
More distractable	5.13	2.22
Physical fatigue	5.12	2.18
Hyperhidrosis	5.00	2.13
Tired	4.97	2.09
Craving cannabis	4.95	2.47
Aversion to cannabis	4.92	2.91
Grogginess	4.91	2.15
Sensitivity to bright lights or loud noises	4.87	2.21
Lingering sensation of being high	4.82	2.58
Dizziness	4.72	2.43
Sore throat	4.70	2.44
Flat emotions	4.68	2.23
Dry mouth	4.66	2.28
Headache	4.65	2.09
Muscle soreness	4.62	2.30
Dry eyes	4.11	2.16
No appetite	4.07	2.38
Red eyes	3.84	2.62

Note: Table 14 presents results on the average severity for each cannabis hangover symptom. SD = standard deviation.

Table 15

Logistic Regression Models for Typical Dose Predicting Symptoms

		95% Confidence Interval	
Symptoms	**Odds Ratio**	**Lower**	**Upper**
Craving cannabis	**1.25***	1.12	1.39
Responsibilities less important	1.22	1.10	1.36
Decreased motivation	1.14	1.04	1.25
Difficulty remembering	1.14	1.04	1.25
Difficulty talking to people	1.13	1.00	1.28
Hyperhidrosis	1.13	0.87	1.47
Brain fog	1.12	1.02	1.23
Lingering sensation of being high	1.10	1.00	1.22
No appetite	1.09	0.95	1.25
Muscle soreness	1.05	0.80	1.36
Grogginess	1.04	0.95	1.14
Sore throat	1.03	0.92	1.15
Dry mouth	1.02	0.94	1.12
Feeling down	1.01	0.90	1.13
Sensitivity to bright lights or loud noises	1.00	0.84	1.19
Difficulty completing normal tasks	0.99	0.88	1.12
Difficulty imagining or being creative	0.99	0.85	1.16
Irritability	0.99	0.89	1.10
Dizziness	0.99	0.86	1.14
Flat emotions	0.97	0.88	1.08
More distractable	0.97	0.88	1.07
Paranoia	0.97	0.84	1.12
Difficulty focusing	0.95	0.86	1.04
Red eyes	0.94	0.86	1.04
Increased anxiety	0.93	0.84	1.03
Tired	0.90	0.82	0.99
Physical fatigue	0.89	0.81	0.99
Confusion/disorientation	0.88	0.77	1.00
Lethargy	0.87	0.78	0.98
Dry eyes	0.86	0.78	0.96
Heart racing	0.84	0.74	0.96
Headache	0.83	0.75	0.93
Nausea	0.79	0.67	0.93
Bloated	0.75	0.64	0.88
Aversion to cannabis	0.71	0.57	0.88
Significance Levels.		*p<0.05, **p<0.01	

Note: Table 15 presents results from 35 logistic regression models.

Table 16

Logistic Regression Models for 30-Day Frequency Predicting Symptoms

		95% Confidence Interval	
Symptoms	**Odds Ratio**	**Lower**	**Upper**
Craving cannabis	**1.04****	1.02	1.05
Grogginess	**1.03***	1.02	1.05
Difficulty remembering	**1.03****	1.02	1.04
Lingering sensation of being high	**1.03***	1.02	1.04
Irritability	**1.03***	1.01	1.04
More distractable	**1.03***	1.01	1.04
Difficulty talking to people	1.02	1.01	1.04
Brain fog	1.02	1.01	1.04
Responsibilities less important	1.02	1.01	1.04
Headache	1.02	1.00	1.03
Dry mouth	1.02	1.00	1.03
Difficulty imagining or being creative	1.01	0.99	1.04
Hyperhidrosis	1.01	0.98	1.04
Decreased motivation	1.01	1.00	1.02
Nausea	1.01	0.99	1.03
Difficulty focusing	1.01	0.99	1.02
Difficulty completing normal tasks	1.01	0.99	1.02
Lethargy	1.01	0.99	1.02
Confusion/disorientation	1.01	0.99	1.02
Bloated	1.00	0.98	1.03
Dizziness	1.00	0.98	1.02
Sore throat	1.00	0.99	1.02
Heart racing	1.00	0.98	1.02
Feeling down	1.00	0.99	1.02
Muscle soreness	1.00	0.97	1.03
No appetite	1.00	0.98	1.02
Increased anxiety	1.00	0.98	1.01
Tired	1.00	0.98	1.01
Physical fatigue	1.00	0.98	1.01
Flat emotions	1.00	0.98	1.01
Dry eyes	0.99	0.97	1.00
Red eyes	0.99	0.97	1.00
Sensitivity to bright lights or loud noises	0.99	0.96	1.01
Aversion to cannabis	0.98	0.95	1.02
Paranoia	0.94	0.91	0.97
Significance Levels.		*p<0.05, **p<0.01	

Note: Table 16 presents results from 35 logistic regression models.

Table 17

Logistic Regression Models for Edible Use Predicting Symptoms

		95% Confidence Interval	
Symptoms	**Odds Ratio**	**Lower**	**Upper**
Dizziness	**2.04****	1.59	2.62
No appetite	**1.76***	1.38	2.25
Nausea	1.65	1.24	2.21
Hyperhidrosis	1.41	0.94	2.13
More distractable	1.38	1.14	1.66
Confusion/disorientation	1.26	0.99	1.59
Difficulty completing normal tasks	1.19	0.95	1.48
Bloated	1.18	0.88	1.58
Lethargy	1.14	0.93	1.40
Flat emotions	1.14	0.94	1.38
Difficulty focusing	1.12	0.94	1.32
Irritability	1.12	0.91	1.39
Physical fatigue	1.10	0.91	1.32
Heart racing	1.10	0.86	1.41
Aversion to cannabis	1.10	0.77	1.59
Difficulty imagining or being creative	1.08	0.81	1.46
Dry eyes	1.07	0.89	1.28
Sore throat	1.05	0.85	1.30
Responsibilities less important	1.04	0.85	1.27
Brain fog	1.03	0.87	1.21
Difficulty remembering	1.02	0.86	1.21
Decreased motivation	0.98	0.83	1.16
Lingering sensation of being high	0.97	0.80	1.16
Difficulty talking to people	0.96	0.76	1.21
Grogginess	0.92	0.78	1.08
Paranoia	0.92	0.70	1.20
Tired	0.90	0.76	1.08
Red eyes	0.89	0.75	1.05
Feeling down	0.87	0.71	1.07
Dry mouth	0.84	0.71	0.98
Increased anxiety	0.80	0.66	0.97
Sensitivity to bright lights or loud noises	0.78	0.57	1.05
Craving cannabis	**0.63***	0.51	0.77
Headache	**0.62***	0.50	0.76
Muscle soreness	0.47	0.29	0.75
Significance Levels.		*p<0.05, **p<0.01	

Note: Table 17 presents results from 35 logistic regression models.

Table 18

Logistic Regression Models for Tolerance Predicting Symptoms

		95% Confidence Interval	
Symptoms	**Odds Ratio**	**Lower**	**Upper**
Craving cannabis	**4.56****	3.90	5.33
Difficulty imagining or being creative	**2.97****	2.36	3.75
Difficulty remembering	**2.74****	2.39	3.14
Irritability	**2.74****	2.33	3.23
Bloated	**2.25****	1.81	2.81
Hyperhidrosis	**2.25****	1.62	3.12
Responsibilities less important	**2.16****	1.85	2.53
No appetite	**2.13****	1.75	2.58
Flat emotions	**1.99****	1.72	2.31
Tired	**1.89****	1.64	2.18
Muscle soreness	**1.88***	1.41	2.50
Lethargy	**1.82****	1.55	2.13
More distractable	**1.74****	1.50	2.01
Lingering sensation of being high	**1.69****	1.47	1.95
Feeling down	**1.69****	1.46	1.96
Difficulty completing normal tasks	**1.68****	1.41	2.00
Decreased motivation	**1.67****	1.46	1.90
Brain fog	**1.66****	1.46	1.88
Sore throat	**1.65****	1.41	1.93
Difficulty talking to people	**1.63****	1.37	1.94
Difficulty focusing	**1.58****	1.39	1.80
Confusion/disorientation	**1.56****	1.31	1.85
Nausea	**1.54***	1.26	1.88
Physical fatigue	**1.53****	1.33	1.76
Dizziness	**1.45***	1.21	1.74
Grogginess	**1.45****	1.28	1.64
Red eyes	**1.44****	1.26	1.64
Headache	**1.42****	1.23	1.63
Dry mouth	**1.32***	1.16	1.50
Dry eyes	1.29	1.12	1.49
Increased anxiety	1.25	1.09	1.44
Heart racing	1.22	1.01	1.47
Paranoia	1.20	1.01	1.44
Sensitivity to bright lights or loud noises	1.07	0.86	1.32
Aversion to cannabis	0.84	0.64	1.09
Significance Levels.		*p<0.05, **p<0.01	

Note: Table 18 presents results from 35 logistic regression models.

Table 19

Logistic Regression Models for Average PBS Frequency Predicting Symptoms

		95% Confidence Interval	
Symptoms	**Odds Ratio**	**Lower**	**Upper**
Craving cannabis	**0.54****	0.50	0.58
Hyperhidrosis	**0.63****	0.56	0.72
Difficulty imagining or being creative	**0.65****	0.59	0.72
Difficulty remembering	**0.69****	0.65	0.73
Responsibilities less important	**0.70****	0.65	0.74
No appetite	**0.74****	0.68	0.80
Irritability	**0.74****	0.69	0.79
Difficulty talking to people	**0.79****	0.74	0.85
Flat emotions	**0.82****	0.77	0.87
Feeling down	**0.84****	0.79	0.90
Decreased motivation	**0.85****	0.81	0.90
Muscle soreness	0.86	0.77	0.98
Lethargy	**0.86***	0.81	0.92
Lingering sensation of being high	**0.86****	0.81	0.91
Sore throat	**0.87***	0.82	0.93
Confusion/disorientation	**0.87***	0.81	0.93
Brain fog	**0.88****	0.84	0.93
Tired	**0.88***	0.83	0.93
Difficulty focusing	**0.89***	0.85	0.94
Dry mouth	**0.90***	0.85	0.95
Grogginess	**0.90***	0.85	0.94
Dry eyes	0.91	0.86	0.96
Physical fatigue	0.92	0.87	0.98
Difficulty completing normal tasks	0.92	0.85	0.99
Bloated	0.92	0.83	1.01
Headache	0.93	0.88	0.99
Increased anxiety	0.93	0.87	0.98
Heart racing	0.94	0.87	1.02
More distractable	0.95	0.89	1.01
Nausea	0.99	0.91	1.08
Red eyes	0.99	0.94	1.05
Dizziness	1.03	0.96	1.12
Paranoia	1.07	0.99	1.15
Sensitivity to bright lights or loud noises	1.08	0.98	1.18
Aversion to cannabis	1.21	1.08	1.35
Significance Levels.		*p<0.05, **p<0.01	

Note: Table 19 presents results from 35 logistic regression models.

Table 20

Descriptive Statistics of Cannabis Use Variables

Variable	n	Mean	SD	Min	Median	Max
30-day frequency	657	2.91	6.19	0.00	0.00	30.00
Mean typical dose (mg of THC)		127.56	229.16	0.17	45.3	1980.00
Mean dose of edibles (mg)		22.99	38.79	0.01	10.00	283.33
Mean dose of flower (mg)		240.57	242.12	2.80	178.91	1164.37
Mean dose of concentrates (mg)		244.70	351.98	0.01	125.00	1980.00
Consumption types:						
Edible use	236					
Flower use	449					
Concentrate use	375					

Note: Table 20 presents descriptive statistics of cannabis use variables.