THESIS

ASSOCIATIONS BETWEEN NUMBER OF STANDARD DOSES OF TETRAHYDROCANNABINOL, CANNABIS USE MOTIVES AND CANNABIS-RELATED NEGATIVE CONSEQUENCES

Submitted by

Alexander J. Tyskiewicz

Department of Psychology

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2022

Master's Committee:

Advisor: Bradley Conner

Mark Prince
Nathaniel Riggs
Sara Tompkins

ABSTRACT

ASSOCIATIONS BETWEEN NUMBER OF STANDARD DOSES OF TETRAHYDROCANNABINOL, CANNABIS USE MOTIVES AND CANNABIS-RELATED NEGATIVE CONSEQUENCES

Objective: Recently, the National Institutes of Health published a notice of information regarding the establishment of a standard unit of Tetrahydrocannabinol (THC) to be used in research. To address this notice, the current study examined if associations between cannabis use and cannabis related consequences and cannabis use motives would differ when using standard dose as a measure of cannabis use compared to cannabis use frequency. I hypothesized that there would be a positive significant relation between each cannabis use motive and cannabis-related consequences. I hypothesized significant positive relations between motives and number of standard doses. I hypothesized that the positive relation between motives and cannabis-related consequences would be partially mediated by cannabis use as measured by standard dose but not cannabis use frequency. I also hypothesized that none of the cannabis use motives would significantly predict cannabis use frequency, cannabis use frequency would not predict cannabis-related negative consequences, and cannabis use frequency would not mediate the relation between cannabis use motives and cannabis-related negative consequences. Method**:** I conducted five path analyses to test study hypotheses in a sample of individuals (n=84) who reported regular to heavy cannabis use. I ran non-inferiority tests to test hypotheses of non-significance. Results: Coping motives significantly positively predicted cannabis-related consequences

($b=0.376$, $SE=0.136$, $p=0.006$), such that a one-unit increase in coping motives was expected to increase cannabis-related consequences by a factor of 1.45 (45%). Number of standard doses significantly positively predicted cannabis-related consequences ($b=0.24$, $SE=0.122$, $p=0.046$) such that a one-unit increase in number of standard doses was expected to increase cannabis-related negative consequences by a factor of 1.27. (27%). In the social motives model, social motives significantly positively predicted cannabis-related negative consequences ($b=.358$, $SE=.133$, $p=.007$) such that a one-unit increase in social motives was expected to increase cannabis related consequences by a factor of 1.43 (43%). Also, social motives significantly positively predicted number of standard doses ($b=0.3$, $SE=0.097$, $p=0.002$) such that a one-unit increase in social motives was expected to increase the number of standard doses by a factor of 1.349 (35%). Enhancement motives significantly positively predicted cannabis-related consequences ($b=0.406$, $SE=0.161$, $p=0.012$) such that a one-unit increase in enhancement motives was expected to increase cannabis related consequences by a factor of 1.50 (50%). Further, rate ratios (RR) revealed that one unit increases in number of standard doses ingested predicted larger increases in cannabis-related negative consequences than did one unit increases in cannabis use frequency across all models with significant results. All indirect effects were not significant. Conclusion: Previous research has reported mixed findings on the relations between cannabis use frequency and motives and cannabis use and consequences. Results suggest that number of standard doses and cannabis use frequency differ in the ways in which they predict both cannabis use motives and cannabis-related negative consequences. Further, results suggest that neither number of standard doses nor cannabis use frequency mediate relations between cannabis use motives and cannabis-related consequences.

AKNOWLEDGEMENTS

I would like to thank my advisor, Bradley T. Conner Ph.D., who has placed more faith in me than I could have ever expected.

To Mark A. Prince Ph.D. and Nathaniel R. Riggs. Your guidance throughout this process has been invaluable to me.

To my partner Allison. Thank you for always believing in me and being there for me. Thank you for making my life beautiful and meaningful. I love you.

To my father, mother, brother, and friends. I have endless appreciation for your love and support.

TABLE OF CONTENTS

Introduction

Tetrahydrocannabinol (THC) is the primary psychoactive component of cannabis and partially determines the extent to which an individual becomes intoxicated via the use of cannabis products (National Academies of Sciences, Engineering, and Medicine, 2017). Intoxication via cannabis occurs when THC naturally found in the cannabis plant binds to the cannabinoid receptors in the central nervous system, mainly the Cannabinoid-1 (CB1) receptor (Iversen, 2003). THC is likely associated with cannabis-related negative consequences (Freeman & Lorenzetti, 2020). To analyze how THC is associated with cannabis-related negative consequences, researchers must assess how specific doses of THC predict negative consequences (Freeman & Lorenzetti, 2020). Cannabis use is typically measured by assessing cannabis use frequency (Volkow & Weiss, 2020). Research suggests that cannabis potency is positively associated with cannabis-related negative consequences (Lafaye et al., 2017; Pierre, 2017). Measures of cannabis use frequency and quantity fail to consider the potency of cannabis products and are therefore unrepresentative of THC ingestion. This is problematic because the failure to consider THC ingestion limits our understanding of problematic use. Understanding nuances of problematic use leads to better treatment and prevention outcomes. Therefore, a comprehensive measure of cannabis use that considers THC ingestion is warranted. Temple and colleagues (2010) argue that results from studies that utilize measure of frequency lead to a lack of detailed knowledge about overall patterns of use, which contributes to a failure to explain the differences between cannabis users. More Specifically, the assumption that individuals who are using more frequently and/or larger quantities are consuming more THC than individuals using less frequently, or smaller quantities may often be incorrect because of the lack of consideration of product potency (Temple et al., 2010).

Theory states that cannabis-related negative consequences come from intoxicating effects of THC. Two variables that contribute to THC ingestion are cannabis use quantity and cannabis product potency. The inclusion of these variables provides a more comprehensive picture of how much THC is in the products that individuals use. If differences in THC use are not examined and these differences are associated with cannabis-related variables, the associations between THC use and cannabis-related variables will go undetected.

Freeman and Lorenzetti (2020) proposed that 5mg of THC should be considered a standard dose of cannabis (Freeman & Lorenzetti, 2020). Accurately measuring dose is an essential part of drug related research, as it allows us to examine how varying levels of THC use predict cannabis related consequences. Measuring doses ingested is done when studying virtually all drugs except cannabis (Turner, 1990; Brämswig et al., 1990; Nielsen, Degenhardt, Hoban, & Gisev, 2014; Miller et al., 2014). Measures of cannabis use frequency and quantity fail to indicate the degree to which the active chemical in cannabis (THC) is ingested (Volkow & Weiss, 2020; Freeman & Lorenzetti, 2020). Therefore, using a measure that represents THC ingestion cannabis use via self-reported quantity and potency data is warranted (Volkow & Weiss, 2020). Converting THC use to number of standard doses ingested may increase the extent to which research inform cannabis users about how to evade cannabis-related negative consequences (Freeman & Lorenzetti, 2020).

The Psychoactive Effects of Cannabis

Cannabis intoxication varies significantly across individuals (Hall et al., 2001). Further, the effects and duration of cannabis intoxication depend upon several variables including THC ingestion, method of consumption, tolerance to the psychoactive components of cannabis, interactions with other substances (for example, alcohol), expectations of intoxication, attitudes towards intoxication, the setting in which an individual uses, mental health status, and emotional state (National Academies of Sciences, Engineering, and Medicine, 2017), among others.

Along with intoxication, motivations to use cannabis and cannabis-related outcomes vary across users (Hall et al., 2001; Schwartz et al., 1989). Individuals who seek cannabis intoxication often do so to cope with unwanted emotions, enhance their enjoyment of experiences, make social situations more enjoyable, alter their perceptual awareness or conform to the use patterns of people around them (Bonar et al., 2017). Individuals who use cannabis also commonly report experiencing relaxation, euphoria, and perceptual alterations (Hall et al., 2001). Effects of cannabis intoxication on cognition include decreased attention and short-term memory (Schwartz et al., 1989). Researchers have also found that intoxication results in impairments in motor skills, reaction time, motor coordination and general psychomotor activity (Hall et al., 2001).

Duration of intoxication also varies as a result of biological differences and use patterns (National Academies of Sciences, Engineering, and Medicine, 2017). Researchers have shown that the duration of cannabis intoxication can sometimes last for less than one hour after ingestion for individuals who use often or those using smaller quantities, while individuals who use infrequently or larger quantities may experience intoxication for several hours (National Academies of Sciences, Engineering, and Medicine, 82017). Further, the cognitive impairments of cannabis intoxication have been shown to last more than 24 hours in some individuals (Hall et al., 2001).

Methods for Measuring Cannabis

Research on cannabis quantifies use in several different ways. Common methods include measuring cannabis use frequency (number of days used in the past 30; Bonn-Miller, Zvolensky, & Bernstien, 2007), quantity of cannabis use in weight (number of grams used in the past 7 days; Pedersen et al., 2012), and time spent under the influence of cannabis (momentary changes in subjective intoxication; Padovano et al., 2018).

The most common way to measure cannabis use is by measuring how often cannabis is used, or cannabis use frequency (Casajuana et al., 2016). This is done in a variety of different ways, the most common method being to measure the number of days individuals used cannabis in the past 30. One frequently used measure of past 30-day use is the Marijuana Smoking History Questionnaire (Bonn-Miller, Zvolensky, & Bernstein, 2007). Other measures of frequency include past 60-day use (Walker et al., 2006), past 90-day use (Levy et al., 2004), past six month use (Bechtold et al., 2015), past year use (Arria et al., 2016) and lifetime use (Zvolensky et al., 2006). However, frequency (measured as number of days in a given time period) is a problematic measure of cannabis use because it has a false ceiling. In other words, if the measure assesses how many days in the last 30 an individual has used cannabis, 30 is the limit and, without a measure of how many times per day or how much cannabis is used on a given day, individuals who use cannabis daily at small doses are classified the same as individuals who uses daily, at high doses, or multiple times per day. Therefore, if individuals using fewer doses endorse different cannabis use motives and experiences with cannabis-related consequences than individuals that use cannabis daily, who use a higher number of standard doses, results will not detect associations between use and other cannabis-related variables.

Measures of cannabis use quantity assess the weight of cannabis products that individuals use (Asbridge et al., 2014). One way cannabis use quantity has been measured is number of joints smoked per day (Zeisser et al., 2012). In another study, participants were asked to report the number of quarter ounces of cannabis they ingested in an average month (Walden & Earleywine, 2008). A major limitation of measuring the quantity of cannabis individuals use is that it fails to consider potency, i.e., the amount of THC in the cannabis products being used. Lastly, it does not account for error in the reporting of cannabis quantity. Research has shown that the most people overestimate the quantity they use (Prince, Conner, & Pearson, 2018).

While some studies solely measure quantity or frequency of cannabis use, other, more thorough techniques involve using multiple methods of measurement concurrently. The Timeline Followback method asks participants to report the amount of cannabis they use in four-hour time blocks over a specified number of days (Pedersen et al., 2012). Other studies have taken both frequency and quantity into consideration but measure them separately with different scales or surveys (Cuttler & Spradlin, 2017; Asbridge et al., 2014; Chen, Kandel & Davies, 1997). The Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU) measures age of onset, frequency, and cannabis use quantity concurrently (Cuttler & Spradlin, 2017). However, a limitation of these measures is that they fail to consider the potency of the cannabis being used. This is a limitation because the extent to which a person is affected by cannabis is largely dependent on the potency of the cannabis they use.

Potency is defined as the concentration of THC in any given cannabis product (McLaren et al., 2008). Prior research has shown that cannabis potency is associated with mental and physical health outcomes (Prince & Conner, 2019). Further, research suggests that increases in the potency of cannabis is related to the increase of cannabis-related negative consequences (Lafaye et al., 2017; Pierre, 2017).

Other less common ways of measuring cannabis utilize the detection of biological markers. For example, THC content can be detected in oral fluid (Niedbala et al., 2001). This type of measure can reliably indicate if a person has or has not consumed cannabis but does not indicate the amount of THC that individuals ingest (Moore et al., 2011). Cannabis use can be identified via urine analysis (Cone et al., 1987; Cone et al., 1988; Schwartz et al., 1985), and blood samples. (Huestis et al., 1992). These methods, however, are also not without their limitations. They carry with them issues regarding accessibility and biological variability among participants. For example, the rate at which people metabolize THC differs depending on an individual's body. Therefore, researchers are unable to detect how much THC an individual ingested with these tests. Further, samples are much more difficult to obtain and process than self-report data. The accessibility of self-report data allows researchers to collect data more efficiently.

Quantity and potency are two main indicators of THC use. Therefore, failure to consider either of these variables would lead to an incomplete picture of how THC use relates to cannabis-related negative consequences. Therefore, it is imperative to adopt new methods of measuring cannabis use that more accurately depict THC ingestion while maintaining accessibility so that researchers can examine links between THC ingestion and cannabis-related consequences.

Cannabis Use Motives

The theory of substance use motives posits that individuals use substances as a method of attaining desired states or outcomes or evading undesired states or outcomes (Cooper et al., 2016). One method of understanding why individuals use substances is to examine motivations individuals have for using substances (Simons et al., 1998). Research on motivations for substance use examines the specific states and outcomes that motivate use. As potential states and outcomes precede the motivations for use, individual dispositions and states of need can influence the motivations individuals experience. These individual dispositions and states of need are preceded by the unique ways in which individuals feel and behave. Moreover, the underlying needs and desires that use addresses shape substance use behaviors (Cooper et al., 2016).

Two dimensions used to organize varying kinds of motives are used across virtually all models of substance use motives (Cooper, 2016). First, there is the distinction between achieving positive incentives and evading negative incentives (Votaw & Witkiewitz, 2021). Second, there is the distinction between behaviors motivated by internal drives or external ones associated with social goals (Mahu et. al., 2021). Each motive can be described as belonging to either the positive reinforcement or negative reinforcement group, and either the self (internal) or social (external) group (Cooper, 2016). Most models of substance use motives include only motives that can be applied to these groups, while some models of motives have included motives that do not apply to these classifications. Motives that do not apply to these four groups usually refer to automatic conditioning (Cooper, 2016).

Several models of cannabis use motives have been developed (Newcomb et al., 1988; Simons et al., 1998; Comeau et al., 2001; Lee et al., 2009). Each of these models includes motivations of positive reinforcement and negative reinforcement that include ones applying to both the self internally and social externally. These models are similar to the model of alcohol use motives developed by Cox and Klinger (2004) because they all include motives that are either the same or closely related to coping, enhancement, social, and conformity motives. One clear difference between cannabis use motive models and the alcohol use model of Cox and Klinger (2004) is the inclusion of motives associated with expanding consciousness, inducing, or increasing creativity, and increasing openness to new things. This addition to prior models of alcohol use may be a result of the capacity for cannabis to induce “psychedelic” effects (Simons et. al., 2000). Simons and colleagues (1998) utilize “expansion” motives as a measure to assess the presence of these motivations within cannabis users. Like enhancement motives, expansion motives can be described as motives driven by self-directed positive reinforcement motives.

Cooper and colleagues (2016) developed five fundamental premises of substance use that can be applied to motivations for cannabis use. 1) individuals use substances in order to change their effective states, 2) individuals adopt beliefs regarding how certain substances affect them, which influences the presence of the motives that precede use, 3) individuals chose whether to use or not, and how much to use a substance in order to attain outcomes, 4) the varying functions and needs that use serves represents psychologically distinct behaviors that are characterized by unique patterns of antecedents and correlates and by unique patterns of use and use-related consequences, and 5) motives provide the final common pathway to substance use through which the influences of more distal variables are mediated.

Cooper’s 1st premise (that individuals use to change their effective states) has been supported regarding cannabis by prior research validating the existence of various cannabis use motives. The endorsement of motives like coping (Bonn-Miller et. al., 2008) support Cooper’s claim in so far as they show that individuals report using to manage and change their effective states (Comeau, 2001).

Cooper’s 2nd premise (that individuals adopt beliefs regarding how certain substances affect them, which influences the presence of the motives that precede use) has been supported in regard to cannabis by research establishing the associations between cannabis use expectances and cannabis use motives (Torrealday et. al., 2008), as it serves as evidence that beliefs about what individuals expect to experience when using cannabis are associated with the motivations for using cannabis that they endorse (Buckner & Schmidt, 2008). Other researchers agree that cannabis use expectancies motivate future substance use (Brown, 1993). The motivational model of Social Learning Theory (Bandura, 1969; 1986) asserts that outcome expectancies drive motivated behavior. This principle applies to substance use behaviors (Brown, 1993) and more specifically cannabis use behaviors (Buckner & Schmidt, 2008).

Research on alcohol use motives and alcohol use has supported Cooper's 3rd premise, that individuals choose to use or not and how much to use in order achieve certain outcomes (Cooper et. at., 2016). That is, prior research has shown that motives predict the amount of ethanol (active ingredient in alcohol) individuals use uniquely. This supports Cooper's third premise because if motives drive use and moreover the amount individuals use, different motivations to use should predict varying levels of use. Cooper's 3rd premise has yet to be examined regarding THC, but research on the association between cannabis use motives and cannabis frequency, quantity, and potency provide some evidence for Cooper's 3rd premise regarding cannabis.

The ways in which cannabis use motives relate to cannabis use frequency are currently unclear, as mixed results are common across studies (Bresin & Mekawi, 2019; Cooper et al., 2016: Buckner, 2013). A recent meta-analysis found that, across 45 studies, cannabis use frequency was significantly positively associated with enhancement, expansion, social, coping motives, but not conformity motives when not controlling for other variables. (Bresin & Mekawi, 2019). When Brensin and Mekawi (2019) adjusted for other motives, only coping, enhancement, and expansion were significantly positively associated with use, while conformity motives were significantly negatively associated with use frequency.

Other research has found significant relations between social, enhancement, coping, and expansion motives with cannabis use frequency (Buckner et al., 2007). Conformity motives have been found to have no significant association with cannabis use frequency in several studies (Simons et al., 1998; Bresin & Mekawi, 2019). While some studies have found there to be no significant relation, several studies have found conformity motives to negatively predict cannabis use (Bresin & Mekawi, 2019). Further, while some studies have found social motives to predict cannabis use, other studies have found there to be no significant relation (Cloutier, Blumenthal, & Mischel, 2016). Overall, the relations among conformity and social motives with cannabis use frequency are inconsistent. For example, these motives have been shown to have positive, negative, and nonsignificant relations with cannabis use frequency (Buckner, 2013; Bonn-Miller et al., 2007; Fox et al., 2011).

Several studies have examined the associations between cannabis use motives and cannabis use quantity. A recent metanalysis found that across 7 studies, coping was positively associated with cannabis use quantity (Brensin, 2019). Brensin (2019) also found that across 6 studies, enhancement and social motives were positively associated with cannabis use quantity, while conformity and expansion motives were not significantly associated with cannabis use quantity. While it has been established that motives predict the frequency and quantity at which individuals use, the associations between motives and THC use have not been established.

Cooper's 4th conclusion includes the notion that distinct motives are associated with consequences uniquely. Research has shown that the ways in which each motive predicts consequences are distinct (Stevens et. al., 2021; Schultz et. al., 2019; Halter et. al., 2022; Anderson et. al., 2015). For example, coping motives have been shown to have a stronger association with cannabis-related negative consequences than other cannabis use motives (Bravo et. al., 2019; Blevins et. al., 2016; Bresin & Mekawi, 2019).

A recent meta-analysis (Pearson, 2019) found that across 19 studies, there was only a medium size correlation between cannabis use frequency and cannabis use problems. This finding is thought by some to indicate that motives might explain why individuals experience consequences over and above use itself (Bresin et. al., 2019). For example, coping motives have a stronger association with negative consequences than other cannabis use motives (Blevins et. al., 2016), which may be because individuals who are using to cope don't have healthy methods of coping with distress, which is related to consequences (Corbin et. al., 2013). Moreover, for individuals who don't have effective coping strategies, the use of substances to cope may inhibit the developing healthy coping strategies (Fox et. al., 2011).

Cooper (2016) posits that the reason motives are associated with use is because varying doses of the active ingredients are necessary to complete certain goals (Cooper et. at., 2016). That is, the effective dose of cannabis necessary to cope with distress may on average be greater than the effective dose of cannabis necessary to enhance a positive experience. Therefore, it follows that specific motives vary in their association with the number of doses individuals ingest. Moreover, research has shown cannabis use motives predict cannabis use frequency and cannabis use quantity. Therefore, motives likely predict number of standard doses of THC as well.

Research has shown that cannabis use motives predict cannabis use uniquely. For example, coping, enhancement, and social motives are consistently associated with cannabis use quantity. Moreover, the strengths of these association vary (Bresin & Mekawi, 2019). Conformity and expansion motives are often found to not predict cannabis use quantity (Stevens et. al., 2021), while enhancement motives are more strongly associated with cannabis use quantity than other motives (Bresin & Mekawi, 2019). The ways in which motives are associated with cannabis use quantity differ from the associations each motive has with cannabis use frequency. Specifically, coping, enhancement, and expansion motives are associated with cannabis use frequency to varying extents (Bresin & Mekawi, 2019). Coping motives are more strongly associated with cannabis use frequency than other motives.

Research on the associations between cannabis use motives and use frequency, potency, and quantity, and Cooper's (2016) 3rd premise suggest that cannabis use motives are likely associated with THC use. Research using measures of cannabis use (frequency, potency, and quantity) have been shown to predict consequences suggests that similarly, THC is likely associated with cannabis-related negative consequences. Research has shown that cannabis use motives are uniquely associated with cannabis-related negative consequences. If motives predict THC use and THC use predicts consequences, THC us may mediate the association between motives and consequences. If THC use mediates the association between cannabis use motives and cannabis-related consequences, THC use may explain variance in consequences where other measures of cannabis use do not (Pearson, 2019).

Varying kinds of use predict consequences uniquely. The effect size of the association between cannabis-related negative consequences and cannabis use frequency is of medium size (Pearson 2019), while the effect size of the association between cannabis use quantity and cannabis-related negative consequences is small (Bravo et. al., 2020).

Prior research has demonstrated that motives predict consequences uniquely. As motivations to use lead to use, and use leads to consequences, use may partially explain the association between motives and consequences. Prince and colleagues (2018) concluded that most of the variability in alcohol-related negative consequences is not explained by alcohol use and stated that other predictors of use besides frequency and quantity should be examined. Similarly, Pearson (2019) concluded that single indicators of cannabis use did not account for most of the variance in cannabis related negative consequences and called for the examination of other predictors of cannabis-related negative consequences. Therefore, examining if a more comprehensive measure of cannabis use that considers quantity and potency is a more robust predictor how individuals experience consequences is warranted. Testing if number of standard doses mediation mediates the association between motives and consequences in a model that includes frequency is warranted, as it helps us to identify if number of standard doses is useful for predicting cannabis-related negative consequences above and beyond measures of frequency.

Cannabis Dose

Recent research has proposed that 5mg of THC should be considered a standard dose of cannabis (Freeman & Lorenzetti, 2020). While this is the first attempt at defining a standard dose of cannabis, there are examples of standard doses for other substances. For example, the standard dose for alcohol was created to allow the accurate quantification of the amount of active ingredients a person ingests (Cooper, 1999). The standard drink was partially developed to show true relations between doses of alcohol and alcohol related consequences (Kalinowski & Humphreys, 2016). The standard dose of alcohol helps individuals track how much alcohol results in specific alcohol related consequences (Carruthers & Binns, 1992). Moreover, the development of the standard dose of alcohol can help individuals identify when they are not capable of driving a car safely. Similarly, if a standard dose of cannabis is developed, it could help researchers examine how number the standard doses of cannabis relates to specific consequences, and help individuals mitigate the consequences they experience.

A standardized measure of cannabis dose is necessary to advance research on cannabis-related negative consequences (Volkow & Weiss, 2020). Further, research regarding standard dose could potentially help those using cannabis ingest the desired amount of cannabis, which would in turn help those who use cannabis for medical purposes to control for dose, allowing them to experience the helpful benefits they desire, and reducing the extent to which they experience unwanted consequences as a result of ingesting more THC than intended (Freeman & Lorenzetti, 2020).

Current Study

The purpose of this study was to test if relations among cannabis use motives and cannabis-related negative consequences were mediated by standard dose to clarify the role cannabis use plays in associations between motives and cannabis-related negative consequences. Based on the literature reviewed, I hypothesized that each motive would positively predict cannabis-related negative consequences, and that standard dose would meditate those relations. I hypothesized that the positive relation between motives and cannabis-related negative consequences would be partially explained by the positive relation between motives and number of standard doses used, followed by the relation between standard dose and cannabis-related negative consequences. I hypothesized that standard dose would predict cannabis related negative consequences in the coping, expansion, conformity, social, and enhancement models. I tested the hypotheses that each motive would positively predict cannabis related negative consequences, standard dose would meditate those relations, and that standard dose would predict cannabis related negative consequences in all 5 models. I also hypothesized that none of the cannabis use motives would significantly predict cannabis use frequency. I hypothesized that cannabis use frequency would not predict cannabis-related negative consequences, and that cannabis use frequency would not mediate the relation between cannabis use motives and cannabis-related negative consequences.

Method

Participants and Procedures

Participants. Members of cannabis consumption clubs and customers at cannabis dispensaries (N=169) in Denver and Longmont, Colorado participated in a study examining cannabis use behaviors, self-reported outcomes, and related variables (e.g., cannabis use motives).

Procedure. At the data collection events, participants completed several self-report surveys on laptops provided by the research team. Participants were sent virtual links to receive $10 Amazon gift cards following their participation. Participants self-reported identifying as 50.7% female and aged 22 to 64 (M = 30.27 years old, SD = 7.53). All participants provided informed consent before participation and this study was approved by the university's internal review board.

Measures

Product Information and Typical use Patterns Survey. Participants completed the Product Information and Typical use Patterns survey which was designed for this study. The survey assesses the quantity, strain, %THC (Δ9- tetrahydrocannabinol concentration), %CBD (cannabidiol concentration) and product type of the cannabis products that participants report using, cannabis use frequency and dispensary purchase information. Lastly, participants were asked to report if their purchase was typical and how much money they usually spend on a typical trip to a dispensary. Information on participant's cannabis use across a typical week was used to calculate the average number of standard doses an individual ingests in a day. 5mg of THC was considered one standard dose of cannabis. To calculate the milligrams of THC ingested, product potency (%THC) was multiplied by the quantity of cannabis used in grams and divided by 1000. Number of standard doses consumed was then calculated by dividing the number of milligrams consumed by 5.

Timeline Follow-back questionnaire. Participants completed the Timeline Follow-back questionnaire (Pedersen et al., 2012), which assesses the potency and quantity of cannabis use and alcohol use by asking participants to report the quantity of cannabis and alcohol they used during six-hour time blocks. The Timeline Follow-back assessed both cannabis use and alcohol use two weeks prior to the administration of the brief survey.

Marijuana Motives Measure. Participants completed the Marijuana Motives Measure**,** a 25-item scale that assesses 5 types of motivation for cannabis use by asking participants to endorse motives they have experienced in the past 30-days (MMM; Simons et al., 1998). Participants indicated how frequently they used cannabis for each motive. Each item indicated the extent to which participants used for each of the five different motives. Potential responses included 1 (almost never/never), 2 (some of the time), 3 (half of the time), 4 (most of the time) and 5 (almost always/always). The sum of the responses from the questions regarding each motive were calculated to express the total scores for each motive. This questionnaire assesses the extent to which participants experience social motives, conformity motives, enhancement motives and coping motives for cannabis use.

Marijuana Consequences Questionnaire. Participants completed the Marijuana Consequences Questionnaire (MACQ) (Simons et al., 2012). The MACQ asks participants if they have experienced 50 cannabis-related negative consequences in the past 30 days. Participants are given the choice to respond 1 = “yes” or 0 = “no”. To calculate a total score, sums of all endorsed items were assessed. Higher scores indicated a greater number of negative consequences experienced.

Analysis Plan

I first tested direct effects without controlling for other variables. Second, I ran 5 path analyses testing if frequency mediates the associations between each cannabis use motive and cannabis related negative consequences. Next, I ran 5 path analyses testing if number of standard doses used mediates the associations between each cannabis use motive and cannabis related negative consequences. I then conducted 5 path analyses to test the study hypotheses that cannabis use mediates the relation between cannabis use motives and cannabis-related negative consequences. More specifically, I ran five mediation models in which cannabis use frequency and number of standard doses consumed served as indicators of cannabis use. Cannabis use motives, cannabis use frequency, and number of standard doses used were scored on a continuous scale. Cannabis-related negative consequences were specified as a negative binomial count variable, as it is a positively skewed count variable. These analyses were completed using Mplus 7.4 (Muthén & Muthén, 1998–2012). Number of standard doses consumed was not normally distributed. Therefore, number of standard doses was binned to into 10^{th} percentiles, which gave the variable a uniform distribution Given cannabis-related negative consequences was specified as a negative binomial, exponentiation of regression coefficients was used to produce incident rate ratios expressing the percent change in cannabis-related consequences for every one-unit change in the accompanying predictor variables. Mediation was tested through examination of indirect effects, which is described below.

To test the hypotheses that each motive would positively predict cannabis related negative consequences, standard dose would meditate those relations, and that standard dose would predict cannabis related negative consequences in all 5 models, I examined p-values and Bayesian credible intervals. Bayesian credible intervals have a greater degree of natural probability interpretations than confidence intervals. A 95% credible interval can be interpreted as a 95% probability that the interval includes the true value of the parameter (Yuan & MacKinnon, 2009). If p-values were less than .05 and confidence intervals did not include 0 relations were considered significant, and hypotheses supported.

Traditional hypothesis testing aims to decrease the chances of making a type I error, (i.e., finding a false positive) (Walker & Nowacki, 2011). Therefore, traditional hypothesis testing would be less conservative in testing if my hypotheses of non-significant effects are supported and increase the chances of making a type II error.

To test the hypotheses that none of the cannabis use motives would significantly predict cannabis use frequency, I conducted non-inferiority tests. Non-inferiority tests are conducted by comparing the Bayesian Credible Intervals to a standardized interval representing a trivial effect. For normal regressions, i.e., paths where the dependent variable was normally distributed, the non-inferiority test compared the Bayesian Credible Interval to the range -.1, .1, because a standardized regression coefficient β is considered small if it is equal to or greater than .1 (Cohen, 1992), so I considered β values less than the absolute value of .1 to be trivial. Further, if the bounds of the Bayesian Credible Interval around the standardized estimate from my model estimate overlapped the range of -1 – 1, non-inferiority was considered established, the effect size was considered to be trivial and provided support for the hypotheses.

To test the hypothesis that cannabis use frequency would not predict cannabis-related negative consequences, I had to first choose an effect size that indicated a meaningful vs. non-meaningful effect (i.e., trivial), as there is currently no established method of discerning effect sizes of rate ratio. As cannabis-related consequences were measured as a count variable ranging from 0 – 30, and 30 was the maximum number of consequences that an individual could endorse, a one unit decrease from endorsing 30 consequences to 29 consequences was considered the smallest clinically meaningful change that could be indicated via rate ratios. This change would be expressed as a rate ratio of .033, which translates to an interval from 0.967 to 1.033 indicating a trivial (non-meaningful) effect. I assessed if the bounds of exponentiated unstandardized confidence intervals overlapped the range of 0.967 – 1.033.

A widely agreed upon effect size for indirect effects has not been established. Vacha-Haase and Thompson (2004) argue that effect sizes for indirect effects should be on a meaningful metric, include confidence intervals, and not vary as a result of sample size. Measures of effect size of indirect effects may be evaluated by the extent to which they abide by these three parameters. Moreover, Preacher and Kelly (2011) argue that measures of effect size should likely be both standardized and bounded. Current measures of effect size for mediation violate these rules to varying extents. For example, the most widely used method of expressing effect size for indirect effects is via informal descriptors, including perfect, complete, and partial mediation (Mathieu & Taylor, 2006). This method violates the rule of utilizing meaningful scaled metrics. Further, they fail to provide confidence intervals, as they are not numerical. Lastly, informal descriptors are dependent on effect size, as they are reliant on the statistical significance of c' (Preacher & Kelley, 2011). Ratio measures of relative magnitude include scales that are uninterpretable. Partially Standardized and completely standardized measures of indirect effects do not violate the three stated parameters, but are not ideal, as they are not bounded. Indices of explained variance violate the rule of being on a meaningful metric. Another measure of effect size is Hansen and McNeal's (1996) Effect Size Index for Two Groups. This measure is not bounded and includes scaling that is not interpretable (Preacher & Kelly, 2011).

To test the hypothesis that cannabis use frequency would not mediate the relation between cannabis use motives and cannabis-related negative consequences, the effect size of the indirect effect was examined. In the absence of an established and agreed upon effect size for an indirect effect, to test non-inferiority for indirect effects, I created a range that indicated the difference between a trivial and non-trivial indirect effect based on the criteria described above for the a- and b-paths. The "A" path in my model (motives predicting frequency) was normal and therefore used the cutoffs for β values. Conversely, the B path (frequency predicting cannabis-related negative consequences) was considered a negative binomial count variable, and therefore produced logit values instead of β values. Note that logits were transformed into Rate Ratios to interpret the direct effects, but in this section, I use the logits as that is what is used in the calculation of the indirect effects. Logits and β's are on different scales. Indirect effects are established through the product of coefficients method (MacKinnon et al., 2002). In the case where the a-path is a normal regression and the b-path is a negative binomial regression, the product of coefficients is the product of an unstandardized regression coefficient and a logit. In order to approximate this product and determine a threshold for a trivial indirect effect, I determined the value of the unstandardized regression coefficient that corresponded to a standardized β of .1 and then multiplied that value times the value of the logit described above which indicates a small effect. This product was then comparable to the Bayesian Credible Interval in Mplus, which is used to determine significance of the indirect effect. If Bayes confidence intervals of the indirect effect overlapped this range, non-inferiority was considered established, and hypotheses supported.

Results

Isolated A-Path Direct Effects:

I first tested the direct effects of the A-path for each mediation model, which was each motive predicting number of standard doses and each motive predicting cannabis use frequency. Conformity motives (b=-0.230 SE=0.112 p=0.020 CI=[-0.439, -0.005]) was significantly negatively associated with cannabis use frequency. Coping motives (b=0.200, SE=0.120, p=0.090, CI=[-0.090, 0.353]), expansion (b=0.119, SE=0.122 p=0.240 CI=[-0.175, 0.277], social motives (b=0.123, SE=0.122, p=0.220, CI=[-0.167, 0.278]), and enhancement motives (b=0.077, SE=0.123, p=0.320, CI=[-0.214, 0.255]) did not significantly predict cannabis use frequency.

Table 1

Path Analysis of Direct Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Fre on Cop	0.200	0.120	0.090	[-0.090, 0.353]	1.22	[1.094, 1.423]
Fre on Conf	0.230	0.112	0.020	[-0.439, -0.005] *	1.25	[1.551, 1.005]
Fre on Soc	0.123	0.122	0.220	[-0.167, 0.278]	1.13	[1.181, 1.321]
Fre on Enha	0.077	0.123	0.320	[-0.214, 0.255]	1.08	[1.238, 1.291]
Fre on Expa	0.119	0.122	0.240	[-0.175, 0.277]	1.12	[1.191, 1.319]

Note: Fre = Cannabis use frequency; Enha = Enhancement Motives; Cop = Coping Motives; Conf = Conformity Motives; Soc = Social Motives; Expa = Expansion Motives; SE = standard error.

Coping motives (b=0.262, SE=0.117, p=0.05, CI=[-0.024, 0.414]), conformity motives (b=0.125, SE=0.117, p=0.470 CI=[-0.194, 0.135]), enhancement motives (b=0.245, SE=0.120, p=0.040 CI=[-0.055, 0.430]) and expansion motives (b=0.283, SE=0.116, p=0.030 CI=[-0.018, 0.298]) did not significantly predict number of standard doses used. Social motives (b=0.311, SE=0.115, p=0.020, CI=[0.006, 0.473]) significantly positively predicted number of standard doses used.

Table 2

Path Analysis of Direct Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
SD on Coping	0.262	0.117	0.050	[-0.024, 0.414]	1.29	[1.024, 1.512]
SD on Conf	0.125	0.122	0.022	[-0.167, 0.282]	1.13	[1.181, 1.325]
SD on Social	0.311	0.115	0.020	[0.006, 0.473]*	1.36	[1.006, 1.604]
SD on Enha	0.245	0.120	0.050	[-0.055, 0.430]	1.27	[1.056, 1.537]
SD on Expan	0.283	0.116	0.030	[-0.003, 0.439]	1.32	[1.003, 1.551]

Note: Fre = Cannabis use frequency; Enha = Enhancement Motives; Cop = Coping Motives; Conf = Conformity Motives; Soc = Social Motives; Expa = Expansion Motives; SD = Number of standard doses used; SE = standard error.

Isolated B-Path and C-Path Direct Effects:

I then tested my B-path, which was number of standard doses predicting cannabis-related negative consequences. Number of standard doses was significantly positively associated with cannabis-related negative consequences (b=0.199, SE=0.121, p<0.001 CI=[0.048, 0.380]).

I then tested the C-path, which was the association between each motive and cannabis-related negative consequences. Coping motives (b=0.562, SE=0.089, p<0.001, CI=[0.309, 0.674]), conformity motives (b=0.340, SE=0.113, p<0.001, CI=[0.036, 0.495]), social motives (b=0.558, SE=0.090, p<0.001, CI=[0.305, 0.674]), expansion motives (b=0.404, SE=0.107, p<0.001, CI=[0.111, 0.555]), and enhancement motives (b=0.301, SE=0.118, p<0.001, CI=[0.211, 0.704]) were significantly positively associated with cannabis-related negative consequences.

Table 3

Path Analysis of Direct Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Cop	0.562	0.089	0.000	[0.309, 0.674] *	1.75	[1.362, 1.962]
Cons on Conf	0.340	0.113	0.000	[0.036, 0.495] *	1.40	[1.036, 1.640]
Cons on Soc	0.558	0.090	0.000	[0.305, 0.674] *	1.74	[1.356, 1.962]
Cons on Enha	0.301	0.118	0.030	[0.001, 0.480] *	1.35	[1.001, 1.616]
Cons on Expa	0.404	0.107	0.000	[0.111, 0.555] *	1.49	[1.117, 1.741]
Cons on SD	0.199	0.121	0.000	[0.048, 0.380] *	1.22	[1.049, 1.462]

Note: Fre = Cannabis use frequency; Enha = Enhancement Motives; Cop = Coping motives; Conf = Conformity motives; Social = Social motives; Enha = Enhancement motives; Expa = Expansion motives; SD = number of standard doses used; SE = standard error.

Coping Motives Frequency Single Mediation Model.

Direct Effects. In the single mediation coping motives model, cannabis use frequency was significantly associated with cannabis-related negative consequences (b=0.367, SE=0.149, p=0.005, CI=[0.045, 0.646], and coping motives were significantly associated with cannabis-related negative consequences (b=0.481, SE=0.150, p<0.001, CI=[0.196, 0.757]. Coping motives were not significantly associated with cannabis use frequency (b=0.204, SE=0.131, p=0.090, CI=[-0.086, 0.440]).

Indirect Effects. Cannabis use frequency did not significantly mediate the association between coping motives and cannabis-related negative consequences.

Table 4

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.367	0.149	0.005	[0.045, 0.646] *	1.44	[1.046, 1.907]
Cons on Cop	0.481	0.150	0.000	[0.196, 0.757] *	1.61	[1.216, 2.131]
Fre on Cop	0.204	0.131	0.090	[-0.086, 0.440]	1.22	[1.089, 1.552]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.012	0.011	0.095	[-0.007, 0.039]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; Cop = Coping motives; Ind Eff = Cannabis-related negative consequences IND number of standard doses used Coping; SE = standard error.

Social Motives Frequency Single Mediation Model.

Direct Effects: In the single mediation social motives model, cannabis use frequency was significantly associated with cannabis-related negative consequences (b=0.332, SE=0.181, p=0.010, CI=[0.049, 0.776], and social motives were significantly associated with cannabis-related negative consequences (b=0.527, SE=0.143, p<0.001, CI=[0.273, 0.840]. Social motives were not significantly associated with cannabis use frequency (b=0.104, SE=0.134, p=0.250, CI=[-0.151, 0.353]).

Indirect Effects. Cannabis use frequency did not significantly mediate the association between social motives and cannabis-related negative consequences.

Table 5

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.332	0.181	0.010	[0.049, 0.776] *	1.39	[1.050, 2.172]
Cons on Soc	0.527	0.143	0.000	[0.273, 0.840] *	1.69	[1.313, 2.316]
Fre on Soc	0.104	0.134	0.250	[-0.151, 0.353]	1.11	[1.162, 1.423]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.006	0.011	0.240	[-0.011, 0.031]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Enha = Enhancement Motives; Ind Eff = Cannabis-related negative consequences IND cannabis use frequency Social; SE = standard error.

Expansion Motives Frequency Single Mediation Model.

Direct Effects: In the single mediation expansion motives model, cannabis use frequency was significantly associated with cannabis-related negative consequences (b=0.412, SE=0.197, p=0.015, CI=[1.021, 2.279], and expansion motives were significantly associated with cannabis-related negative consequences (b=0.456, SE=0.168, p<0.001, CI=[0.118, 0.779]. Coping motives were not significantly associated with cannabis use frequency (b=0.095, SE=0.124, p=0.215, CI=[-0.111, 0.349]).

Indirect Effects. Cannabis use frequency did not significantly mediate the association between conformity motives and cannabis-related negative consequences (b=0.005, SE=0.010, p=0.230, CI=[-0.009, 0.028]).

Table 6

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.412	0.197	0.015	[0.021, 0.824] *	1.51	[1.021, 2.279]
Cons on Expa	0.456	0.168	0.000	[0.118, 0.779] *	1.57	[1.125, 2.179]
Fre on Expa	0.095	0.124	0.215	[-0.111, 0.349]	1.10	[1.117, 1.417]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.005	0.010	0.230	[-0.009, 0.028]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; Expa = Expansion Motives; Indirect Effect 1 = Cannabis-related negative consequences IND number of standard doses used Expansion; SE = standard error.

Conformity Motives Frequency Single Mediation Model.

Direct Effects: In the single mediation coping motives model, cannabis use frequency was significantly associated with cannabis-related negative consequences (b=0.367, SE=0.149, p=0.005, CI=[0.045, 0.646], and coping motives were significantly associated with cannabis-related negative consequences (b=0.481, SE=0.150, p<0.001, CI=[0.196, 0.757]. Coping motives were not significantly associated with cannabis use frequency (b=0.204, SE=0.131, p=0.090, CI=[-0.086, 0.440]).

Indirect Effects. Cannabis use frequency did not significantly mediate the association between conformity motives and cannabis-related negative consequences (b=0.005, SE=0.001, p=0.230, CI=[-0.009, 0.028]).

Table 7

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.367	0.149	0.005	[0.045, 0.646] *	1.44	[1.046, 1.907]
Cons on Conf	0.481	0.150	0.000	[0.196, 0.757] *	1.61	[1.216, 2.131]
Fre on Conf	0.204	0.131	0.090	[-0.086, 0.440]	1.22	[1.089, 1.552]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.012	0.011	0.095	[-0.007, 0.039]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; Conf = Conformity Motives; Ind Eff = Cannabis-related negative consequences IND number of standard doses used Conformity; SE = standard error.

Enhancement Motives Frequency Single Mediation Model.

Direct Effects: In the single mediation enhancement motives model, cannabis use frequency was significantly associated with cannabis-related negative consequences (b=0.385, SE=0.148, p<0.001, CI=[0.099, 0.782], and enhancement motives were significantly associated with cannabis-related negative consequences (b=0.386, SE=0.188, p<0.001, CI=[0.069, 0.812]). enhancement motives were not significantly associated with cannabis use frequency (b=0.114, SE=0.010, p=0.250, CI=[-0.226, 0.354]).

Indirect Effects. Cannabis use frequency did not significantly mediate the association between enhancement motives and cannabis-related negative consequences (b=0.012, SE=0.011, p=0.0.095, CI=[-0.007, 0.039]).

Table 8

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.385	0.148	0.000	[0.099, 0.782] *	1.46	[1.104, 2.185]
Cons on Enha	0.386	0.188	0.000	[0.069, 0.812] *	1.47	[1.071, 2.252]
Fre on Enha	0.114	0.149	0.250	[-0.226, 0.354]	1.12	[1.253, 1.424]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.004	0.010	0.250	[-0.012, 0.029]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; Enha = Enhancement Motives; Ind Eff = Cannabis-related negative consequences IND number of standard doses used Enhancement; SE = standard error.

Coping Motives Standard Dose Single Mediation Model.

Direct Effects. In the single mediation coping motives model, coping motives were significantly associated with cannabis-related negative consequences (b=0.528, SE=0.164, p<0.001, CI=[0.260, 0.903]). Coping motives were not significantly associated with number of standard doses used (b=0.295, SE=0.120, p=0.010, CI=[0.030, 0.490]), and number of standard doses was not significantly associated with cannabis-related negative consequences (b=0.367, SE=0.149, p=0.005, CI=[0.045, 0.646]).

Indirect Effects. Number of standard doses used did not significantly mediate the association between coping motives and cannabis-related negative consequences (b=0.008, SE=0.010, p=0.170, CI=[-0.012, 0.032]).

Table 9

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on SD	0.151	0.162	0.160	[-0.217, 0.447]	1.12	[1.242, 1.563]
Cons on Cop	0.528	0.164	0.000	[0.260, 0.903] *	1.69	[1.296, 2.466]
SD on Cop	0.295	0.120	0.010	[0.030, 0.490]	1.34	[1.030, 1.632]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.008	0.010	0.170	[-0.012, 0.032]

Note: Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Cop = Coping Motives; Ind Eff = Cannabis-related negative consequences IND number of standard doses used Coping; SE = standard error.

Enhancement Motives Standard Dose Single Mediation Model.

Direct Effects. In the single mediation enhancement motives model, enhancement motives were significantly associated with cannabis-related negative consequences (b=0.528, SE=0.164, p<0.001, CI=[0.260, 0.903]). Enhancement motives were not significantly associated with number of standard doses used (b=0.295, SE=0.120, p=0.010, CI=[0.030, 0.490]), and number of standard doses was not significantly associated with cannabis-related negative consequences (b=0.367, SE=0.149, p=0.005, CI=[0.045, 0.646]).

Indirect Effects. Number of standard doses used did not significantly mediate the association between enhancement motives and cannabis-related negative consequences (b=0.008, SE=0.010, p=0.170, CI=[-0.012, 0.032]).

Table 10

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on SD	0.145	0.168	0.210	[-0.164, 0.513]	1.15	[1.178, 1.670]
Cons on Enha	0.357	0.175	0.020	[0.023, 0.732] *	1.42	[1.023, 2.079]
SD on Enha	0.234	0.123	0.065	[-0.060, 0.438]	1.26	[1.061, 1.549]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.003	0.006	0.235	[-0.006, 0.019]

Note: Cons = Cannabis-related negative consequences; Enha = Enhancement Motives; Ind Eff = Cannabis-related negative consequences IND number of standard doses used Enhancement; SE = standard error.

Conformity Motives Standard Dose Single Mediation Model.

Direct Effects. In the single mediation conformity motives model, conformity motives were significantly associated with cannabis-related negative consequences (b=0.567, SE=0.150, p<0.001, CI=[0.027, 0.659]). Conformity motives were not significantly associated with number of standard doses used (b=0.308, SE=0.125, p=0.013, CI=[-0.144, 0.409]), and number of standard doses was not significantly associated with cannabis-related negative consequences (b=0.149, SE=0.216, p=0.005, CI=[-0.207, 0.587]).

Indirect Effects. Number of standard doses used did not significantly mediate the association between conformity motives and cannabis-related negative consequences (b=0.003, SE=0.012, p=0.360, CI=[-0.017, 0.038]).

Table 11

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on SD	0.149	0.216	0.300	[-0.207, 0.587]	1.16	[1.229, 1.798]
Cons on Conf	0.567	0.150	0.000	[0.027, 0.659] *	1.76	[1.027, 1.932]
Sd on Conf	0.308	0.125	0.013	[-0.144, 0.409]	1.36	[1.154, 1.505]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.003	0.012	0.360	[-0.017, 0.038]

Note: Cons = Cannabis-related negative consequences; Standard Dose = Number of standard doses used; Conf = Conformity Motives; Indirect Effect 1 = Cannabis-related negative consequences IND number of standard doses used Conf; SE = standard error.

Social Motives Standard Dose Single Mediation Model.

Direct Effects. In the single mediation social motives model, social motives were significantly associated with cannabis-related negative consequences (b=0.567, SE=0.150, p<0.001, CI=[0.275, 0.847]), and social motives were significantly associated with number of standard doses used (b=0.308, SE=0.125, p=0.013, CI=[0.023, 0.512]), and number of standard doses was not significantly associated with cannabis-related negative consequences (b=0.149, SE=0.216, p=0.005, CI=[-0.207, 0.587]).

Indirect Effects. Number of standard doses used did not significantly mediate the association between social motives and cannabis-related negative consequences.

Table 12

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on SD	0.099	0.155	0.217	[-0.207, 0.407]	1.10	[1.229, 1.316]
Cons on Soc	0.567	0.150	0.000	[0.275, 0.847] *	1.76	[1.316, 2.332]
SD on Soc	0.308	0.125	0.013	[0.023, 0.512] *	1.36	[1.023, 1.668]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.005	0.010	0.223	[-0.014, 0.028]

Note: Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Social = Social Motives; Ind Eff = Cannabis-related negative consequences IND number of standard doses used Enhancement; SE = standard error.

Expansion Motives Standard Dose Single Mediation Model.

Direct Effects. In the single mediation expansion motives model, expansion motives were significantly associated with cannabis-related negative consequences (b=0.471, SE=0.171, p<0.001, CI=[0.160, 0.812]), and expansion motives were significantly associated with number of standard doses used (b=0.283, SE=0.115, p=0.005, CI=[0.065, 0.512]), and number of standard doses was not significantly associated with cannabis-related negative consequences (b=0.128, SE=0.150, p=0.240, CI=[-0.182, 0.422]).

Indirect Effects. Number of standard doses used did not significantly mediate the association between expansion motives and cannabis-related negative consequences (b=0.005, SE=0.008, p=0.245, CI=[-0.012, 0.023]).

Table 13

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on SD	0.128	0.150	0.240	[-0.182, 0.422]	1.13	[1.199, 1.555]
Cons on Expa	0.471	0.171	0.000	[0.160, 0.812] *	1.60	[1.173, 2.252]
SD on Expan	0.283	0.115	0.005	[0.065, 0.512] *	1.32	[1.067. 1.668]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.005	0.008	0.245	[-0.012, 0.023]

Note: Cons = Cannabis-related negative consequences; Standard Dose = Number of standard doses used; Expan = Expansion Motives; Indirect Effect = Cannabis-related negative consequences IND number of standard doses used Expan; SE = standard error.

Enhancement Motives Standard Dose Single Mediation Model.

Direct Effects. In the single mediation enhancement motives model, enhancement motives were significantly associated with cannabis-related negative consequences (b=0.357, SE=0.175, p=0.020, CI=[0.023, 0.732]). Enhancement motives were not significantly associated with number of standard doses used (b=0.234, SE=0.123, p=0.065, CI=[-0.060, 0.438]), and number of standard doses was not significantly associated with cannabis-related negative consequences (b=0.145, SE=0.168, p=0.210, CI=[-0.164, 0.513]).

Indirect Effects. Number of standard doses used did not significantly mediate the association between enhancement motives and cannabis-related negative consequences (b=0.003, SE=0.006, p=0.235, CI=[-0.006, 0.019]).

Table 14

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on SD	0.145	0.168	0.210	[-0.164, 0.513]	1.15	[1.178, 1.670]
Cons on Enha	0.357	0.175	0.020	[0.023, 0.732] *	1.42	[1.023, 2.079]
SD on Enha	0.234	0.123	0.065	[-0.060, 0.438]	1.26	[1.061, 1.549]

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff	0.003	0.006	0.235	[-0.006, 0.019]

Note: Cons = Cannabis-related negative consequences; Standard Dose = Number of standard doses used; Enha = Enhancement Motives; Indirect Effect = Cannabis-related negative consequences IND number of standard doses used Enhancement; SE = standard error.

Coping Motives Parallel Mediation Model.

Direct Effects: I then examined the direct effects when controlling for all other variables in the model. In the coping motives model (see figure 1), coping motives significantly positively predicted cannabis-related negative consequences (b=0.38, SE=0.14, p=0.006, CI=[.025, 0.139]), such that a one-unit increase in coping motives was expected to increase cannabis-related consequences by a factor of 1.45 (45%). Standard Dose significantly positively predicted cannabis-related negative consequences (b=0.24, SE=0.12, p=0.046, CI=[0.03, 0.195]), such that a one-unit increase in number of standard doses was expected to increase cannabis-related negative consequences by a factor of 1.27. (27%). All other direct effects were not significant.

Indirect Effects. Examination of Bayesian Credible Intervals revealed that all indirect effects were not significant.

Non-inferiority tests. The bounds of confidence intervals for the association between coping and frequency were [0.962, 1.034], which were both within -1 and 1. Therefore, non-inferiority was established. The bounds of exponentiated confidence intervals for the association between cannabis use frequency predicting consequences was [0.962, 1.034], which were within 0.967 and 1.033 Therefore, non-inferiority was established. The bounds of confidence intervals for the indirect effect of frequency on the association between coping motives and cannabis-related negative consequences were [-0.016, 0.015], which did overlap -0.006 and 0.006. Therefore, non-inferiority was established.

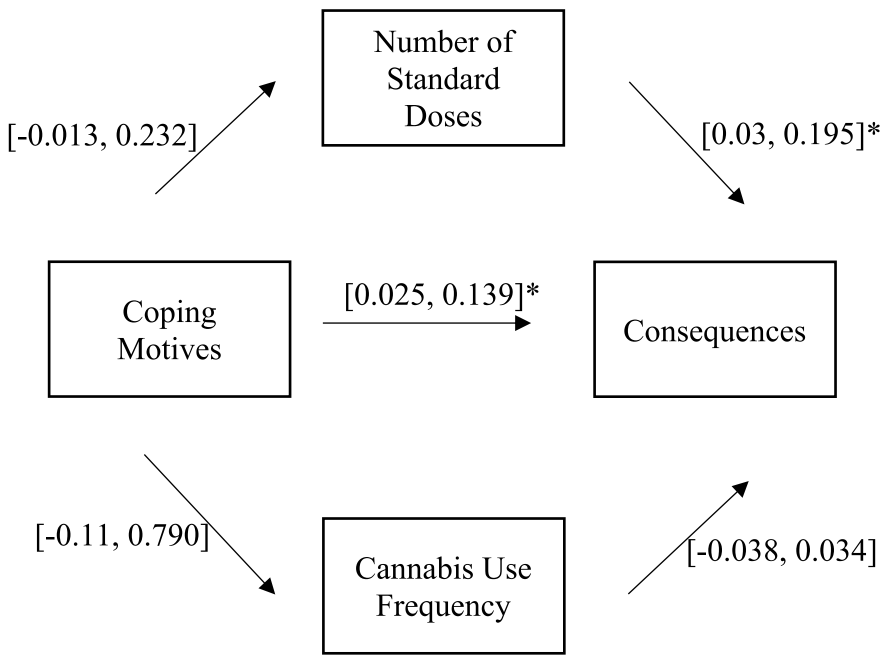

Figure 1

Note. Final model of the mediating effect.

Table 15

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	-0.019	0.145	0.893	[-0.038, 0.034]	0.98	[0.962, 1.034]
Cons on SD	0.245	0.122	0.046	[0.030, 0.195] *	1.27	[1.03, 1.215]
Cons on Cop	0.376	0.136	0.006	[0.025, 0.139] *	1.45	[1.025, 1.149]
SD on Cop	0.186	0.106	0.078	[-0.013, 0.232]		
Fre on Cop	0.161	0.079	0.052	[-0.110, 0.790]		

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff 1	0.039	0.032	0.217	[-0.005, 0.034]
Ind Eff 2	-0.003	0.020	0.892	[-0.016, 0.015]

Note: Frequency = Cannabis use frequency; Cons = Cannabis-related negative consequences; Standard Dose = Number of standard doses used; Coping = Coping Motives; Indirect Effect 1 = Cannabis-related negative consequences IND number of standard doses used coping; Indirect Effect 2 = Cannabis-related negative consequences IND cannabis use frequency coping; SE = standard error.

Conformity Motives Model.

Direct Effects. In the conformity motives model (see figure 2), standard dose significantly predicted cannabis-related negative consequences (b=0.09, SE=0.05, p=0.046, CI=[0.073, 0.610]), such that a one-unit increase in number of standard doses was expected to increase cannabis-related negative consequences by a factor of 1.1 (10%). All other direct effects were not significant.

Indirect Effects. Examination of the Sobel test and Bayes estimator revealed that all indirect effects were not significant.

Non-Inferiority tests. The bounds of confidence intervals for the association between conformity motives and cannabis use frequency were [-0.434, 0.053] which overlapped -1 and 1. Therefore, non-inferiority was established. The range of confidence intervals for the association between cannabis use frequency and cannabis-related consequences was [0.96, 1.043], which overlapped 0.967 and 1.033. Therefore, non-inferiority was established. The bounds of confidence intervals for the indirect effect of frequency on the association between conformity motives and cannabis-related negative consequences were [-0.348, 0.728], which overlapped -0.001 and 0.001. Therefore, non-inferiority was established.

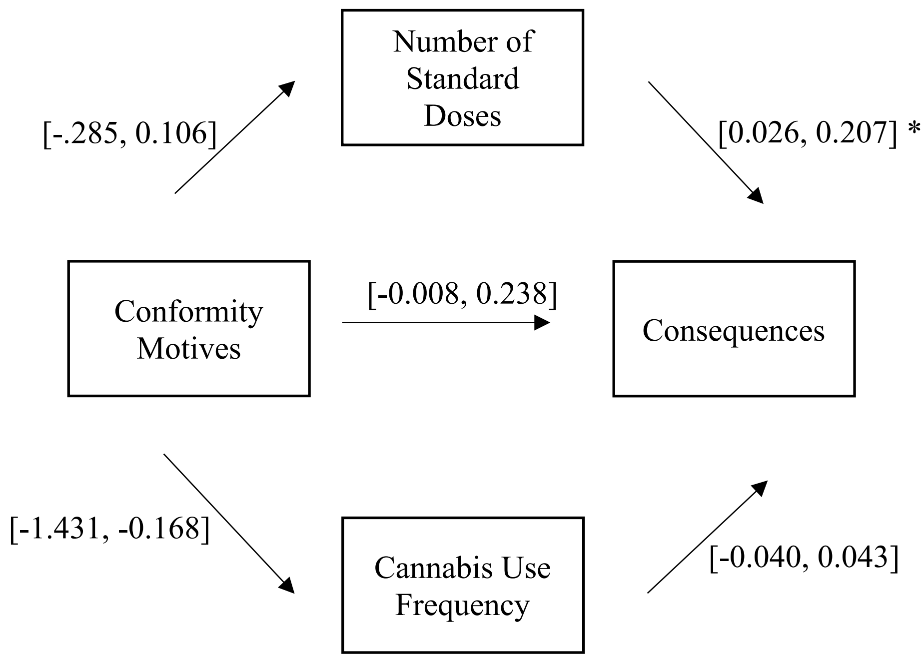

Figure 2

Note. Final model of the mediating effect.

Table 16

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.054	0.148	0.717	[-0.040, 0.043]	1.05	[0.960, 1.043]
Cons on SD	0.260	0.139	0.046	[0.026, 0.207] *	1.29	[1.026, 1.229]
Cons on Conf	0.231	0.138	0.094	[-0.008, 0.238]	1.25	[0.992, 1.268]
SD on Conf	-0.098	0.100	0.325	[-.285, 0.106]		
Fre on Conf	-0.235	0.134	0.080	[-0.434, 0.053]		

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff 1	-0.022	0.025	0.386	[-0.812, 0.417]
Ind Eff 2	-0.011	0.032	0.730	[-0.348, 0.728]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Conf = Conformity Motives; Ind Eff 1 = Cannabis-related negative consequences IND number of standard doses used conformity; Ind Eff 2 = Cannabis-related negative consequences IND cannabis use frequency conformity; SE = standard error.

Social Motives Model.

Direct Effects. In the social motives model (see figure 3), social motives significantly positively predicted cannabis-related negative consequences (b=0.36, SE=0.13, p=0.007, CI=[0.004, 0.136]) such that a one-unit increase in standard doses was expected to increase cannabis-related negative consequences by a factor of 1.43. (43%). Also, social motives significantly positively predicted number of standard doses (b=0.3, SE=0.097, p=0.002, CI=[00.041, 0.252]) such that a one-unit increase in sense social motives was expected to increase the number of standard doses by a factor of 1.349 (35%). All other direct effects were not significant.

Indirect Effects. Examination of the Sobel test and Bayes estimator revealed that all indirect effects were not significant.

Non-Inferiority tests. The bounds of confidence intervals for the association between social motives and cannabis use frequency were [-0.155, 1.519] which overlapped -1 and 1. Therefore, non-inferiority was established. The range of confidence intervals for the association between cannabis use frequency and cannabis-related consequences were [0.981, 1.036], which overlapped 0.967 and 1.033. Therefore, non-inferiority was established. The bounds of confidence intervals for the indirect effect of frequency on the association between social motives and cannabis-related negative consequences were [-0.006, 0.011], which overlapped -0.001 and 0.001. Therefore, non-inferiority was established.

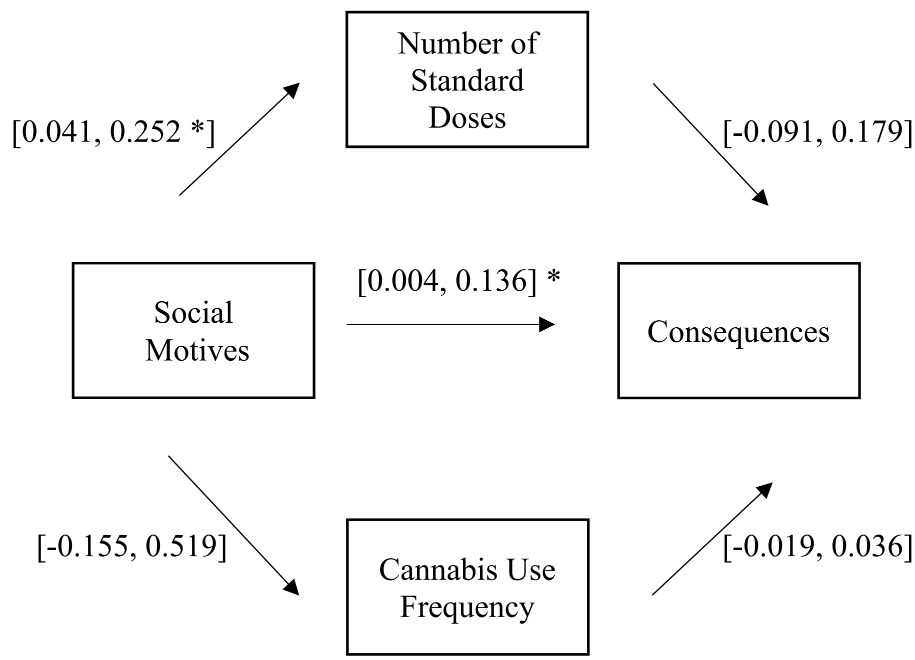

Figure 3

Note. Final model of the mediating effect.

Table 17

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.070	0.146	0.632	[-0.019, 0.036]	1.07	[0.981, 1.036]
Cons on SD	0.146	0.137	0.286	[-0.091, 0.179]	1.15	[0.913, 1.196]
Cons on Soc	0.358	0.133	0.007	[0.004, 0.136] *	1.43	[1.004, 1.145]
SD on Soc	0.300	0.097	0.002	[0.041, 0.252 *]		
Fre on Soc	0.090	0.096	0.352	[-0.155, 0.519]		

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff 1	0.038	0.039	0.331	[-0.019, 0.026]
Ind Eff 2	0.005	0.014	0.697	[-0.006, 0.011]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Soc = Social Motives; Ind Eff 1 = Cannabis-related negative consequences IND number of standard doses used Social; Ind Eff 2 = Cannabis-related negative consequences IND cannabis use frequency Social; SE = standard error.

Enhancement Motives Model.

Direct Effects. In the enhancement motives model (see figure 4), enhancement motives significantly positively predicted cannabis-related negative consequences (b=0.41, SE=0.16, p=0.012, CI=[0.125, 0.766]), such that a one-unit increase in enhancement motives was expected to increase cannabis-related negative consequences by a factor of 1.5 (50%). Enhancement motives significantly positively predicted number of standard doses consumed (b=0.2, SE=0.1, p=0.014, CI=[-0.042, 0.425]). All other direct effects were not significant.

Indirect Effects. Examination of the Sobel test and Bayes estimator revealed that all indirect effects were not significant.

Non-Inferiority tests. The bounds of confidence intervals for the association between enhancement motives and cannabis use frequency were [-0.211, 0.383], which overlapped -1 and 1. Therefore, non-inferiority was established. The range of confidence intervals for the association between cannabis use frequency and cannabis-related consequences were [0.973, 1.034], which were not within 0.967 and 1.033. Therefore, non-inferiority was established. The bounds of confidence intervals for the indirect effect of frequency on the association between enhancement motives and cannabis-related negative consequences were [-0.006, 0.004], which overlapped -0.004 and 0.004. Therefore, non-inferiority was established.

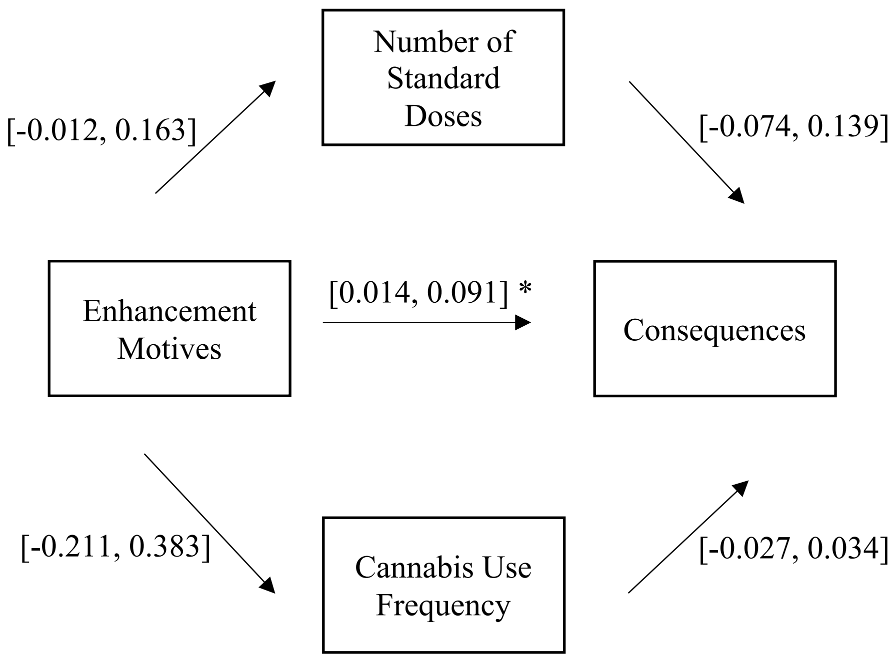

Figure 4

Note. Final model of the mediating effect.

Table 18

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.052	0.147	0.722	[-0.027, 0.034]	1.05	[0.973, 1.034]
Cons on SD	0.141	0.139	0.311	[-0.074, 0.139]	1.15	[0.928, 1.149]
Cons on Enha	0.406	0.161	0.012	[0.014, 0.091] *	1.50	[1.014, 1.095
SD on Enha	0.222	0.108	0.041	[-0.012, 0.163]		
Fre on Enha	0.064	0.109	0.560	[-0.211, 0.383]		

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff 1	0.004	0.005	0.400	[-0.007, 0.014]
Ind Eff 2	0.000	0.001	0.775	[-0.006, 0.004]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Enha = Enhancement Motives; Ind Eff 1 = Cannabis-related negative consequences IND number of standard doses used Enhancement; Ind Eff 2 = Cannabis-related negative consequences IND cannabis use frequency Enhancement SE = standard error.

Expansion Motives Model.

Direct Effects. In the expansion motives model (see figure 5), all direct effects were nonsignificant.

Indirect Effects. Examination of the Sobel test and Bayes estimator revealed that all indirect effects were not significant.

Non-Inferiority tests. The bounds of confidence intervals for the association between expansion motives and cannabis use frequency were [-0.429, 0.249], which overlapped -1 and 1. Therefore, non-inferiority was established. The range of confidence intervals for the association between cannabis use frequency and cannabis-related consequences were [0.977, 1.043], which overlapped 0.967 and 1.033. Therefore, non-inferiority was established. The bounds of confidence intervals for the indirect effect of frequency on the association between expansion motives and cannabis-related negative consequences were [-0.047, 0.037], which overlapped -0.004 and 0.004. Therefore, non-inferiority was established.

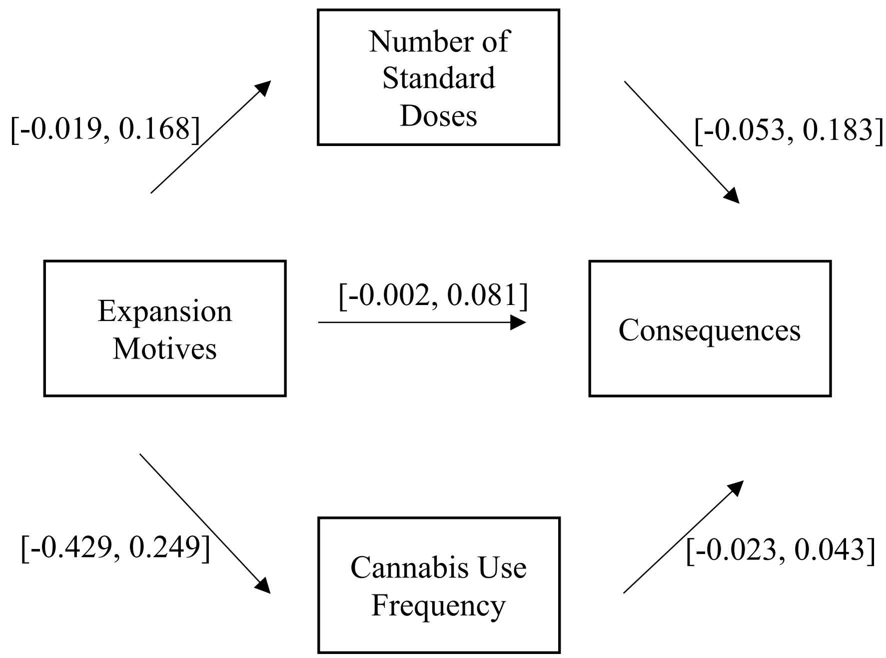

Figure 5

Note. Final model of the mediating effect.

Table 19

Path Analysis of Direct and Indirect Effects

Path	*b estimates*	*SE (b)*	*p-values*	*BCI*	*RR*	*RRCI*
Cons on Fre	0.077	0.151	0.612	[-0.023, 0.043]	1.08	[0.977, 1.043]
Cons on SD	0.230	0.140	0.100	[-0.053, 0.183]	1.25	[0.948, 1.200]
Cons on Expa	0.238	0.141	0.090	[-0.002, 0.081]	1.26	[0.998, 1.084]
SD on Expa	0.183	0.117	0.117	[-0.019, 0.168]		
Fre on Expa	-0.019	0.121	0.875	[-0.429, 0.249]		

	b estimates	*SE (b)*	*P-values*	*BCI*
Ind Eff 1	0.036	0.031	0.251	[-0.017, 0.120]
Ind Eff 2	-0.001	0.008	0.876	[-0.047, 0.037]

Note: Fre = Cannabis use frequency; Cons = Cannabis-related negative consequences; SD = Number of standard doses used; Expa = Expansion Motives; Ind Eff 1 = Cannabis-related negative consequences IND number of standard doses used Expansion; Ind Eff 2 = Cannabis-related negative consequences IND cannabis use frequency Expansion; SE = standard error.

Summary of Results

Isolated direct effects:

In the isolated direct paths models, the only cannabis use motive to significantly predict cannabis use frequency was social motives, while the only cannabis use motive to significantly predict number of standard doses used was social motives. Coping motives, conformity motives, social motives, enhancement motives expansion motives, cannabis use frequency, and number of standard doses used were significantly associated with consequences.

Single mediation frequency models:

In all five single mediation models testing if cannabis use frequency mediated the association between cannabis use motives and cannabis-related negative consequences, all the B-paths and C-paths were significant, and all the A-paths were not significant. That is, in all five models, cannabis-related negative consequences was significantly associated with both cannabis use frequency and each cannabis use motive.

Single mediation standard dose models:

In all five single mediation models testing if number of standard doses used mediated the association between cannabis use motives and cannabis-related negative consequences, all C-paths were significant, all the B-paths were not significant. That is, each motive significantly predicted cannabis-related negatives, and number of standard doses used did not predict consequences in any of the models. Social motives and expansion motives significantly predicted number of standard doses, while coping, enhancement, and conformity models.

Parallel mediation models:

Coping, social, and enhancement motives were significantly associated with cannabis-related negative consequences while conformity and expansion motives were not. Cannabis use frequency was not associated with any of the motives or consequences in any of the models. Social models were significantly associated with number of standard doses used while all other motives were not. Number of standard doses used were significant in the coping and conformity models, and not in social, expansion, and enhancement models.

Discussion

To accurately assess the impacts of cannabis use, measures must assess the amount of THC ingested (Volkow & Weiss, 2020). Current methods of measuring cannabis use fail to assess the amount of THC individuals ingest. Cannabis use is most commonly assessed by measures of use frequency. Frequency measures are particularly problematic in that they do not account for variability in quantity and potency of cannabis products used. The National Institutes of Health published a notice of information regarding the establishment of a standard unit of THC to be used in research (Freeman & Lorenzetti, 2020). To address this notice, the current study examined if associations would differ when using number of standard doses as a measure of cannabis use compared to cannabis use frequency.

Isolated direct effects of the frequency model A-Paths indicated that coping, social, enhancement, and expansion motives were significantly positively associated with cannabis use frequency, which was consistent with prior literature. Conformity motives were also significantly associated with cannabis use frequency, which was inconsistent with prior research, as most prior studies have found the association to be insignificant (Bresin & Mekawi, 2019). Isolated direct effects also indicated that while social motives were associated with number of standard doses used, coping, conformity, enhancement, and expansion motives were not.

Isolated direct effects of A-Paths indicated that both number of standard doses used and cannabis use frequency were significantly associated with cannabis-related negative consequences.

While prior research has reliably shown that coping, enhancement, and social motives are predictive of consequences, the current study showed that all cannabis use motives predicted cannabis-related consequences when not controlling for other variables.

In all 5 models testing if frequency mediates the association between motives and consequences, all 5 cannabis use motives were significantly associated with cannabis-related negative consequences, and frequency predicted consequences, while the association between all 5 motives and cannabis use frequency was insignificant. In all 5 models testing if number of standard doses mediates the association between motives and consequences, all 5 cannabis use motives predicted cannabis-related negative consequences, the associations between expansion and social motives and number of standard doses used were significant, while all other paths were not significant.

In the parallel mediation models, social motives significantly positively predicted number of standard doses consumed, and number of standard doses consumed significantly positively predicted cannabis-related negative consequences in two of the five models tested. Conversely, cannabis use frequency was not significantly associated with any study variables in any of the parallel models. Further, one unit increases in number of standard doses ingested predicted significantly larger increases in cannabis-related negative consequences than did one unit increases in cannabis use frequency. This finding suggests that various cannabis related variables may be associated with number of standard doses differently than cannabis use frequency. Therefore, measures of cannabis use frequency are limited in the extent to which they represent the ingestion of THC.

Number of standard doses used was not significantly associated with cannabis-related negative consequences in the single mediation model but was in two of the parallel mediation models. This suggests that number of standard doses may only predict cannabis-related negative consequences when controlling for frequency. That is, adding frequency to the model may have decreased measurement error as a result of frequency accounting for some variance in consequences that number of standard doses used did not. Moreover, the finding that number of standard doses used predicted consequences while frequency of use did not suggest that number of standard doses used accounts for variance in consequences that frequency does not.

The current study used a sample of participants that used frequently, which in turn resulted in a ceiling effect in the frequency of use measure. This suggests that in populations that use frequently, number of standard doses should be used as a measure of cannabis use to identify associations between cannabis use and other related variables. This finding is of particular importance, as heavy use has been associated with a higher rate of negative outcomes.

The significant associations between number of standard doses used and cannabis-related negative consequences in the isolated direct effect model and two parallel mediation models have several implications. Firstly this association supports the notion that cannabis-related negative consequences result from ingesting cannabis (National Academies of Sciences, Engineering, and Medicine, 2017). More specifically, that the psychoactive components of cannabis cause individuals to have negative and unwanted experiences.

Prior research has established that cannabis use frequency positively predicts cannabis-related negative consequences (Pearson, 2019). One implication of this prior research is that cannabis use frequency is a viable target of interventions aimed at decreasing cannabis-related negative consequences (Bresin & Mekawi, 2019). The current study suggests that number of standard doses ingested may also be an effective target of cannabis related interventions.

Researchers have suggested that cannabis products should include information regarding the number of standard doses they contain, and that doing so would help consumers experience few consequences (Freeman & Lorenzetti, 2020). This study showed that number of standard doses predicts consequences, which supports the notion that selling products that report the number of standard doses may help individual's evade cannabis-related negative consequences. That is, the current findings include information that may help individuals evade cannabis-related negative consequences.

While the associations between number of standard doses used and consequences suggests some implications regarding how use explains consequences, the insignificance of indirect effects indicate that cannabis use doesn't explain the association between motives and consequences. Therefore, implications of the current study echo that of Pearson (2019) and Prince et al. (2018) in that these findings warrant research examining other indicators of consequences not including use.

Null Hypotheses Rejected. Results supported my hypotheses that coping, social, and enhancement motives would positively predict cannabis-related negative consequences. Results were consistent with prior literature on the relation between coping, social, and enhancement motives and cannabis-related negative consequences and confirmed prior findings (Bresin & Mekawi, 2019; Cooper et al., 2016; Buckner et al., 2007). This finding adds to the literature in that it indicates that the associations between coping, social, and enhancement motives and cannabis-related negative consequences do not differ among heavy users as compared to other populations (Cooper et al., 2016).

Results supported the hypothesis that cannabis use frequency and number of standard doses consumed would differ in the ways they are associated with cannabis use motives and cannabis-related negative consequences. Specifically, number of standard doses was associated with cannabis use motives in three of the five models, and cannabis-related consequences in two of the five models. Conversely, cannabis use frequency was not associated with cannabis use motives or cannabis-related consequences in any of the models. One potential explanation of this finding is that number of standard doses ingested assesses potency and quantity as well as frequency of use. Results supported my hypotheses that cannabis use frequency would not be significantly associated with cannabis use motives or cannabis-related consequences, cannabis use frequency would not mediate the relation between cannabis use motives and cannabis-related negative consequences, and that cannabis use frequency would not mediate the associations between cannabis use motives and cannabis-related negative consequences. The way in which cannabis use frequency was measured may have contributed to this finding. That is, there was a ceiling effect for the cannabis use frequency variable. More specifically, a significant portion of participants endorsed using cannabis every day. Therefore, potential differences in frequency were undetected, as participants did not have the ability to endorse the number of times they used each day.

Rejected Hypotheses. Results did not support my hypotheses involving conformity and expansion motives positively predicting cannabis-related negative consequences. Results may be partially explained by the population sampled. That is, conformity and expansion motives may predict cannabis-related consequences among individuals who don’t use at high frequencies, but not among individuals who do use at high frequencies. These findings suggest that cannabis use frequency may moderate the relation between conformity and expansion motives and cannabis-related negative consequences. That is, the relation between conformity and expansion motives and cannabis-related negative consequences may be dependent upon how frequently individuals use.

Results did not support my hypothesis involving the positive relation between motives and cannabis-related negative consequences to be partially explained by the positive relation between motives and number of standard doses used, followed by the relation between standard dose and cannabis-related negative consequences. That is, number of standard doses did not mediate the relation between use motives and cannabis-related negative consequences. This finding suggests that cannabis use motives do not predict cannabis-related consequences via number of standard doses ingested.

Limitations and future directions. Limitations of the current study suggest potential directions for future research. One limitation of the current study is that findings may not be generalizable to individuals who are not heavy users. Further, the current study was conducted using cross sectional data. Therefore, results are strictly correlational, and causation cannot be assumed. Another limitation is that results using the number of standard doses variable were only compared to results using cannabis use frequency, and no other measures of cannabis use like quantity and potency. Another limitation of the current study is its small sample size, which resulted in the analyses having low statistical power. Future studies may examine these associations using more diverse populations.

Number of standard doses was converted into a uniform distribution. Therefore, the measure of THC use utilized in this study might have been weak in its ability to identify associations between number of standard doses and other related variables.

Another limitation of the current study is the way in which non-inferiority was established for indirect effects. Non-inferiority od indirect effects was reliant on effect size. The way in which I established effect size for indirect effects was novel, and therefore has not been validated by other researchers. Limitations in the way I examined effect size of indirect effects are currently unknown.

Conclusions. The current findings support the use of standard dose in cannabis research as an estimate of cannabis use. Results suggest that relations between cannabis use frequency or standard doses have with motives and cannabis-related consequences differ in significant ways and that, when measured in standard dose or cannabis use frequency, cannabis use is not a significant mediator of the relation between motives and consequences.

References

Arterberry, B. J., Padovano, H. T., Foster, K. T., Zucker, R. A., & Hicks, B. M. (2019). Higher average potency across the United States is associated with progression to first cannabis use disorder symptom. *Drug and alcohol dependence*, *195*, 186-192.

Asbridge, M., Duff, C., Marsh, D. C., & Erickson, P. G. (2014). Problems with the identification of 'problematic' cannabis use: Examining the issues of frequency, quantity, and drug use environment. *European addiction research*, *20*(5), 254-267.

Bechtold, J., Simpson, T., White, H. R., & Pardini, D. (2015). Chronic adolescent marijuana use as a risk factor for physical and mental health problems in young adult men. *Psychology of Addictive Behaviors*, *29*(3), 552.

Bonar, E. E., Goldstick, J. E., Collins, R. L., Cranford, J. A., Cunningham, R. M., Chermack, S. T., ... & Walton, M. A. (2017). Daily associations between cannabis motives and consumption in emerging adults. Drug and Alcohol Dependence, 178, 136-142.

Bonn-Miller, M. O., Zvolensky, M. J., & Bernstein, A. (2007). Marijuana use motives: Concurrent relations to frequency of past 30-day use and anxiety sensitivity among young adult marijuana smokers. *Addictive behaviors*, *32*(1), 49-62.

Bottorff, J. L., Johnson, J. L., Moffat, B. M., & Mulvogue, T. (2009). Relief-oriented use of marijuana by teens. *Substance Abuse Treatment, Prevention, and Policy*, *4*(1), 1-10.

Bravo, A. J., Prince, M. A., Pearson, M. R., & Marijuana Outcomes Study Team. (2017). Can I use marijuana safely? An examination of distal antecedents, marijuana protective behavioral strategies, and marijuana outcomes. Journal of studies on alcohol and drugs, 78(2), 203-212.

Buckner, J. D., Bonn-Miller, M. O., Zvolensky, M. J., & Schmidt, N. B. (2007). Marijuana use motives and social anxiety among marijuana-using young adults. *Addictive behaviors*, *32*(10), 2238-2252.

Buckner, J. D., Walukevich, K. A., & Henslee, A. M. (2018). Event-specific cannabis use and cannabis use motives. Substance use & misuse, 53(7), 1093-1098.

Bresin, K., & Mekawi, Y. (2019). Do marijuana use motives matter? Meta-analytic associations with marijuana use frequency and problems. *Addictive behaviors*, *99*, 106102.

Carruthers, S. J., & Binns, C. W. (1992). The standard drink and alcohol consumption. Drug and Alcohol Review, 11(4), 363-370.

Callaghan, R. C., Sanches, M., Benny, C., Stockwell, T., Sherk, A., & Kish, S. J. (2019). Who consumes most of the cannabis in Canada? Profiles of cannabis consumption by quantity. *Drug and alcohol dependence*, *205*, 107587.

Chen, K., Kandel, D. B., & Davies, M. (1997). Relationships between frequency and quantity of marijuana use and last year proxy dependence among adolescents and adults in the United States. *Drug and alcohol dependence*, *46*(1-2), 53-67.

Cohen, J. (1992). Statistical power analysis. Current directions in psychological science, 1(3), 98-101.

Cone, E. J., Johnson, R. E., Darwin, W. D., Yousefnejad, D., Mell, L. D., Paul, B. D., & Mitchell, J. (1987). Passive inhalation of marijuana smoke: urinalysis and room air levels of delta-9-tetrahydrocannabinol. *Journal of analytical toxicology*, *11*(3), 89-96.

Cone, E. J., Johnson, R. E., Paul, B. D., Mell, L. D., & Mitchell, J. (1988). Marijuana-laced brownies: behavioral effects, physiologic effects, and urinalysis in humans following ingestion. *Journal of Analytical Toxicology*, *12*(4), 169-175.

Connell, J., Brazier, J., O'Cathain, A., Lloyd-Jones, M., & Paisley, S. (2012). Quality of life of people with mental health problems: a synthesis of qualitative research. *Health and quality of life outcomes*, *10*(1), 138.

Cooper, M. L., Kuntsche, E., Levitt, A., Barber, L. L., & Wolf, S. (2016). Motivational models of substance use: A review of theory and research on motives for using alcohol, marijuana, and tobacco.

Cruwys, T., & Gunaseelan, S. (2016). "Depression is who I am": Mental illness identity, stigma and wellbeing. *Journal of Affective Disorders*, *189*, 36-42.

Cuttler, C., & Spradlin, A. (2017). Measuring cannabis consumption: psychometric properties of the daily sessions, frequency, age of onset, and quantity of cannabis use inventory (DFAQ-CU). *PLoS One*, *12*(5), e0178194.

El-Mallakh, R. S., & Brown, C. (2007). The Effect of Extreme Marijuana Use on the Long-Term Course of Bipolar I Illness: Single Case Study. *Journal of psychoactive drugs*, *39*(2), 201-202.

Faraone, S. V., Wilens, T. E., Petty, C., Antshel, K., Spencer, T., & Biederman, J. (2007). Substance use among ADHD adults: implications of late onset and subthreshold diagnoses. *American Journal on Addictions*, *16*(sup1), 24-34.

Freeman, T. P., & Lorenzetti, V. (2020). 'Standard THC units': a proposal to standardize dose across all cannabis products and methods of administration. *Addiction*, *115*(7), 1207-1216.

Freeman, T. P., & Winstock, A. R. (2015). Examining the profile of high-potency cannabis and its association with severity of cannabis dependence. Psychological medicine, 45(15), 3181-3189.

Ghasemiesfe, M., Ravi, D., Vali, M., Korenstein, D., Arjomandi, M., Frank, J., ... & Keyhani, S. (2018). Marijuana use, respiratory symptoms, and pulmonary function: a systematic review and meta-analysis. Annals of internal medicine, 169(2), 106-115.

Gillman, A. S., Yeater, E. A., Feldstein Ewing, S. W., Kong, A. S., & Bryan, A. D. (2018). Risky sex in high-risk adolescents: associations with alcohol use, marijuana use, and co-occurring use. AIDS and Behavior, 22(4), 1352-1362.

Green, B. E., & Ritter, C. (2000). Marijuana use and depression. *Journal of health and social behavior*, 40-49.

Gross, J. J., Uusberg, H., & Uusberg, A. (2019). Mental illness and well-being: an affect regulation perspective. *World Psychiatry*, *18*(2), 130-139.

Gruber, A. J., Pope Jr, H. G., & Brown, M. E. (1996). Do patients use marijuana as an antidepressant?. *Depression*, *4*(2), 77-80.

Gruber, S. A., Sagar, K. A., Dahlgren, M. K., Racine, M., & Lukas, S. E. (2012). Age of onset of marijuana use and executive function. Psychology of addictive behaviors, 26(3), 496.

Guttmannova, K., Kosterman, R., White, H. R., Bailey, J. A., Lee, J. O., Epstein, M., ... & Hawkins, J. D. (2017). The association between regular marijuana use and adult mental health outcomes. *Drug and alcohol dependence*, *179*, 109-116.

Hansen, B., Miller, K., & Weber, C. (2020). Early evidence on recreational marijuana legalization and traffic fatalities. Economic inquiry, 58(2), 547-568.

Hartz, S. M., Pato, C. N., Medeiros, H., Cavazos-Rehg, P., Sobell, J. L., Knowles, J. A., ... & Pato, M. T. (2014). Comorbidity of severe psychotic disorders with measures of substance use. *JAMA psychiatry*, *71*(3), 248254.

Herzog, D. B., Franko, D. L., Dorer, D. J., Keel, P. K., Jackson, S., & Manzo, M. P. (2006). Drug abuse in women with eating disorders. *International Journal of Eating Disorders*, *39*(5), 364-368.

Huestis, M. A., Henningfield, J. E., & Cone, E. J. (1992). Blood cannabinoids. I. Absorption of THC and formation of 11-OH-THC and THCCOOH during and after smoking marijuana. *Journal of analytical Toxicology*, *16*(5), 276-282.

Hjorthøj, C. R., Hjorthøj, A. R., & Nordentoft, M. (2012). Validity of timeline follow-back for self-reported use of cannabis and other illicit substances—systematic review and meta-analysis. *Addictive behaviors*, *37*(3), 225-233.

Ishida, J. H., Wong, P. O., Cohen, B. E., Vali, M., Steigerwald, S., & Keyhani, S. (2019). Substitution of marijuana for opioids in a national survey of US adults. *PloS one*, *14*(10), e0222577

Iversen, L. (2003). Cannabis and the brain. Brain, 126(6), 1252-1270.

Jugl, S., Sajdeya, R., Morris, E. J., Goodin, A. J., & Brown, J. D. (2021). Much Ado about Dosing: The Needs and Challenges of Defining a Standardized Cannabis Unit. Medical Cannabis and Cannabinoids, 4(2), 121-124.

Kalinowski, A., & Humphreys, K. (2016). Governmental standard drink definitions and low-risk alcohol consumption guidelines in 37 countries. Addiction, 111(7), 1293-1298.

Keith, D. R., Hart, C. L., McNeil, M. P., Silver, R., & Goodwin, R. D. (2015). Frequent marijuana use, binge drinking and mental health problems among undergraduates. *The American Journal on Addictions*, *24*(6), 499-506.

Kelley, M. E., Wan, C. R., Broussard, B., Crisafio, A., Cristofaro, S., Johnson, S., ... & Compton, M. T. (2016). Marijuana use in the immediate 5-year premorbid period is associated with increased risk of onset of schizophrenia and related psychotic disorders. *Schizophrenia research*, *171*(1-3), 62-67.

Knopf, A. (2021). NIDA sets 5 mg of THC as standard cannabis unit for research. Alcoholism & Drug Abuse Weekly, 33(19), 6-7.

Lachowicz, M. J., Preacher, K. J., & Kelley, K. (2018). A novel measure of effect size for mediation analysis. Psychological Methods, 23(2), 244.

Lazarini-Lopes, W., da Silva-Júnior, R. M., Servilha-Menezes, G., Do Val-da Silva, R. A., & Garcia-Cairasco, N. (2020). Cannabinoid Receptor Type 1 (CB1R) Expression in Limbic Brain Structures After Acute and Chronic Seizures in a Genetic Model of Epilepsy. Frontiers in Behavioral Neuroscience, 14.

Levy, S., Sherritt, L., Harris, S. K., Gates, E. C., Holder, D. W., Kulig, J. W., & Knight, J. R. (2004). Test-retest reliability of adolescents' self-report of substance use. *Alcoholism: Clinical and Experimental Research*, *28*(8), 1236-1241.

MacKinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. Psychological methods, 7(1), 83.

Mariani, J. J., Brooks, D., Haney, M., & Levin, F. R. (2011). Quantification and comparison of marijuana smoking practices: Blunts, joints, and pipes. *Drug and alcohol dependence*, *113*(2-3), 249-251.

McLaren, J., Swift, W., Dillon, P., & Allsop, S. (2008). Cannabis potency and contamination: a review of the literature. Addiction, 103(7), 1100-1109.

Meda, S. A., Gueorguieva, R. V., Pittman, B., Rosen, R. R., Aslanzadeh, F., Tennen, H., ... & Pearlson, G. D. (2017). Longitudinal influence of alcohol and marijuana use on academic performance in college students. PLoS One, 12(3), e0172213.

Merlo, J., Wessling, A., & Melander, A. (1996). Comparison of dose standard units for drug utilisation studies. european Journal of Clinical pharmacology, 50(1), 27-30.

Moore, C., Coulter, C., Uges, D., Tuyay, J., Van der Linde, S., Van Leeuwen, A., ... & Orbita Jr, J. (2011). Cannabinoids in oral fluid following passive exposure to marijuana smoke. *Forensic Science International*, *212*(1-3), 227-230.

Murray, R. M., Quigley, H., Quattrone, D., Englund, A., & Di Forti, M. (2016). Traditional marijuana, high-potency cannabis and synthetic cannabinoids: increasing risk for psychosis. *World Psychiatry*, *15*(3), 195-204.

National Academies of Sciences, Engineering, and Medicine. (2020). *The health effects of cannabis and cannabinoids: the current state of evidence and recommendations for research*. National Academies Press.

Niedbala, R. S., Kardos, K. W., Fritch, D. F., Kardos, S., Fries, T., Waga, J., ... & Cone, E. J. (2001). Detection of marijuana use by oral fluid and urine analysis following single-dose administration of smoked and oral marijuana. *Journal of Analytical Toxicology*, *25*(5), 289-303.

No, M. S. (2001). The health and psychological effects of cannabis use. National Drug and.

Parnes, J. E. (2016). Marijuana use impacted by legalization and individual factors. *2000-2019 CSU Theses and Dissertations*.

Pearson, M. R., Liese, B. S., Dvorak, R. D., & Marijuana Outcomes Study Team. (2017). College student marijuana involvement: Perceptions, use, and consequences across 11 college campuses. Addictive behaviors, 66, 83-89.

Pedersen, E. R., Grow, J., Duncan, S., Neighbors, C., & Larimer, M. E. (2012). Concurrent validity of an online version of the Timeline Followback assessment. *Psychology of Addictive Behaviors*, *26*(3), 672.

Prince, M. A., & Conner, B. T. (2019). Examining links between cannabis potency and mental and physical health outcomes. *Behaviour research and therapy*, *115*, 111-120.

Prince, M. A., Conner, B. T., & Pearson, M. R. (2018). Quantifying cannabis: A field study of marijuana quantity estimation. *Psychology of Addictive Behaviors*, *32*(4), 426.

Preacher, K. J., & Kelley, K. (2011). Effect size measures for mediation models: quantitative strategies for communicating indirect effects. Psychological methods, 16(2), 93.

Prince, M. A., Pearson, M. R., Bravo, A. J., & Montes, K. S. (2018). A quantification of the alcohol use-consequences association in college student and clinical populations: A large, multi-sample study. The American journal on addictions, 27(2), 116-123.

Rabiner, D. L., Anastopoulos, A. D., Costello, E. J., Hoyle, R. H., McCabe, S. E., & Swartzwelder, H. S. (2009). Motives and perceived consequences of nonmedical ADHD medication use by college students: Are students treating themselves for attention problems?. *Journal of Attention Disorders*, *13*(3), 259-270.

Ramaekers, J. G., Kauert, G., Theunissen, E. L., Toennes, S. W., & Moeller, M. R. (2009). Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. Journal of psychopharmacology, 23(3), 266-277.

Sarvet, A. L., Wall, M. M., Keyes, K. M., Olfson, M., Cerdá, M., & Hasin, D. S. (2018). Self medication of mood and anxiety disorders with marijuana: Higher in states with medical marijuana laws. *Drug and alcohol dependence*, *186*, 10-15.

Schwartz, R. H., Gruenewald, P. J., Klitzner, M., & Fedio, P. (1989). Short-term memory impairment in cannabis-dependent adolescents. American Journal of Diseases of Children, 143(10), 1214-1219.

Schwartz, R. H., & Hawks, R. L. (1985). Laboratory detection of marijuana use. *Jama*, *254*(6), 788-792.

Shaffer-Hudkins, E., Suldo, S., Loker, T., & March, A. (2010). How adolescents' mental health predicts their physical health: Unique contributions of indicators of subjective well-being and psychopathology. *Applied Research in Quality of Life*, *5*(3), 203-217.

Simons, J., Correia, C. J., Carey, K. B., & Borsari, B. E. (1998). Validating a five-factor marijuana motives measure: Relations with use, problems, and alcohol motives. *Journal of Counseling Psychology*, *45*(3), 265.

Simons, J. S., Dvorak, R. D., Merrill, J. E., & Read, J. P. (2012). Dimensions and severity of marijuana consequences: Development and validation of the Marijuana Consequences Questionnaire (MACQ). Addictive Behaviors, 37(5), 613-621.

Slade, T., Johnston, A., Oakley Browne, M. A., Andrews, G., & Whiteford, H. (2009). 2007 National Survey of Mental Health and Wellbeing: methods and key findings. *Australian and New Zealand Journal of Psychiatry*, *43*(7), 594-605.

Sokolovsky, A. W., Gunn, R. L., Micalizzi, L., White, H. R., & Jackson, K. M. (2020). Alcohol and marijuana co-use: Consequences, subjective intoxication, and the operationalization of simultaneous use. Drug and alcohol dependence, 212, 107986.

Treloar Padovano, H., & Miranda Jr, R. (2018). Subjective cannabis effects as part of a developing disorder in adolescents and emerging adults. Journal of abnormal psychology, 127(3), 282.

Vadhan, N. P., Corcoran, C. M., Bedi, G., Keilp, J. G., & Haney, M. (2017). Acute effects of smoked marijuana in marijuana smokers at clinical high-risk for psychosis: A preliminary study. *Psychiatry research*, *257*, 372-374.

VanderVeen, J. D., Hershberger, A. R., & Cyders, M. A. (2016). UPPS-P model impulsivity and marijuana use behaviors in adolescents: A meta-analysis. Drug and alcohol dependence, 168, 181-190.

Volkow, N. D., Swanson, J. M., Evins, A. E., DeLisi, L. E., Meier, M. H., Gonzalez, R., ... & Baler, R. (2016). Effects of cannabis use on human behavior, including cognition, motivation, and psychosis: a review. *JAMA psychiatry*, *73*(3), 292-297.

Volkow, N. D., & Weiss, S. R. (2020). Importance of a standard unit dose for cannabis research. *Addiction (Abingdon, England)*, *115*(7), 1219.

Walden, N., & Earleywine, M. (2008). How high: quantity as a predictor of cannabis-related problems. *Harm Reduction Journal*, *5*(1), 20.

Walker, D. D., Roffman, R. A., Stephens, R. S., Wakana, K., & Berghuis, J. (2006). Motivational enhancement therapy for adolescent marijuana users: A preliminary randomized controlled trial. *Journal of consulting and clinical psychology*, *74*(3), 628.

Wilkinson, S. T., Stefanovics, E., & Rosenheck, R. A. (2015). Marijuana use is associated with worse outcomes in symptom severity and violent behavior in patients with PTSD. *The Journal of clinical psychiatry*, *76*(9), 1174.

Wu, L. T., Pilowsky, D. J., & Schlenger, W. E. (2005). High prevalence of substance use disorders among adolescents who use marijuana and inhalants. *Drug and Alcohol Dependence*, *78*(1), 23-32.

Zeisser, C., Thompson, K., Stockwell, T., Duff, C., Chow, C., Vallance, K., ... & Lucas, P. (2012). A ‘standard joint’? The role of quantity in predicting cannabis-related problems. *Addiction Research & Theory*, *20*(1), 82-92.

Zvolensky, M. J., Bernstein, A., Marshall, E. C., & Feldner, M. T. (2006). Panic attacks, panic disorder, and agoraphobia: Associations with substance use, abuse, and dependence. *Current psychiatry reports*, *8*(4), 279-285.

Zvolensky, M. J., Lewinsohn, P., Bernstein, A., Schmidt, N. B., Buckner, J. D., Seeley, J., & Bonn-Miller, M. O. (2008). Prospective associations between cannabis use, abuse, and dependence and panic attacks and disorder. *Journal of psychiatric research*, *42*(12), 1017-1023.