THESIS

EXPLORING DAILY-LEVEL CHARACTERISTICS OF THE CANNABIS-EXERCISE RELATIONSHIP

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Spring 2024

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ABSTRACT

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Physical inactivity is a growing public health concern. According to the Centers for Disease Control and Prevention, only 53.3% of U.S. adults meet the recommendation for aerobic physical activity, and alarmingly, only 23.2% meet the recommendation for both aerobic and muscle-training activity. This leads researchers to wonder what strategies or behaviors may facilitate exercise engagement. Interestingly, preliminary research has shown that cannabis, one of the most widely used substances in the United States, may be positively related to physical activity. However, most research on cannabis and exercise has been cross-sectional and administered low doses of low-THC cannabis, which is not representative of common legal market cannabis products or typical use patterns in the U.S. Additionally, these studies did not evaluate other factors that may occur in the context of the cannabis-exercise relationship such as affect. The current study will leverage a daily-diary design to explore relationships between exercise, cannabis use, and affect. It will also characterize a sample of participants who both use cannabis and frequently exercise in terms of their demographics, cannabis use, exercise engagement, exercise enjoyment, goal attainment, and motives for combining cannabis with exercise. Overall, this study aims to (1) characterize daily-level associations between exercise engagement and cannabis use, (2) explore daily-level associations between exercise engagement and affect over the course of the study, and (3) utilize descriptive statistics to characterize the

sample in order to understand who is likely to use cannabis and exercise, how they do it, why, and their resultant experiences.

ACKNOWLEDGEMENTS

I would like to start by thanking my advisor, Dr. Hollis Karoly, for demonstrating what it means to be a woman in academia. You have shown me how to trust my intuition, have confidence in myself, and stand up for what is just and important. You have accepted and embraced all my interests and passions and held space for me along my winding journey. Thank you for always quickly returning edits and helping me across the finish line. I couldn't have done any of this without you!

To my partner, Alex Shapiro, there are truly no words to express my gratitude to you. No one recognizes the sacrifice and dedication required by a partner of a Ph.D. student. Thank you for carrying all my mixed emotions with such grace and care and helping me laugh off the small (and sometimes big) stuff. You are my biggest fan and my best friend, and the reason I always find strength to keep working hard. Thank you for spending countless hours watching Liverpool games, which always bought me much needed writing time.

Finally, to my mama Annette. The woman who attained her Ph.D. with 8 children in tow, you are my inspiration. I have no idea how you managed it, but I'm grateful you did. Your successes paved the way for own my successes. You taught me I can do absolutely anything, and to always follow my heart. Thank you for fielding every call, and relentlessly believing in me even when I forget to believe in myself.

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Introduction

Cannabis is one of the most widely used substances in the United States, and an estimated 22.0% of people 12 or older (or 61.9 million people) have reported cannabis use in the past year (National Survey on Drug Use and Health, 2022). Despite the high prevalence of use, there are discordant perceptions about whether cannabis is health-promoting or confers health-related risks (National Academies of Sciences and Medicine, 2017). As of 2023, 24 states have legalized recreational cannabis, while 38 states have legalized cannabis for medicinal purposes (State Medical Cannabis Laws, 2023). Qualifying conditions for medicinal cannabis include a range of ailments such as chronic pain, cancer, irritable bowel syndrome, Tourette syndrome, anxiety, depression, sleep disorders, and many more (National Academies of Sciences and Medicine, 2017). The therapeutic potential of cannabis is matched by adverse health outcomes including cognitive, psychological, and physical consequences (Chan et al., 2021; Lovell et al., 2020; Pearson, 2019). This juxtaposition highlights the necessity to further explore and characterize the effects of cannabis on health and health behaviors, such as exercise.

Cannabis and Exercise

Recently, there has been a growing interest in cannabis as it relates to physical fitness and overall health and wellness. On the surface, this interest seems counterintuitive. Colloquially, cannabis users have been stereotyped as “lazy stoners” that experience “couch-lock” and “the munchies”, which deter from a healthy lifestyle. Stereotypical sedentary behavior is alarming, as it is widely known to be an important factor related to obesity (Blümel et al., 2015, 2016; Must

& Tybor, 2005). With the prevalence of obesity in America rising to 41.9% (National Health and Nutrition Examination Survey, 2021), it is important to understand if factors such as cannabis use are associated with increased health-risk behaviors that may lead to obesity. Interestingly, in previous longitudinal cohort studies, researchers found that overweight and obesity rates were lower among cannabis users (Hayatbakhsh et al., 2010). Moreover, those who used cannabis daily were the least likely to be overweight or obese (Hayatbakhsh et al., 2010). Additionally, a recent review and metanalysis found that a majority of studies supported the negative correlation between cannabis and obesity (Clark et al., 2018). Given this, it is important to investigate whether there may be cannabis-related health-promoting behaviors, such as exercise, that decrease the risk of obesity.

Regular exercise boasts a variety of physical and psychological health benefits (Gould et al., 2014; Nystoriak & Bhatnagar, 2018; Ruegsegger & Booth, 2018; Saeed et al., 2019). The World Health Association (WHO) recommends that adults aged 18-64 should engage in 150 minutes of moderate intensity aerobic physical activity each week to improve fitness, functional health, and reduce the risk of noncommunicable disease such as diabetes, heart disease, cancer and depression (World Health Organization [WHO], 2020). However, according to the CDC only 53% of U.S. adults meet the aforementioned exercise guidelines (Center for Disease Control [CDC], 2021). To investigate physical activity patterns in sample who uses cannabis, Ong and colleagues (2021) used an analytic sample from the National Health and Nutrition Examination Survey (NHANES) to assess cannabis use, accelerometer measured activity and sedentary behavior, as well as self-reported physical activity. The researchers found there to be no significant differences in sedentary behavior between cannabis user and non-user groups. However, after controlling for all covariates, they found that *frequent* cannabis users engaged in

more physical activity than their non-using counterparts. Conversely, a study by Vidot and colleagues (2017) found that physical activity was lower among cannabis users compared to never-users, and that as frequency of cannabis use increased, time spent exercising decreased (Vidot et al., 2017). These discordant study findings represent the overall ambiguity and lack of clear consensus within the cannabis and exercise literature. Gillman and colleagues (2015) completed a review and found a paucity of research on the topic and concluded the relationship between cannabis use and exercise to be unclear. However, the authors did postulate mechanisms that may mediate the relationship such as exercise performance, motivation, and recovery.

As is the case with the broader literature on cannabis and exercise, the results on the effect of cannabis on exercise performance are mixed. Due to federal restrictions, and cannabis bans by athletic agencies such as the World-Anti Doping Agency (WADA) it is nearly impossible to study prevalence and reason for use among professional athletes. The debate around cannabis as a performance-enhancing or performance-harming drug has recently gained media attention, with American sprinter Sha'Carri Richardson being suspended from the 2021 Summer Olympics due to a positive cannabis test (Jaeger, 2022).

The impact of cannabis on exercise performance becomes further muddled when one considers the multitude of ways exercise performance can be measured. Broadly, exercise performance and cardiorespiratory fitness are typically measured via maximal oxygen uptake (VO2Max) (Bassett & Howley, 2000), peak work capacity (PWC), or the maximum power a person can output (D. A. Kaminsky et al., 2014; Kramer et al., 2020), as well as blood pressure and heart rate (Blair et al., 1996; Dimkpa, 2009; L. A. Kaminsky et al., 2019). A recent review of the literature found that across four studies, no significant differences arose between cannabis-

users and non-users for peak work capacity, VO2Max, or blood pressure (Kramer et al., 2020; Lisano et al., 2019, 2020; Maksud & Baron, 1980; Wade et al., 2019). Three studies in the review measured resting heart rate, with only one reporting a lower resting HR in cannabis-users, in concordance with the results reported in Benowitz & Jones' (1975) clinical trial comparing non-users to users. These findings suggest that cannabis use may not enhance performance, however, performance is not the only indicator of a successful workout. Researchers have begun to explore factors such as enjoyment, and exercise-related cannabis use motives to understand how and why individuals may use cannabis during physical activity.

A recent study by Ogle and colleagues (2022) sought to answer this question. Recent research has implemented the survey method to understand consumption patterns of those who combine cannabis with exercise (before, after, or both), perceived benefits of combining cannabis with exercise (positive subjective experiences) and exercise habits (Lisano et al., 2018; YorkWilliams et al., 2019). The study by Ogle and colleagues built off previous survey studies to gain a more thorough understanding of how and why people combine cannabis with exercise (Ogle et al., 2022). In their study, researchers developed a 32-question survey that posed questions regarding type of cannabis used while exercising, types of physical activity participants engaged in, where and when people used cannabis with exercise, and motives for combining cannabis with exercise. Results indicated that a majority of the sample smoked cannabis, and participants most frequently paired cannabis and exercise for activities like hiking, yoga, walking and weightlifting. Ogle and colleagues offered a more comprehensive list of why someone may use cannabis in conjunction with exercise, and a majority of their participants reported doing so to "help me focus/concentrate," "help me enjoy the exercise experience,"

"enhance mind/body/spirit connection," and "to keep me in the zone." This expanded list of reasons why someone may use cannabis with exercise proved to be more complete, and more effectively characterized the paired behaviors. Overall, Ogle and colleague's study set the stage for understanding who is combining cannabis with exercise, how they're doing it, and why. However, the study specifically selected participants who self-reported using cannabis before or after exercise, and therefore failed to characterize the prevalence of combining cannabis and exercise in a population of cannabis users who also exercise (not necessarily together). Additionally, they utilized a cross-sectional survey where recall-bias may have influenced results. The study also did not include a question about individual's geographic location; therefore authors could not conclude whether participants resided in states with legalized recreational or medicinal cannabis, or even if they lived in the U.S. This makes it difficult to collect detailed information on cannabis strain or type and may be less generalizable.

To refine this methodology, it is important to assess cannabis and exercise behaviors in a more general population of cannabis users who exercise to understand the prevalence of combining the two. Additionally, data on motives to combine cannabis with exercise and descriptive information such as type, timing, and quantity of both cannabis use and exercise should be collected longitudinally to capture temporal data related to the two behaviors. For this reason, the present study will use Ogle and colleagues' comprehensive motives questionnaire to explore whether the results apply to a more general population. Additionally, the present study will implement a daily diary design to reduce recall-bias and gain a better understanding cannabis and exercise behaviors over time. With the increasingly widespread legalization and use of cannabis, it is vital to explore how people pair cannabis with various behaviors, such as exercise, to understand the perceived risks and benefits.

Exercise and Affect

In addition to the physical health benefits provided by exercise, it is widely accepted in the literature that exercise is also linked to a host of psychological benefits as well (Berger & Motl, 2000; LaFontaine et al., 1992; Mandolesi et al., 2018; Mikkelsen et al., 2017). Conversely, physical inactivity and sedentary behavior may contribute to a decline in mental health (Booth et al., 2017) and an overall poorer quality of life (Gualano et al., 2017). A poor quality of life is the antithesis of well-being, which Diener and colleagues (1984) originally defined as a multidimensional construct that involves (1) the presence of positive affect (2) the absence of negative affect and (3) life satisfaction (Diener, 1984; Diener et al., 1997). Not surprisingly, those who exercise more report higher levels of well-being (Fox, 1999; Lox et al., 1999; Penedo & Dahn, 2005), due to the positive impact exercise has on each of the three dimensions. Specifically, research suggests exercise may increase positive affect, decrease negative affect, and improve facets of life satisfaction (Barnett, 2013; Baştuğ & Duman, 2010; Biddle, 1995; Cruz-Ferreira et al., 2011; Edwards et al., 2008).

Positive affect, in particular, is essential to the improvement and maintenance of wellbeing (Baştuğ & Duman, 2010), and is importantly enhanced by exercise both acutely and longitudinally (Basso & Suzuki, 2017; Reed, 2013). Affect in general can be conceptualized as a circumplex that extends beyond the discrete and limited theories of basic emotion (Ekman, 1992; Panksepp, 1998; Tomkins, 1962, 1963). The circumplex model regards affective experiences to be on a continuum, with valence (positive-negative) and activation (activated-deactivated) dimensions on the horizontal and vertical axis, respectively (Posner et al., 2005). The model can be used to describe the nuanced and interrelated experience of affect, which is especially important for clinicians assessing psychiatric diagnoses. Not surprisingly, mood and affect are

foundational elements of mental health, and alterations or disruptions can lead to a variety of mental health disorders. With the incidence of mental health conditions on the rise (National Alliance on Mental Illness, 2022), it is imperative to employ interventions that are both accessible and effective in decreasing symptoms and distress. Regular exercise may be an important intervention option that is low-cost, low-burden and empirically supported. Regular exercise has been implicated as a viable intervention for disorders such as anxiety, depression, and panic disorder (Gaudlitz et al., 2015; LaFontaine et al., 1992; Scott et al., 2000; Ströhle et al., 2009), and has even been said to improve mental wellbeing as equally as psychotherapy (Raglin, 1991). At present, there is no conclusive evidence on a single mechanism that reliably affects the exercise-mood relationship, but it is clear that a positive association exists.

Interestingly, this positive relationship between exercise and mood/affect may be bidirectional. As stated, exercise can improve mood and affect, and positive affect has been found to be predictive of engagement in health behaviors, such as exercise (Ong et al., 2011; Pressman et al., 2019; Sin et al., 2015). The increased health behavior engagement then encourages further positive mood and affect, representing a positive feedback loop and potentially creating lasting behavior change (Van Cappellen et al., 2018). This is an exciting association for researchers and providers interested in increasing well-being and exercise engagement. To characterize the relationship further, and inform future studies and care, it is important to gather longitudinal data, as in the proposed study design, that assesses daily affect and exercise engagement within the context of other behaviors such as substance use.

Endocannabinoid System

The endocannabinoid system (ECS) is a vast neuromodulatory network (Lu & Mackie, 2021), with receptors expressed throughout both the brain and body (Skaper & Di Marzo, 2012).

These endocannabinoid receptors bind both exogenous cannabinoids (e.g., tetrahydrocannabinol; THC) found in the cannabis plant, as well as endogenous cannabinoids (endocannabinoids) (Lu & Mackie, 2016). The most well-studied endocannabinoids, 2-arachidonoylglycerol (2-AG) and N-arachidonoylethanolamine (anandamide, AEA), bind to two identified receptors, CB1 and CB2 (Lu & Mackie, 2016). CB1 receptors are highly expressed throughout the central nervous system, whereas CB2 receptors are expressed in the peripheral nervous system (Ahn et al., 2008). CB1 is thought to play a part in neuromodulatory, analgesic, and psychoactive effects, whereas CB2 is thought to be involved primarily in anti-inflammatory and immunomodulatory effects (Mechoulam & Parker, 2013). Interestingly, these effects are very similar to those experienced during exercise. This may be due to the finding that exercise activates the ECS, as evidenced by an early experimental study where participants who took part in 45 minutes of moderate intensity exercise showed increased circulating plasma levels of endogenous cannabinoids compared to sedentary controls (Sparling et al., 2003). In animal models, exercise has been shown to trigger ECS-dependent analgesic effects in the central and peripheral nervous system (Galdino et al., 2014). These findings suggest that endocannabinoids are at least partly responsible for the neurobiological effects of exercise in humans (Raichlen et al., 2013).

In the literature, the "runner's high", or the euphoric, anxiolytic, analgesic, and sedative effects following intense exercise, has long been attributed to endorphin release via the endogenous opioid system (Dishman & O'Connor, 2009; Morgan, 1985). However, more recently, data has emerged to rebut this endorphin hypothesis (Grijalba & Comer, 2017; Winiarz, 2019). Research has demonstrated that running increases both β-endorphins (an opioid) and anandamide (AEA; endocannabinoid) in human and animal models (Carr et al., 1981; Sparling et al., 2003); however, there is one important caveat: unlike endocannabinoids, β-endorphins are

large molecules which cannot cross the blood-brain barrier (Dietrich & McDaniel, 2004; Pardridge et al., 1990). This suggests that endorphins cannot be solely responsible for the runner's high. Many studies to date have supported this finding with use of animal models (Dubreucq et al., 2013; Fuss et al., 2015; Fuss & Gass, 2010). Even more compelling is the work on this topic that has recently been corroborated in humans. Siebers and colleagues (2021) sought to investigate whether exercise-induced euphoria and anxiolytic effects were dependent on the opioid system. Researchers administered naltrexone (an opioid receptor antagonist which blocks the effects of endogenous opioids) in a double-blind, randomized, placebo-controlled experiment, in which participants either ran or walked on a treadmill. Participants who ran had higher plasma levels of endocannabinoids, and increased euphoria and decreased anxiety compared to those who walked. Interestingly, opioid blockade did not prevent subjective effects of the runner's high, which suggests that exercise-induced positive experiences do *not* depend on opioid signaling, but more likely on the endocannabinoid system, as previously demonstrated in mice (Crombie et al., 2018). A recent systemic review summarized further evidence of an association between features of the runner's high (euphoria, anxiolysis, hypoalgesia, and sedation) and the endocannabinoid system (Siebers et al., 2022). Of the 21 studies included, a majority reported a significant increase in endocannabinoids post exercise, as well as increased positive affect, reduced anxiety, and reduced pain sensitivity. These positive experiences are thought to be neurobiological rewards that motivate human exercise (Ekkekakis et al., 2005; Ogles & Masters, 2003), which make the endocannabinoid system an interesting target for future exercise research. At this time, more work is needed to better understand the time course of these effects and how individual differences may play a role in experiences of the runners high during various forms of exercise.

In sum, it makes sense to postulate that individuals who enjoy the exercise-induced effects that result from ECS activation, may also seek to experience this effect with plant-based cannabis. Thus, cannabis and exercise may also exhibit a positive relationship, similar to the well-characterized positive relationship between alcohol and exercise (Barry & Piazza-Gardner, 2012; Kopp et al., 2015; Leasure et al., 2015; Musselman & Rutledge, 2010; Niedermeier et al., 2018). Indeed, the limited existing research on exercise and cannabis has found that cannabis users frequently endorse using cannabis simultaneously with exercise and do so shortly before or afterwards to increase enjoyment, enhance recovery, and increase motivation to exercise (YorkWilliams et al., 2019), similar to the mechanisms resulting from the ECS-mediated runner's high. No studies to date have examined how long-term cannabis use might impact exercise behavior but given the fact that both cannabis and exercise activate the ECS and prompt specific central and peripheral effects, it makes sense that the two may be positively associated and their relationship needs to be characterized further to inform potential clinical applications.

Current Study

The relationship between cannabis and exercise has been investigated in those who have endorsed combining cannabis and exercise; however, it has not been explored more generally in the population of cannabis users who also exercise across a variety of variables. Additionally, previous research has collected data cross-sectionally; however, cannabis and exercise behaviors have not been explored longitudinally, nor within the context of other factors such as affect. This study recruited individuals between the ages of 21-64 that reside in Colorado and California to complete a 14-day daily diary study. Each daily diary collected information on participant's cannabis use (strain, THC potency, amount consumed), and exercise behaviors (type, total minutes), as well as timing for each of the aforementioned behaviors. These daily diaries also

collected information on daily, state-level affect. Based on the bidirectional relationship that affect and exercise have with one another, this study also seeks characterize daily-level associations between exercise and affect over the course of the study. Finally, as a replication and extension of Ogle et al.'s (2022) paper, this study examined exercise related cannabis use motivations in a population of cannabis users who also exercise, but do not necessarily combine these behaviors.

Hypotheses

1. Characterize daily-level associations between exercise engagement and cannabis use.

a. Hypothesis 1a: Overall, I expect to see positive within-person associations over the course of the study between exercise engagement and cannabis use.

2. Explore daily-level associations between exercise and affect over the course of the study.

a. Hypothesis 2a: I predict that on days with higher levels of positive affect participants will report greater exercise engagement.

3. Use descriptive statistics to characterize the sample in terms of demographics, cannabis use, exercise engagement, exercise enjoyment, goal attainment, and motives for combining cannabis with exercise.

Method

Participants and Procedure

Participants

Residents from states with legalized recreational cannabis (predominantly Colorado and California) aged 21 or older who currently exercise at least 150 minutes each week (the minimum WHO recommended exercise guideline) and use cannabis at least twice weekly were recruited as a part of a study on daily level cannabis use and exercise. Sociodemographic information and survey measures on study constructs were collected from participants who consented to take part in the study. The sample (n = 52) was comprised of 28 (53.8%) individuals assigned male and birth, and 24 (46.2%) individuals assigned female at birth. The sample was predominantly white (86.5%, *n*= 45), and the mean age was 30.36 years old (*SD* = 8.77). For full demographic information see Table 1.

Procedure

Participants were recruited via social media, posted flyers, and Craigslist to complete an online eligibility survey powered through REDCap. Participants received the following information before completing the prescreening for the study: *Thank you for your interest in this study! This research study is designed to examine the relationship between cannabis use and exercise. Specifically, through this research, we are hoping to better understand how daily levels of cannabis use are related to exercise engagement, facilitation, enjoyment, recovery, and functioning overall. In order to determine whether this study is a good fit for you, we ask that you respond to some eligibility questions. These questions will take about 10-15 minutes of your time. The information collected will be kept confidential and you do not have to answer any*

question that makes you feel uncomfortable; however, if you don't respond it might mean that we cannot determine whether this study is a good fit for you. If you are eligible to participate in the study, we will keep this information secure. If you do not qualify for this study, we will keep the information collected in this survey, but there will be no way for anyone to link that information to you. After completing all of the questions, a member of the research team will contact you regarding your eligibility. If you have any questions or concerns regarding this screening, you can contact the PI of the study, Dr. Hollis Karoly at 970-491-3677 or the IRB who oversees our research at 970-491-1553. Participation in this survey is voluntary. If you consent to participating in this online screener, please click yes. If you do not consent and do not wish to participate, please click no. Thank you.

Once participants completed the prescreening, a member of the research team determined their eligibility based on the criteria listed in the above section. Upon determining eligibility, researchers called the eligible subject to notify them, and deliver the verbal consent over the phone. During this call, the researcher read over the verbal consent, and explained the daily diary study procedure in detail and resultant compensation for completing all parts of the study. Participants were told that they would earn $12 for completing the baseline survey and that they would earn $2 per daily diary across 14 daily diaries total. In total, participants could earn up to $40. Afterwards, participants were sent a baseline survey to complete electronically that captures their demographics, as well as trait-level affect, psychological functioning, and cannabis-use questions with measures listed below. The following day, the first daily diary in a series of 14 daily diaries was sent via email at 5:00PM, a pattern that continued each day forward. The daily diary questions assessed cannabis use, mood, exercise (type, duration), motives to combine cannabis and exercise, as well as their experience in doing so.

Measures

Baseline Measures

Demographic Characteristics. Participants answered questions regarding age, race, sex, ethnicity, gender identity, sexual orientation, family history, and social history.

Positive and negative affect schedules (PANAS-X). The PANAS (Watson, D., & Clark, L., 1994) and Larsen and Diener's affect circumplex model (Larsen & Diener, 1992), asks participants to rate the extent to which they identify with a positive emotion (i.e. joyful) or a negative emotion (i.e. hostile) on a 5-point scale. Ratings will be summed separately to calculate a score for positive affectivity, separate from negative affectivity. The PANAS has good internal consistency (0.86 – 0.90) and has been shown to be stable (Watson et al., 1988). Previous studies demonstrate good criterion validity of this affect scale (Armeli et al., 2003, Csikszentmihalyi and Larson, 1992, Simons et al., 2005).

Difficulty in Emotion Regulation Scale (DERS-18). The DERS-18 (Victor & Klonsky, 2016) is an 18-item, six-factor brief short-form questionnaire (sample items: "I am clear about my feelings", "When I'm upset, I can still get things done") that is scored on a scale that ranges from 1 ("almost never [0-10%]") to 5 ("almost always [91-100%]). The responses produce scores on six emotion regulation subscales (lack of emotional awareness, nonacceptance of emotional responses, lack of emotional clarity, difficulty in engaging in goal-directed behavior, impulse control difficulties, nonacceptance of emotional responses, and limited access to emotion regulation strategies). Higher scores (closer to 90) indicate less emotional regulation. The DERS-18 has been shown to have high internal consistency ($\alpha = .91$) and good convergent validity as demonstrated by statistically significant correlations between overall DERS-18 scores

and constructs of interest (Victor & Klonsky, 2016). More recent research shows support for the reliability and validity of the DERS using factor analysis (Hallion et al., 2018).

Short Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale (SUPPS-P). The SUPPS-P (Lynam, 2013) is a 20-item self-report measure that assesses urgency, premeditation, perseverance, sensation seeking, and positive urgency. These factors relate to five dimensions of impulse behavior. Items (sample items: "I quite enjoy taking risks," "Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse") are scored on a 4-point Likert scale ranging from 1 (Agree Strongly) to 4 (Disagree Strongly). The SUPPS-P has been shown to be strongly correlated with the longform UPPS-P subscales: negative urgency (r = 0.69), positive urgency (r = 0.83), lack of perseverance (r = 0.63), lack of premeditation (r = 0.71), and sensation seeking (r = 0.64). Additionally, the UPPS-P replicated the internal consistency across subscales (α=0.74–0.88) and inter-scale correlations found in psychometric properties of the longform UPPS-S (Cyders et al., 2014; Whiteside et al., 2005).

Daily Session, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU). The DFAQ-CU is a 39-item measure of frequency, age of onset, and quantity of cannabis used. The DFAQ-CU has been determined to be a psychometrically sound measure (Cuttler & Spradlin, 2017), and factors included in the measure are reliable, with Cronbach's alpha coefficients ranging from .69 (daily sessions) to .95 (frequency). The factors were also found to demonstrate high convergent validity, predictive validity, and discriminant validity when compared to other measures.

Modified Marijuana Motives Questionnaire (MMQ). The Marijuana Motives Questionnaire (Simons et al., 1998) is a 25-item questionnaire modeled after the Drinking

Motives Questionnaire (DMQ), with good internal consistency and concurrent validity. There are 5 factors: Enhancement, Conformity, Expansion, Coping, and Social. The questionnaire in the present study includes 10 additional exercise-related cannabis use motives questions such as "to replace the high I get from exercise on a day off from exercise."

Daily Diary Measures

Daily online reporting (3min/day) is feasible for measuring cannabis use and exercise. During the 14-day period, participants reported their cannabis use and exercise behaviors daily via online survey methods that have been established through Dr. Karoly's ongoing NIH-funded study (grant number K23AA028238, Project Title: Exploring the Effects of Cannabinoids on Alcohol Consumption and the Microbiota-Gut-Brain Axis). Participants responded daily at 5pm about the past 24 hours, following validated procedures for daily diary studies of alcohol use. See Appendix A for all questions presented in the daily diary survey.

Analysis Plan

Data Handling and Preparation

Prior to testing these hypotheses, missing data was analyzed to determine if there were systematic patterns of missingness and missing data was addressed. Little's Test of Missing Completely at Random (MCAR) was used to decide if significant differences existed between complete and incomplete data (Li, 2013). In structural equation modeling techniques, various methods for handling missing data can be applied, including listwise deletion, pairwise deletion, similar response pattern imputation, and full information maximum likelihood (FIML). Among these options, FIML estimation has been found to be superior due to being unbiased, more efficient, and for producing non-inflated Type 1 errors (Enders & Bandalos, 2001; Graham, 2003). Presently, researchers agree that FIML is a viable option for MSEM, as it yields unbiased

parameter estimates so long as it done under MCAR or MAR conditions (Enders, 2022), as is the case in the present dataset. Therefore, models used for Aim 1 and Aim 2 employed full information maximum likelihood estimation, which allowed the inclusion of cases with missing data.

For Aim 1, both the outcome (exercise engagement) and predictor (cannabis use) were analyzed as binary variables and were group-mean centered. Group mean centering effectively removes person-level variance and is warranted because multilevel models and centering principles have been shown, algebraically and statistically, to behave the same whether predictors are continuous or categorical (Yaremych et al., 2023).

For descriptive data related to THC percentages, data cleaning procedures were performed using recommendations from Tabachnick and Fidell (Tabachnick et al., 2013). Specifically, univariate outliers (scores of > 95% THC) were examined individually and adjusted by reducing outlying values to one score above the highest percentage possible for cannabis concentrates, which has been reported to be about 95% in the present literature (Bidwell et al., 2018; Light et al., 2015; Raber et al., 2015).

After estimating the log odds ratio in the present logistic regression models, each were converted to Cohen's d according to recommendations in the literature (Hasselblad & Hedges, 1995; Polanin & Snilstveit, 2016). The conversion calculations were done using an online effect size converter tool. This was done so that the effect size could be expressed in a standardized metric, and to provide a clearer understanding of the magnitude of the relationship between the predictor variable and the binary outcome.

Primary Analyses

Analyses for Aim 1 and 2 was conducted using MPlus 8.8 (L. K. Muthén & Muthén, 1998 –2022). Analyses for Aim 3 were conducted with R Version 2023.12.0 + 369 (R Core Team 2024). Means, standard deviations, and frequencies were calculated for all variables. Median and ranges were calculated for all for non-normal variables. To account for the repeated measures design of this project, hypotheses were tested in a Multilevel Structural Equation Modeling (MSEM) framework (Curran, 2003; Mehta & Neale, 2005). A strength of MSEM is that it combines elements from both multilevel modeling (MLM) and structural equation modeling (SEM). It allows for the analysis of hierarchical structures, latent variables, within- and between- group effects, as well as cross-level interactions, making MSEM more flexible than MLM or SEM alone(Heck & Thomas, 2020; Mehta & Neale, 2005). In the present study, dailylevel observations were nested within individuals, so multilevel modeling via random coefficient regression was used to test within-subject patterns of exercise and cannabis use, as well as exercise and affect, in the daily data (Shiverdecker & LeBreton, 2019). In longitudinal, behavioral sciences studies, MSEM can be especially useful because it provides increased power (Curran & Bauer, 2011; Mehta & Neale, 2005) and can accommodate missing data so that data from participants with incomplete data can be retained and their data can still be evaluated (Schminkey et al., 2016).

Figures 1 and 2 show the path diagrams used for MSEM models. Hypotheses 1 and 2 were tested in these models, respectively. Based on simulations done by Arend & Shafer (2019) for hierarchically structured data such as this, 50 participants reporting data for 14 days allowed me to be appropriately powered to detect small effects in level 1 analyses. A post-hoc model evaluation will be done for Hypothesis 1 to compare model results to the power analysis.

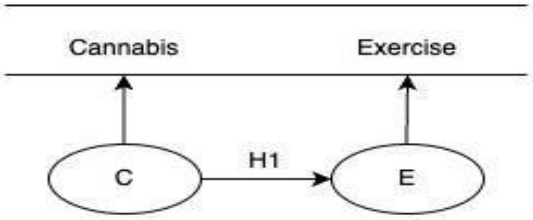

Figure 1
Multilevel structural equation model (MSEM) for testing relations among cannabis use and exercise engagement at the within-person level. H1= Hypotheses 1a; C= within-person (i.e., episode-level) cannabis use measured via daily diary submissions; E= within-persons exercise behavior measured via daily diary submissions.

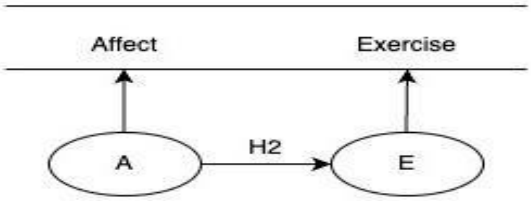

Figure 2
Multilevel structural equation model (MSEM) for testing relations among exercise engagement and affect at the within-person level. H2= Hypothesis 2a; A= within-persons affect; E= within persons exercise behavior measured via daily diary submissions.

Hypothesis 1. The hypothesis that a positive association would emerge between exercise and cannabis over the course of the study would be supported if the model produced a significant positive effect, where cannabis use was positively associated with exercise engagement (level 1, fixed effect). I analyzed cannabis use days and non-use days and tested whether response to the cannabis-use question (0=no, 1=yes) predicted exercise engagement that day using random coefficient regression.

Hypothesis 2. The hypothesis that a positive association would emerge between exercise and positive affect at the daily-level would be supported if the model produced a significant positive effect, where higher levels of positive affect on a given day predicted exercise engagement (level 1, fixed effect). I analyzed daily-level affect and tested whether average

positive affect endorsement each day predicted exercise engagement that day using random coefficient regression.

Hypothesis 3. Descriptive statistics such as detailed demographics, study compliance, demographics, cannabis use, exercise engagement, exercise enjoyment, goal attainment, and motives for combining cannabis with exercise were reported in an exploratory manner.

Results

The intraclass correlation (ICC) for the outcome variable (binary exercise engagement) was .204, indicating that, conceptually and statistically, MSEM was an appropriate analysis to perform.

Hypothesis 1: A positive within-person association over the course of the study between cannabis use and exercise engagement.

Level 1 – Within-Person Results

Model fit is unavailable for logit models that use maximum likelihood with robust standard errors (MLR). Both the outcome (exercise engagement) and predictor (cannabis use) were analyzed as binary variables and were group-mean centered. Counter to hypothesis 1 at level 1, the within-level analysis revealed a non-significant positive estimate (b =.209, SE = .261, p = .425) for the regression of exercise behavior on cannabis use. The calculated effect size was converted to a Cohen's d value of 0.679, representing a medium effect size were the results significant. As previously stated, the power analysis indicated that this study was powered to detect small effects. Given the discrepancy between the power analysis and the observed results (i.e., a non-significant medium-sized effect), I determined that a further examination of assumptions for multilevel models was warranted. This examination revealed that the person-centered variables, exercise engagement and cannabis use, were non-normal, thus violating the normality assumption. Along with missing data and small sample size, the violation of the normality assumption likely caused our results to differ from what was expected from a simulation with idealized variables. Therefore, I determined that the effect size was likely more trustworthy in interpreting the relationship between exercise engagement and cannabis use at the

daily level. The results were interpreted based on the direction of the effect, and the magnitude, which was positive and medium.

Hypothesis 2: A positive within-person association over the course of the study between affect and exercise engagement.

Level 1 – Within-Person Results

Model fit is unavailable for logit models that use maximum likelihood with robust standard errors (MLR). To analyze the relationship that exercise engagement (outcome) had on positive affect (predictor), a positive affect score was calculated for each participant's daily response by averaging their scores (1=very slightly/not at all, to 5=extremely) on positively valanced emotions (i.e., happy, calm, lively) from the visual analog mood scale. Consistent with our hypothesis, at the day-level (L1), there was a significant within-person association between positive affect and exercise engagement (b = .618, SE = .214, p = .004). The calculated effect size was converted to a Cohen's d value of 1.023, representing a large effect size.

Hypothesis 3: Use descriptive statistics to characterize the sample.

Descriptive Statistics

This sample was comprised of 28 (53.8%) individuals assigned male and birth, and 24 (46.2%) individuals assigned female at birth. The sample was predominantly white (86.5%, *n*= 45), and the mean age was 30.36 years old (*SD* = 8.77). 16 participants identified as cis men (30.7%), 14 identified as men (26.9%), 16 identified as cis women (30.7%), 9 identified as women (17.3%), 1 identified as gender conforming (1.92%), 1 as demi-girl (1.92%), 1 identified as another gender not listed (1.92%), and 1 indicated they did not wish to respond (1.92%). Note, percentages do not sum to 100, as participants were free to select more than one gender. 73.1% (n= 38) of the sample identified as not Hispanic and/or Latino, 17.3% (*n*= 9) of the sample

identified as Hispanic and/or Latino, and 9.6% (*n*=5) of the sample identified as another ethnicity. See Table 1 for full demographic information of all participants in the present sample. In the overall sample, 30 (57.7%) participants reported using cannabis with exercise at least 1 day in the study period. Of those "combiners," 15 (50.0%) reported their sex assigned at birth was male, and their mean age was 31.03 years (*SD* = 9.93). This subsample was predominantly white (86.6%, *n*=26), and 70.0% (*n*=21) of the sample identified as not Hispanic and/or Latino. Twenty-two (42.3%) participants in the sample never reported combining cannabis with their exercise throughout the study. Participants in this subsample had a mean age of 29.45 years (*SD* = 8.87), and 59.1% (*n*=13) reported their sex assigned at birth was male. These participants were also predominantly white (91.0%, *n*=20), and 77.3% (n=17) identified as not Hispanic and/or Latino. For demographic information on those who combined versus those who did not, see table 2.

Trait-level positive and negative affect scores were calculated for this sample using the PANAS-X. On average, on a scale of 10 (less of the given affect) to 50 (more of the given affect), participants reported a positive affect score of 28.77 (*SD*= 8.24), and a negative affect score of 15.42 (*SD*= 4.94). On the difficulties in emotion regulation scale (DERS), a higher score (closer to 90) indicates greater emotional distress. Participants, on average, reported a score of 37.71 (*SD*= 10.20).

If all participants had completed all 14 surveys, we would have a total of 728 surveys (i.e., 52 participants x 14 days). We had good compliance with daily diary completion, as the data set contained 602 surveys (82.69% of the possible surveys). On average, participants completed 11.58 out of 14 possible days of surveys (*SD* = 2.53 days). When Little's Test of Missing Completely at Random (MCAR) was performed, the results were not significant

(p=0.280), which indicates that missing data was MCAR (Li, 2013). Additionally, the missingness of data was visualized using the "naniar" package in R Version 2023.12.0 + 369 (R Core Team 2024) and appeared to be missing at random from visual inspection.

This was a sample of individuals who regularly used cannabis, as evidenced by the fact they most commonly reported using cannabis more than once per day and started using cannabis regularly (2 or more times per month for 6 months or longer) around age 19.4 (*SD* = 5.23 years). Participants in the sample primarily reported consuming flower cannabis (59.6%, *n*= 31), followed by edibles (26.9%, *n*= 14), and concentrates (13.5%, *n*= 7). Additionally, participants reported consuming 0.37 grams (*SD* = 0.36) of cannabis per use session, and over the study reported using 1.001 grams (*SD* = 1.71) per day. Throughout the study, on average, participants used cannabis 73.1% (*SD* = 44.3) of days within the study period, or about 10 of 14 days. On the days that participants used cannabis overall, the average THC percentage of their product was 30.88 (*SD* = 23.16). Those who combined cannabis with their exercise reported an average THC percentage of 34.8 (*SD* = 23.04). Those who exercised, and used cannabis, but not together, reported an average THC percentage of 31.34 (*SD* = 24.55). Finally, those who used cannabis and did not exercise reported an average THC percentage of 27.31 (*SD* = 20.27). See Table 1 for full information on cannabis use patterns.

Additionally, participants endorsed exercising 64.0% (*SD* = 48.0) of days within the study period, or about 9 of 14 days. Overall, people in the study reported exercising 59.33 minutes per day (*SD* = 73.96), and on days where they exercised, participants reported an average of 92.6 minutes (*SD* = 73.8). On the days that participants reported exercising, they endorsed doing so while feeling the effects of cannabis on 29.1% of the study days. Of the 52 participants in the study, 30 participants (57.7%) reported combining cannabis and exercise at

least 1 time throughout the study. On days when participants combined cannabis with their exercise, 73.2% of days participants reported meeting their exercise goals at least 80% of the time, comparable to the 76.36% of days when participants did NOT exercise while feeling the effects of cannabis. On a scale of 1 (Enjoyed it) to 7 (hated it), those who combined cannabis with exercise on a given day on average rated their exercise experience as a 2.21 (*SD* = 1.22), while those who did not combine behaviors on a given day rated theirs at a 2.01 (*SD* = 1.18), suggesting no significant difference between enjoyment of exercise on days when cannabis was used compared to days when it was not used (*t*=1.55, p=.1214, see Table 3). Additionally, those who combined cannabis and exercise on a given day reported their experience of combining the behaviors was most often exactly as they had expected (36.4%), or better than expected (21.5%), see Figure 3. The top 5 most endorsed reasons to combine cannabis and exercise were to achieve exercise-related benefits from cannabis use, specifically:

"to help me focus/concentrate," "helps me enjoy the exercise experience," "enhances mind/body/spirit connection," "enhances body awareness," and "keeps me in the zone," see figure 6. On days when participants combined cannabis with exercise, respondents most often reported brisk walking/jogging (34.6%), followed by weightlifting (15.7%), another type of exercise (e.g., disc golf, bike polo, frisbee golf, skiing, snowboarding, rock climbing, skateboarding, 12.4%), running (8.6%), and equally reported yardwork, biking, and hiking (each 5.95%), see Figure 4. Among participants who did not combine cannabis with exercise on a given day, the most commonly endorsed forms of exercise included weightlifting (25.8%), walking/jogging (20.7%), biking/cycling (11.6%), running (8.5%), yoga (8.0%), see Figure 5.

Discussion

The current study sought to expand our understanding of who combines cannabis with exercise, how they do it, and why. It also explored what effect combining cannabis has on exercise outcomes including amount of exercise engagement, exercise enjoyment, exercise experience, and exercise goals. In terms of amount of exercise engagement, a nonsignificant relationship was found between exercise and cannabis at the within-person level. However, based on an ad-hoc analysis due to a discrepancy between power analysis and observed results (i.e., a non-significant medium-sized effect), it was determined that effect-size was likely more trustworthy in interpreting the relationship between exercise engagement and cannabis use at the daily level. Therefore, it was interpreted based on the direction of the effect, and the magnitude, which was positive and medium, in line with what was originally hypothesized based on the literature. This finding was in line with a study by YorkWilliams et al. (2019), who utilized cross-sectional subjective surveys to understand cannabis and exercise behaviors and reported that those who combined cannabis with exercise engaged in 43.4 more minutes of weekly exercise on average compared to those who did not combine cannabis with their exercise (YorkWilliams et al., 2019). The present study expanded this finding by altering the methodology to collect data longitudinally and assess for differences at the within-person level, as opposed to the between-person level. The present study set the groundwork for exploring within-person differences in cannabis and exercise engagement, and it will be important for research moving forward to assess moderators to that relationship. The present study suggests that there may be a positive trend between cannabis and exercise, which suggests that for some individuals, cannabis may be a useful tool for exercise engagement. This has important implications for public health. Presently, about 1 in 2 American adults do not get

enough physical activity, leading to higher incidence in heart disease, type 2 diabetes, and cancer. As a result, 117 billion dollars in health care costs are accrued in the U.S. alone related to low physical activity engagement (National Center for Chronic Disease Prevention and Health Promotion, 2022). Given the fact that cannabis and exercise literature is still in its infancy, any recommendations for using cannabis to increase exercise engagement would be premature. However, it is evident from the present study that pairing cannabis with exercise may help reduce the most commonly endorsed barriers to exercise engagement, such as non-enjoyment and boredom (Cohen-Mansfield et al., 2003; Korkiakangas et al., 2011; Wolff et al., 2023). It is important to note that the present study recruited participants who regularly use cannabis that are already meeting the minimum recommendation for weekly exercise. Therefore, future research should focus on sedentary individuals who use cannabis to determine whether exercise behaviors change as a function of cannabis-use, and whether cannabis is a viable intervention for increasing exercise engagement.

Another primary finding of this study was the significant within-person association between positive affect and exercise engagement. On any given day, the higher one's positive affect was, the more likely they were to engage in exercise. This is in line with previous research, which has demonstrated that psychological factors, such as positive affect and cognitive attitudes, predict exercise engagement (Kiviniemi et al., 2007; Lawton et al., 2009; Sheeran et al., 2018). Although it is difficult to determine causality from the present study, the relationship between affect and exercise has been shown to exist in both directions, for example, a metanalysis on the topic found that in general, exercise was associated with increased positive activated affect (Reed & Ones, 2006). This is important to consider, because it may suggest a positive feedback loop between positive affect and exercise, whereby positive affect may

encourage someone to engage in exercise, and exercise may prompt positive affect, and so on and so forth. In the literature, this is referred to as the upward spiral theory of lifestyle change, which "explains how positive affect can facilitate long-term adherence to positive health behaviors" (Van Cappellen et al., 2018). When people link positive affect and cognitions with a health behavior, such as exercise, they are more likely to engage with it (Kiviniemi & Duangdao, 2009; Lawton et al., 2009; Shiota et al., 2021). To create lasting change, it is especially important that the positive affect occurs *during* the health behavior to promote nonconscious and conscious motives to pursue the behavior in the future (Van Cappellen et al., 2018). Although the present study did not assess positive affect during exercise, and how it may have differed on cannabis-use days vs. no-use days, another recent study did. Gibson and colleagues (2023) recently found that participants reported significantly higher positive affect during their cannabis vs. non-cannabis exercise sessions (Gibson et al., 2023). This finding suggests that cannabis may facilitate the experience of positive affect during exercise, which could potentially promote the upward spiral for exercise engagement. Whether one's exercise includes cannabis or not, the finding that positive affect was significantly associated with exercise is an important one. Increasing positive affect that precipitates and/or happens during exercise may be a meaningful target for interventions to increase physical activity. As the literature suggests, this may be achieved through cannabis use with exercise, or via other techniques such as "emphasizing the immediate pleasure of a healthy activity" or by "increasing the salience of rewards beyond individual physical health" in order to highlight longer-term rewards (Shiota et al., 2021). Capitalizing on the effect positive affect can have on physical activity may both reduce sedentary behavior and negative psychological states experienced alongside conditions related to physical inactivity.

In contrast to most previous work, this study did not explicitly select individuals on the basis that they combine cannabis and exercise (Lisano et al., 2018; Ogle et al., 2022), rather we required that participants do each of the behaviors (exercising and using cannabis) at a certain frequency (see inclusion/exclusion criteria). Baseline measurements were included, which allowed for the sample to be characterized based on demographics, trait-level affect, emotion regulation, and lifetime cannabis use patterns. This sample was evenly comprised of participants who were assigned male at birth (53.8%) and female at birth (46.2%). The distribution of sex assigned at birth is similar to that of Lisano et al. (2019) and Ogle et al. (2022), which each included approximately equal numbers of male and female participants (Lisano et al., 2019; Ogle et al., 2022). The sample was predominantly comprised of young adults who identified as white, and not Hispanic or Latino. Comparatively, the National Survey on Drug Use and Health (NSDUH) reports that those who regularly use cannabis in the U.S. are more diverse across race and ethnicity (NSDUH, 2022). Therefore, our sample may not be nationally representative of cannabis users by demographic, but it is important to note the present sample only included individuals aged 21 years and older, and predominantly included participants from Colorado, a state that has a higher percentage of white residents (83.68%) than the national average (75.5%) (United States Census, 2023). In the present study, the breakdown of race, ethnicity age, sex, and gender was fairly similar between those who combined cannabis with exercise at least once in the study period (combiners) and those who did not (non-combiners). Additionally, the present sample was similar in terms of trait level affect and emotion regulation when compared to other previously explored nonclinical samples (Burton et al., 2022; Watson & Clark, 1994), and can therefore be considered a representative, non-clinical convenience sample. We also used the DFAQ-CU to characterize participants' overall cannabis use habits. Our sample was comprised

of frequent cannabis users who endorsed starting to use cannabis regularly around age 19 (on average). When compared to another sample of individuals who regularly use cannabis (Cuttler & Spradlin, 2017), some interesting and important cannabis-use differences emerged. With regard to primary cannabis type used, the present sample reported much greater edible and concentrates use compared to Cuttler and Spradlin's (2018) sample. Additionally, the present sample reported past week cannabis use (regardless of type) at a much greater frequency compared to the sample included in Cuttler and Spradlin's (2017) paper. Next, across every type of cannabis (e.g., flower, edibles, concentrates), participants in the present study reported using more product per session and engaging in more use sessions per day. In terms of potency, modal THC percentages in both flower and concentrate products were reportedly higher for the present sample compared to Cuttler and Spradlin's (2017) sample. In total, the present sample appears to engage in cannabis use, across every domain, more than Cuttler and Spradlin's (2017) sample. This difference could be due to a variety of reasons such as the growing acceptance and legalization of cannabis across the country in the past 10 years (Pew Research Center, 2022). Additionally, over the past 7 years, cannabis potency has steadily increased, with an increase in availability of so-called "elite", highly potent flower strains containing between 25-30% THC or more, and concentrates hitting upwards of 90% (Wise, 2024). Therefore, different cannabis use patterns between Cuttler and Spradlin's sample and present sample may be due, at least in part, to sociopolitical and market shifts in cannabis consumption.

Throughout the study, detailed information on cannabis and exercise behaviors were also collected at the daily level. Overall, the study was comprised of frequent exercisers who engaged in about 59.33 minutes of exercise per day, which is considerably greater than the 30 minutes per day recommended by the World Health Organization (WHO, 2022). On the days participants

reported exercising, they endorsed doing so while feeling the effects of cannabis on 29.1% of the study days, and as stated, 30 of the 52 participants combined cannabis with their exercise at least once throughout the study. Interestingly, whether participants combined cannabis with their exercise or not, meeting exercise goals was endorsed at nearly the same rate for both groups. Additionally, there was no significant difference in exercise enjoyment ratings between days which participants combined cannabis with exercise and days they did not. This finding suggests that cannabis may not be detrimental in one's ability to have a fulfilling, enjoyable exercise. Unlike Ogle et al.'s (2022) study which assessed for unanticipated or undesired experiences while pairing cannabis and exercise, the present study assessed one's experience of combining the behaviors on a Likert-type scale (1, Much better than expected, to 7, Much worse than expected). About one third of participants in Ogle et al.'s 2022 study endorsed unanticipated or undesired experiences, whereas in the present study, only about 5% of days that participants combined behaviors were rated as worse than expected, and about 6% of days were reported as much worse than expected. This difference in results may be due to word choice between the questions. For example, in Ogle and colleague's (2022) paper, participants may have predominantly experienced unanticipated events that were not necessarily negative, however there was no way to differentiate between unanticipated and undesired experiences, as they were phrased together within one question. In contrast, the present study asked participants to rate their experience of combining cannabis with exercise on a scale, which may have better captured negative or adverse experiences, without including unanticipated experiences. The finding in the present study suggests that, in addition to cannabis not deterring from one's goals and enjoyment of exercise, it is not linked to adverse experiences.

The present study also sought to replicate Ogle and colleague's (2022) study by providing the same expansive list of options for why someone may have combined cannabis with exercise. However, we collected data in a sample of individuals who use cannabis and engage in exercise (but not necessarily together), whereas Ogle et al.'s (2022) study selected individuals on the basis that they combine the two behaviors. The present study was designed to determine whether similar cannabis-exercise motives arose in a more representative sample. In the present study, the top five endorsed reasons for using cannabis in conjunction with exercise included: "to help me focus/concentrate," "helps me enjoy the exercise experience," "enhances mind/body/spirit connection," "enhances body awareness," and "keeps me in the zone." Interestingly, these were also the 5 top reasons endorsed in Ogle et al.'s paper, in the same order and were similar to findings by Lisano et al. (2019), and YorkWilliams (2019), which also assessed motives to combine cannabis with exercise. However, each of the previous studies also found motives such as pain management/relief, and to aid in recovery, which the present study did not find. This discrepancy may be due to the comprehensive list of motives given to participants in the present study. Or it may be due to the fact that the present study only assessed motives if a participant endorsed exercising while feeling the effects of cannabis from earlier in the day, whereas other studies asked about motives for using cannabis before, during, and after exercise, when pain management and recovery may be more frequently endorsed.

The present study also sought to explore types of exercise those who combine cannabis and exercise engage in. By far, the most endorsed types of exercise that participants engaged in on days which they combined cannabis with exercise were brisk walking/jogging, followed by weightlifting, another type of exercise (e.g., disc golf, bike polo, frisbee golf, skiing, snowboarding, rock climbing, skateboarding), running, and equally reported yardwork, biking,

and hiking. This is mostly consistent with Ogle et al.'s study, in which participants mostly endorsed hiking, yoga, aerobic machines, walking, and weightlifting. The small difference in exercise type frequency could be due to the geographic locations in which each study took place. Ogle's study recruited participants from across the United States, therefore it makes sense that their study included modes of exercise that may be accessible anywhere (e.g., aerobic machines, yoga). Conversely, the present study recruited participants from Colorado and California, where activities such as snowboarding, skiing, and rock climbing are readily available and are common among recreational exercisers. Interestingly, participants who combined cannabis and exercise in the present study reported a high frequency of leisurely and recreational activities such as frisbee golf, disc golf, and yard work. It may be the case that these activities are perceived as "lower risk" compared to more intense forms of exercise and are therefore more easily paired with cannabis consumption. Research on cannabis and recreational and/or leisure activities warrants further attention.

It is worth mentioning that in the present study, as well as those conducted previously, weightlifting and/or resistance training appeared as exercises frequently paired with cannabis (Lisano et al., 2018; Ogle et al., 2022). In the literature, weightlifting, as one word, has been defined as a specific sport, in which one may engage competitively in moves that require lifting maximal amounts of weights through moves such as snatches, cleans, and high pulls through high weight and high velocity (Morris et al., 2022). In contrast, weight lifting, as two words, is defined in the literature as simply lifting a weight (M. H. Stone et al., 2006). Further still, resistance training is typically defined as "a collective that refers to methods of physical conditioning that involve the progressive use of a wide range of resistive loads," and resistive loads could include free weights and machines (Morris et al., 2022; M. H. Stone et al., 2006).

Considering the morphological and semantic similarities between the actual words for these exercises and their definitions, it is quite possible that participants in these studies conflated the exercises (weightlifting, weight lifting, and resistance training). Regardless of the reason, the frequency with which combining cannabis with weightlifting and/or resistance training occurred warrants further attention. Traditionally, cannabis and exercise literature has focused on aerobic fitness level through use of treadmills and bikes (Kramer et al., 2020). This is detrimental for two reasons. First, we presently have a limited understanding on the subjective effects of combining cannabis with lifting weights/resistance training, and the impact it may have on an individual's safety. Second, we also have a limited understanding on the objective effects cannabis has on the strength and output required for lifting weights/resistance training. To date, studies have mainly focused on CBD supplementation in resistance exercise, and while mild benefits have been found for skeletal muscles (Isenmann et al., 2021), results have been contradictory (Cochrane Snyman et al., 2021; W. J. Stone et al., 2023).Considering the fact that weightlifting and/or resistance training continue to be commonly reported in conjunction with cannabis, and that limited data exists on the impact THC has on these types of exercise, further studies are necessary to understand the role cannabis plays on the subjective and objective experience of resistance and/or weight training.

Exploring the impact that cannabis has on performance is an interesting future direction overall. The World Anti-Doping Agency (WADA) creates a prohibited list, and substances are included if they satisfy any two of the following three criteria: "it has the potential to enhance or enhances sport performance;" "it represents an actual or potential risk to the Athlete;" and "it violates the spirit of the sport" (WADA, 2024). As of 2024, all natural and synthetic cannabinoids are prohibited, with the exception of cannabidiol. While the "spirit of the sport"

criterion is subjective and difficult to measure empirically, the two other criteria have gained attention in cannabis research, and results may contradict WADA's claims. Likely fueled by years of stigma, historical cannabis research has tended to overestimate the risk of cannabis use. A comparative risk assessment of alcohol, tobacco, and other illicit drugs, found cannabis to fall into the "low risk" category, whereas as substances such as tobacco and alcohol fall into the "risk" and "high risk" categories, respectively (Lachenmeier & Rehm, 2015). Notably, both nicotine and alcohol are not found on WADA's prohibited list. Participants in the present study seldomly reported negative experiences when combining cannabis and exercise, suggesting that subjectively, cannabis may not pose a potential risk, especially for experienced users. With regard to cannabis and performance, numerous studies have shown that not only does cannabis not improve objective measurements of performance such as work capacity, heart rate, and VO2max, but in some cases, it worsens performance (Burr et al., 2021; Docter et al., 2020; Ware et al., 2018). In the present study, 30 options for motives to combine cannabis with exercise were provided, and "increasing performance" was the 8th most endorsed option, at a much lower frequency than those endorsed in the top 5. Further still, subjective performance increases do not equate to objective performance increases. Research has shown that athletes often use cannabis with the hope of enhancing performance without knowing whether it actually does or not (Burr et al., 2021; Docter et al., 2020). WADA also cites that cannabis can cause muscle relaxation and reduce pain during post-workout recovery, which could enhance performance. However, much of this research has been done with CBD, not THC. While some studies postulate CBD may reduce muscle damage via reduced serum creatine kinase (CK) (Isenmann et al., 2021; Schouten et al., 2022), results have been modest at best. Those that have explored the effects of THC on muscle

function restoration have been limited and used mouse models (Maqbool et al., 2023). There are survey studies which suggest participants may believe that THC aids in their recovery from exercise (Gibson & Bryan, 2023; Pinzone et al., 2023), but, it is important to note these studies only provide subjective data, and at present there are no studies that objectively measure THC in athletic recovery and pain management in humans as it relates to athletic performance, thus revealing a gap in the literature that requires future investigation. In total, WADA's claim that cannabis meets the criteria to be a banned substance should be re-examined in light of recent research (e.g., regarding effects of THC on performance).

Limitations and Future Directions

There are several limitations to this study. First, the sample is predominately white young adults from states in which cannabis is legalized for medicinal and recreational use (i.e., California, Colorado), so cannabis use behaviors may lack generalizability to other populations. Future research may benefit from including participants across the lifespan in states where cannabis has not been legalized. This study also did not assess for, or explicitly include individuals with cannabis use disorder. Future studies may benefit from assessing CUDs and testing these questions in a more severe cannabis using population. Second, considering the states this sample was recruited from, it may be the case that these participants are on average more active than participants in other areas across the United States, which could account for the significant relationship found between exercise and affect. According to the CDC, Colorado is the most active state in the U.S., with just over 83% of residents reporting regular exercise. California is not far behind, with 80% of residents reporting regular exercise. In contrast, states like Alabama have residents reporting that less than 70% of them are regular exercisers (CDC, 2023). Although this sample was not recruited to include competitive or endurance athletes, it

did contain participants who engaged in very high rates of exercise. For example, one participant engaged in 600+ minutes of exercise per day due to a very physical job, far higher than the 150 minutes per week guideline that was used as inclusion criteria for this study. It will be important that future studies include states with lower exercise rates, to understand whether state of residence moderates the relationship between affect and exercise, and/or cannabis use and exercise. Third, although this study is comprehensive in that it gathered many observations of individuals across different days and different contexts, causation cannot be presumed because there is no experimental manipulation, and certain effects are cross-sectional. However, given the fact that participants responded to questionnaires daily, this likely reduced fallacies in retrospective recall, thus increasing ecological validity. Additionally, temporal data for cannabis use and exercise was collected throughout this study, but not yet analyzed. It will be important in the future to explore potential timing effects related to these behaviors. Fourth, this study had a relatively small sample size, and due to the daily nature of this study, some data were missing. These two factors, combined with the fact that person-centered variables were non-normal, likely caused our results to differ from what was expected from a power simulation with idealized variables. It will be important for future studies to take this into account when performing a priori power analyses, and to examine assumptions for multilevel models before analyses are finalized. Also, studies may benefit from increasing their sample size and number of daily diaries assigned for each individual in an effort to increase power and explore more comprehensive relationships at both the individual and group level. Fifth, while the present study collected information to characterize the sample in terms of cannabis use, it did not ask participants to report cannabis type used at the daily level. Therefore, percentages of THC may be skewed, as average potencies were collapsed across types, from low potency products to very high potency

ones. It is vital that future studies collect detailed daily-level information on type of cannabis used, and corresponding THC percentage. This will allow researchers to explore cannabis use patterns for those who combine cannabis with exercise, and more fully understand implications and outcomes associated with each cannabis type, and whether exercise experiences change as a function of potency. Lastly, self-reported behaviors like exercise and positive affect may have been prone to social-desirability bias, in which participants over-report "good behavior." In order to rectify this, future studies may benefit from incorporating objective measurements of exercise, such as a pedometer or a fitness watch for a more accurate assessment of activity.

Perhaps the most important future direction may be related to exploring the role cannabis may play in physical activity amongst otherwise healthy, sedentary individuals. As discussed, physical inactivity is a leading cause of heart disease, type 2 diabetes, and cancer. The present study revealed that cannabis may be related to higher rates of exercise, potentially through its impact on exercise enjoyment, concentration, or other mindfulness elements, in conjunction with motives endorsed in previous studies like recovery and pain relief. Whatever the mechanism may be, it is vital that this research be extended to sedentary individuals, to explore whether cannabis could support a more active lifestyle. Specifically, it will be important to first understand this relationship in sedentary individuals who are experienced with cannabis use, rather than those who are cannabis-naïve. Relatedly, future research could explore this relationship in individuals with a psychiatric or physical diagnosis who could benefit from increased exercise. The therapeutic benefits of exercise on physical and mental diagnoses are numerous, therefore exploring factors that could boost exercise engagement are relevant at both a personal and public health level. In both populations, a similar daily diary approach could be used to determine the effectiveness of a cannabis-use intervention on exercise at the daily-level.

Conclusion

This study explored the daily-level dynamics between cannabis use, exercise, and affect, as well as the characteristics of individuals who engage in both activities, either separately or together. Replicating prior research, the present study highlighted a significant positive within person association between exercise and affect. Additionally, based on the magnitude and direction of the effect size, the present results demonstrated a medium, positive relationship between cannabis use and exercise, suggesting that daily-level cannabis use may be positively related to daily-level exercise engagement, a finding that warrants further investigation and refinement with a more diverse or larger sample. Importantly, this study extended previous work on motivations for combining cannabis and exercise, emphasizing subjective experiences over objective outcomes. The study added further information to the sparse existing literature on motives to combine cannabis and exercise, and revealed enjoyment, focus, and mindfulness motives as important variables for future studies. Notably, participants rarely reported negative experiences, suggesting the potential viability of combining cannabis and exercise as an intervention to enhance exercise participation in certain populations. Future research should explore temporal relationships and objective impacts (e.g., performance) to inform the public on risks, benefits, and best practices for integrating cannabis use and exercise.

Tables and Figures

Table 1. Respondent Characteristics Overall

Characteristics	N (%) or M (*SD*)
Age (years)	30.36 (*8.77*)
Sex Assigned at Birth	
Female	24 (46.2%)
Male	28 (53.8%)
Gender	
Cis woman	16 (30.7%)
Cis man	16 (30.7%)
Man	14 (26.9%)
Woman	9 (17.3%)
Trans woman	0 (0%)
Trans man	0 (0%)
Demi-girl	1 (1.92%)
Gender non-conforming	1 (1.92%)
Another gender not listed	1 (1.92%)
Do not wish to respond	1 (1.92%)
Ethnicity	
Hispanic/Latino/a/e/x	9 (17.3%)
Non-Hispanic/Latino/a/e/x	38 (73.1%)
Another Ethnicity	5 (9.6%)
Race	
American Indian or Alaska Native	3 (5.77%)
Asian	5 (9.6%)
Black or African American	2 (3.84%)

Native Hawaiian or Pacific Islander	0 (0%)
White	45 (86.5%)
Another race	1 (1.92%)
Do not wish to respond	2 (3.84%)
Cannabis Use Patterns	
Age of Regular Use (years)	19.4 (5.23)
Primarily Flower Cannabis	31 (59.6%)
Primary Edibles	14 (26.9%)
Primarily Concentrates	7 (13.5%)
Past Week Cannabis Use	50 (96.15%)
Flower Cannabis Use Patterns	
Flower Cannabis Grams Per Session	0.37 (0.36)
Flower Cannabis Use Sessions Per Day	2.64 (2.02)
Flower Cannabis Grams Consumed Per Day	1.001 (1.71)
Flower THC Percentage	
10 - 14%	2 (5.4%)
15 - 19%	6 (16.2%)
20 - 24%	22 (59.45%)
25 - 30%	5 (13.5%)
greater than 30%	2 (5.4%)
Concentrates Use Patterns	
Hits of Concentrates in a Typical Day	6.23 (8.98)
Concentrate Use Sessions Per Day	2.82 (3.24)
Average Concentrate THC Percentage	
30 - 39%	1 (10%)
40 - 49%	1 (10%)
50 - 59%	0 (0)
60 - 69%	0 (0)

70 - 79%	3 (30%)
80 - 90%	4 (40%)
greater than 90%	1 (10%)
Edible Use Patterns	
Average mgs of THC in edibles	16.4 (13.51)
Primary Method	
Joints	6 (11.5%)
Hand Pipe	13 (25.0%)
Bong	12 (23.1%)
Vaporizer	8 (15.4%)
Edibles	12 (23.1%)
Other	1 (1.9%)
Exercise minutes per day overall	59.33 (73.96)
Exercise minutes on exercise day	92.6 (73.8)
Negative affect	15.42 (4.94)
Positive affect	28.77 (8.24)
DERS-18	37.71 (10.2)

Table 2. Demographics for "Combiners" vs. "Non-combiners"

	Those Who Combined Cannabis with Exercise at Least Once N (%) or M (*SD*)	**Those Who Did NOT Combine Cannabis with Exercise at Least Once N (%) or M (*SD*)**
Age	31.03 (*9.93*)	29.45 (*8.87*)
Sex Assigned at Birth		
Female	15 (50%)	9 (40.9%)
Male	15 (50%)	13 (59.1%)
Gender		
Cis woman	8 (26.6%)	8 (36.4%)
Cis man	7 (23.3%)	8 (36.4%)
Man	8 (26.6%)	6 (27.3%)
Woman	8 (26.6%)	1 (4.5%)
Trans woman	0 (0)	0 (0)
Trans man	0 (0)	0 (0)
Demi-girl	1 (3.33%)	0 (0)
Gender non-conforming	1 (3.33%)	0 (0)
Another gender not listed	1 (3.33%)	0 (0)
Do not wish to respond	1 (3.33%)	1 (4.5%)
Ethnicity		
Non-Hispanic/Latino/a/e/x/	21 (70%)	3 (13.6%)
Hispanic/Latino/a/e/x/	6 (20%)	17 (77.3%)
Another Ethnicity	3 (10%)	2 (9.1%)
Race		
American Indian or Alaska Native	3 (10%)	0 (0)
Asian	2 (6.6%)	3 (13.6%)
Black or African American	1 (3.3%)	1 (4.5%)
Native Hawaiian or Pacific Islander	0 (0)	0 (0)
White	26 (86.6%)	20 (90.9%)
Another race	0 (0)	1 (4.5%)
Do not wish to respond	2 (6.6%)	0 (0)

Table 3. Cannabis Use and Exercise Patterns on Days Participants Combined Cannabis with Exercise vs. Not

	Days when Participants Combined Cannabis with Exercise		**Days when Participants Did Not Combine Cannabis with Exercise**	
	%	**M (*SD*)**	**%**	**M (*SD*)**
Meeting Exercise Goals at least 80% of the Time	73.2		76.36	
Enjoyment Rating		2.21 (*1.22*)		2.01 (*1.18*)
Amount of Cannabis Used in Grams		1.72 (*2.51*)		0.70 (*1.49*)
Potency of Cannabis Used		34.8 (*23.04*)		31.34 (*24.55*)

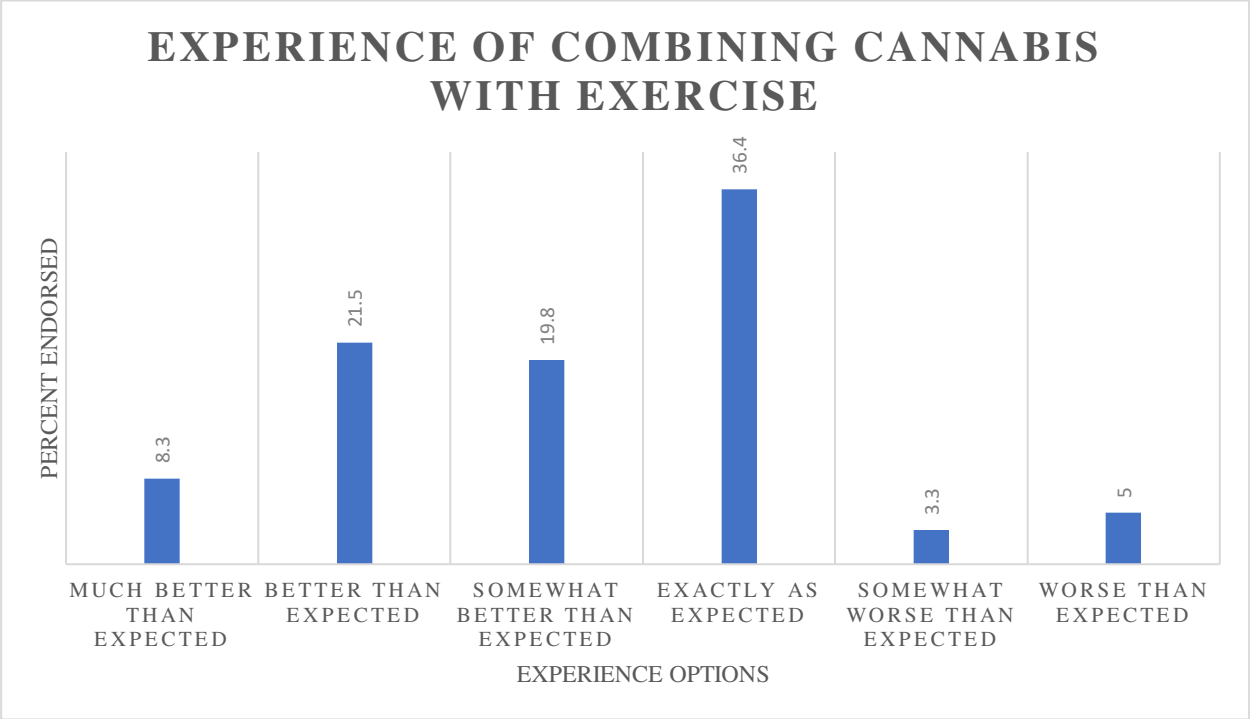

Figure 3. Participant's reported experience combining cannabis with exercise.

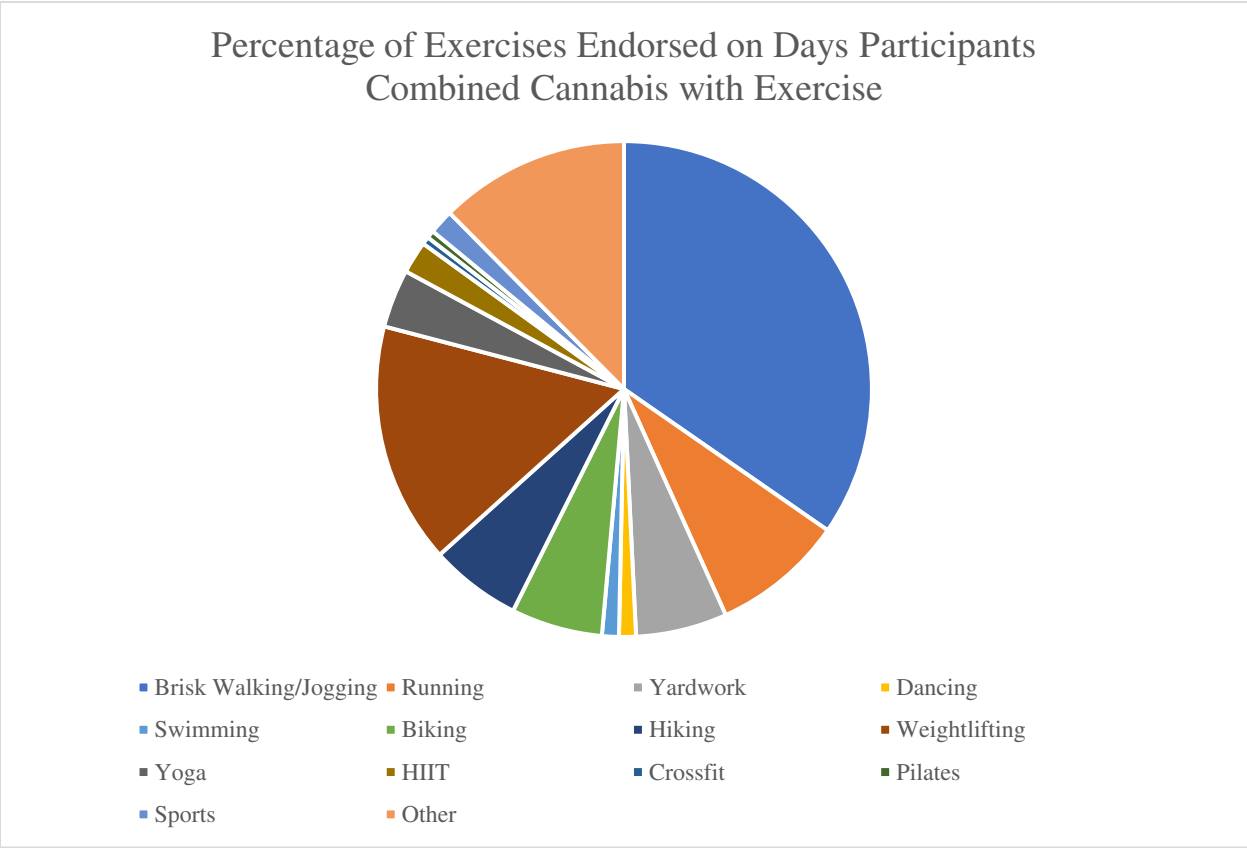

Figure 4. Endorsed Exercises on Days Participants Combined Cannabis with Exercise

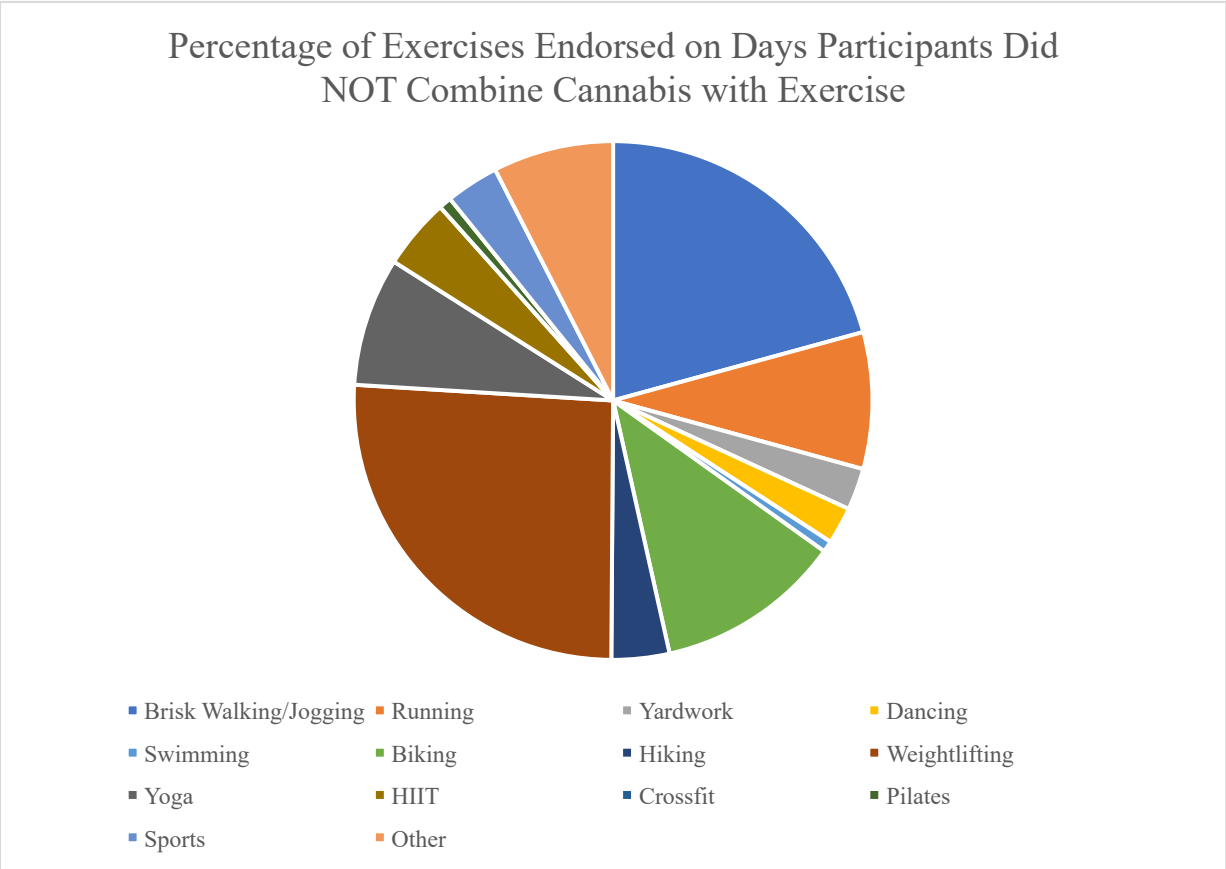

Figure 5. Endorsed Exercises on Days Participants did NOT Combine Cannabis with Exercise

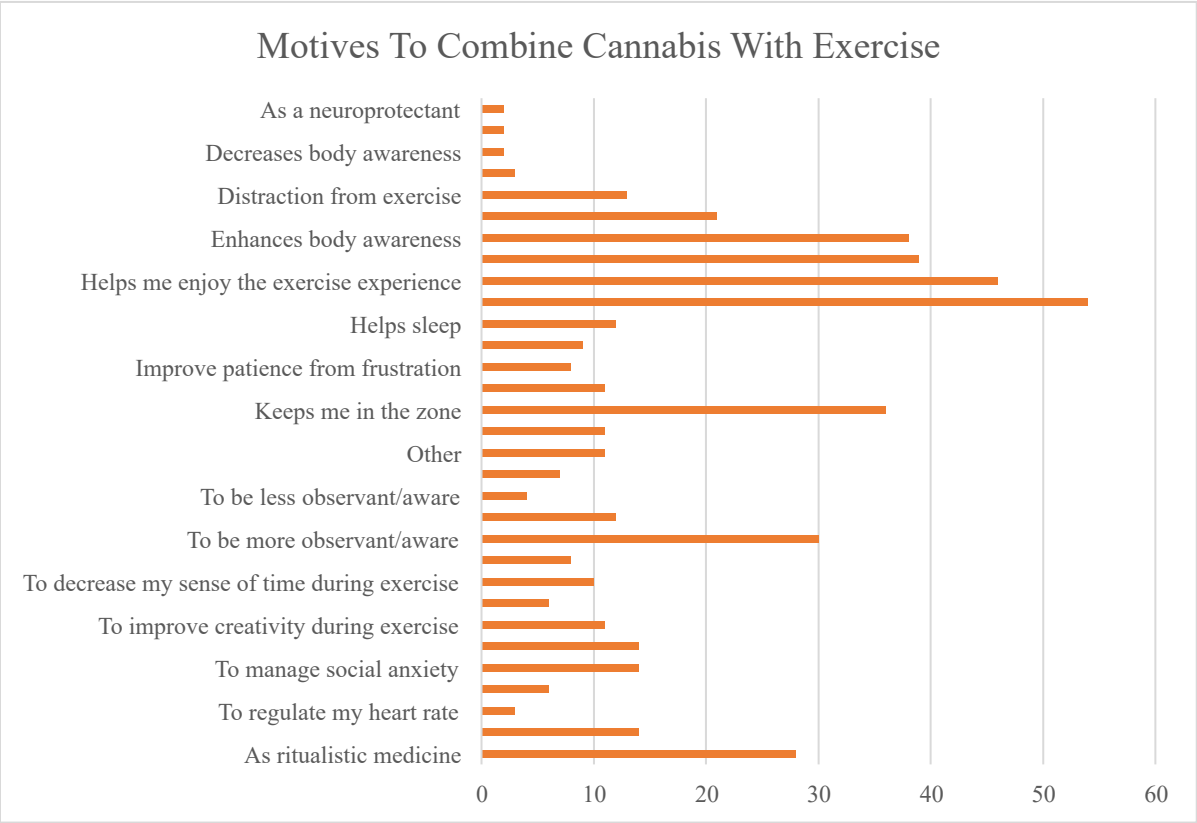

Figure 6. Motives to Combine Cannabis with Exercise Among "Combiners"

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Appendix

Appendix A

Demographics

1. What is your age? (free response)
2. What was the sex assigned to you at birth?

    Male

    Female

    Intersex

    Another

    Do not wish to respond

3. How do you define your gender identity? Choose all that apply.

    Agender

    androgenous cis man

    cis woman demiboy

    demigirl gender fluid

    non-binary gender

    non-conforming

    genderless

    genderqueer

    man

    third gender

    trans man

Trans man

Trans woman

Transgender

Transperson

Two spirit

Woman

Another: _____

Do not wish to respond

4. What is the highest level of education you have completed? Please select one option.

Less than high school

High-school diploma or GED

Some college

Associates degree or Technical Certification

Bachelor's degree

Master's degree

Doctoral degree

5. Are you employed?

Full-time employed, (work 30 or more hours per week)

Part-time, (work less than 30 hours per week)
Unemployed, disabled, retired, other

Full-time student

Homemaker/stay at home parent

6. What is your present household income range in the past year? (Chose one)

$0 - $9,999

$10,000 - $19,999

$20,000 - $29,999

$30,000 - $39,000

$40,000 - $49,000

$50,000 - $59,000

over $ 60,000

7. How do you define your ethnicity? Chose one.

Hispanic or Latin/a/o/x/e

Not Hispanic or Latin/a/o/x/e

Another

Do not wish to respond

8. How do you define your race? Chose all that apply.

American Indian or Alaskan Native

Asian

Black or African American

Native Hawaiian or Other Pacific Islander

White

Another
Do not wish to respond

9. If you selected “Another” to any category above, please describe. (Free response)

PANAS-X

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way right now. Use the following scale to record your answers: 1= very slightly/not at all, 2= a little, 3=moderately, 4=quite a bit, 5=extremely 1. _____ cheerful 2. _____ disgusted 3. _____ attentive 4. _____ bashful 5. _____ sluggish 6. _____ daring 7. _____ surprised 8. _____ strong 9. _____ scornful 10. _____ relaxed 11. _____ irritable 12. _____ delighted 13. _____ inspired 14. _____ fearless 15. _____ disgusted with self 16. _____ sad 17. _____ calm 18. _____ afraid 19. _____ tired 20. _____ amazed 21. _____ shaky 22. _____ happy 23. _____ timid 24. _____ alone 25. _____ alert 26. _____ upset 27. _____ angry 28. _____ bold 29. _____ blue 30. _____ shy 31. _____ active 32. _____ guilty 33. _____ joyful 34. _____ nervous 35. _____ lonely 36. _____ sleepy 37. _____ excited 38. _____ hostile 39. _____ proud 40. _____ jittery 41. _____ lively 42. _____ ashamed 43. _____ at ease 44. _____ scared 45. _____ drowsy 46. _____ angry at self 47. _____ enthusiastic 48. _____ downhearted 49. _____ sheepish 50. _____ distressed 51. _____ blameworthy 52. _____ determined 53. _____ frightened 54. _____ astonished 55. _____ interested 56. _____ loathing 57. _____ confident 58. _____ energetic 59. _____ concentrating 60. _____ dissatisfied with self

DERS-18

Response categories: 1= Almost Never (0-10%), 2= Sometimes (11-35%), 3=About Half the Time (36-65%), 4=Most of the Time (66-90%), 5= Almost Always (91-100%)

1. _____ I pay attention to how I feel. 2. _____ I have no idea how I am feeling.

3. _____ I have difficulty making sense out of my feelings. 4. _____ I am attentive to my feelings. 5. _____ I am confused about how I feel. 6. _____ When I'm upset, I acknowledge my emotions. 7. _____ When I'm upset, I become embarrassed for feeling that way. 8. _____ When I'm upset, I have difficulty getting work done. 9. _____ When I'm upset, I become out of control. 10. _____ When I'm upset, I believe that I will remain that way for a long time. 11. _____ When I'm upset, I believe that I'll end up feeling very depressed. 12. _____ When I'm upset, I have difficulty focusing on other things. 13. _____ When I'm upset, I feel ashamed with myself for feeling that way. 14. _____ When I'm upset, I feel guilty for feeling that way. 15. _____ When I'm upset, I have difficulty concentrating. 16. _____ When I'm upset, I have difficulty controlling my behaviors. 17. _____ When I'm upset, I believe that wallowing in it is all I can do. 18. _____ When I'm upset, I lose control over my behaviors.

SUPPS-P

1. I generally like to see things through to the end.* (R)
2. My thinking is usually careful and purposeful.*
3. When I am in great mood, I tend to get into situations that could cause me problems.
4. Unfinished tasks really bother me. (R)
5. I like to stop and think things over before I do them. (R)
6. When I feel bad, I will often do things I later regret in order to make myself feel better now.
7. Once I get going on something I hate to stop. (R)

8. Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse.
9. I quite enjoy taking risks.*
10. I tend to lose control when I am in a great mood.
11. I finish what I start.
12. I tend to value and follow a rational, "sensible" approach to things. (R)
13. When I am upset I often act without thinking.*
14. I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.*
15. When I feel rejected, I will often say things that I later regret.*
16. I would like to learn to fly an airplane.
17. Others are shocked or worried about the things I do when I am feeling very excited.
18. I would enjoy the sensation of skiing very fast down a high mountain slope.
19. I usually think carefully before doing anything.* (R)
20. I tend to act without thinking when I am really excited.*

DFAQ-CU Inventory

Instructions: Please read each of the following questions and mark the response alternative that best describes your use of cannabis. *Note that the term cannabis is being used to refer to marijuana, cannabis concentrates, and cannabis-infused edibles.*

1. Have you ever used cannabis?
   0 = No
   1 = Yes

**If response = 0 then skip to end of questionnaire*

2. Which of the following best captures when you last used cannabis?
   1 = over a year ago 7 = last week
   2 = 9 – 12 months ago 8 = this week 3 = 6 – 9 months ago 9 = yesterday
   4 = 3 – 6 months ago 10 = today*
   5 = 1 – 3 months ago 11 = I am currently high*
   6 = less than 1 month ago

   **If response = 10 (today) or 11 (I am currently high) then answer 2b below*

   2b. How high are you right now? 0 = I am not at all high
   1 = I am a little bit high
   2 = I am moderately high
   3 = I am very high
   4 = I am extremely high

3. Which of the following best captures the average frequency you currently use cannabis?
   0 = I do not use cannabis
   1 = less than once a year
   2 = once a year
   3 = once every 3-6 months (2-4 times/yr))
   4 = once every 2 months (6 times/yr)
   5 = once a month (12 times/yr)
   6 = 2 – 3 times a month
   7 = once a week
   8 = twice a week
   9 = 3 – 4 times a week
   10 = 5 – 6 times a week
   11 = once a day
   12 = more than once a day

4. Which of the following best captures how long you have been using cannabis **at this frequency?**
   1 = less than 1 month 7 = 2 – 3 years
   2 = 1 – 3 months 8 = 3 – 5 years
   3 = 3 – 6 months 9 = 5 – 10 years
   4 = 6 – 9 months 10 = 10 – 15 years
   5 = 9 – 12 months 11 = 15 – 20 years
   6 = 1 – 2 years 12 = more than 20 years
5. Before the period of time you indicated above, how frequently did you use cannabis?
   0 = I did not use cannabis
   1 = less than once a year
   2 = once a year
   3 = once every 3-6 months (2-4 times/yr.)
   4 = once every 2 months (6 times/yr.)
   5 = once a month
   6 = 2 – 3 times a month
   7 = once a week
   8 = twice a week
   9 = 3 – 4 times a week
   10 = 5 – 6 times a week
   11 = once a day
   12 = more than once a day

6. How many days of the past week did you use cannabis?
   0 = 0 days
   1 = 1 day
   2 = 2 days
   3 = 3 days
   4 = 4 days
   5 = 5 days
   6 = 6 days
   7 = 7 days

7. Approximately how many days of the past month did you use cannabis? _____

8. Which of the following best captures the number of times you have used cannabis in your entire life?
   1 = 1 – 5 times in my life
   2 = 6 – 10 times in my life
   3 = 11 – 50 times in my life
   4 = 51 –100 times in my life
   5 = 101 – 500 times in my life
   6 = 501 – 1000 times in my life
   7 = 1001 – 2000 times in my life
   8 = 2001 – 5000 times in my life
   9 = 5001 – 10,000 times in my life
   10 = More than 10,000 times in my life

9. Which of the following best captures your pattern of cannabis use throughout the week?
   0 = I do not use cannabis at all
   1 = I only use cannabis on weekends
   2 = I only use cannabis on weekdays
   3 = I use cannabis on weekends and weekdays

10. How many hours after waking up do you typically first use cannabis?
   0 = I do not use cannabis at all
   1 = 12 – 18 hours after waking up
   2 = 9 – 12 hours after waking up
   3 = 6 – 9 hours after waking up
   4 = 3 – 6 hours after waking up
   5 = 1 – 3 hours after waking up
   6 = within 1 hour of waking up
   7 = within ½ hour of waking up
   8 = immediately upon waking up

11. How many times a day, on a typical weekday, do you use cannabis? _____

12. How many times a day, on a typical weekend, do you use cannabis? _____

13. What is the primary method you use to ingest cannabis?
   0 = I do not use cannabis
   1 = Joints
   2 = Blunts (cigar sized joints)
   3 = Hand pipe
   4 = Bong (water pipe)
   5 = Hookah
   6 = Vaporizer (e.g., Volcano, Vape pen)
   7 = Edibles
   8 = Other _____

14. Which of the following other methods to ingest cannabis do you use **regularly** (at least 25% of the time use you cannabis)? [Mark all that apply]

0 = None
1 = Joints
2 = Blunts (cigar sized joints)
3 = Hand pipe
4 = Bong (water pipe)
5 = Hookah
6 = Vaporizer (e.g., Volcano, Vape pen)
7 = Edibles
8 = Other _____

15. What is the primary form of cannabis you use?

0 = None****
A = Marijuana***
B = Concentrates (e.g., Oil, Wax, Shatter, Butane Hash Oil, Dabs)**
C = Edibles*
D = Other_____

16. What other forms of cannabis do you use **regularly** (at least 25% of the time you use cannabis)? [Mark all that apply]

0 = None****
A = Marijuana***
B = Concentrates (e.g., Oil, Wax, Shatter, Butane Hash Oil, Dabs)**
C = Edibles*
D = Other_____

*****If response to questions 15 and 16 = 0 (None) then skip to question 29*
****If responses to questions 15 or 16 = A (Marijuana) then answer questions 17-21*
***If responses to question 15 or 16 = B (Concentrates) then answer questions 22-26*
**If responses to question 15 or 16 = C (Edibles) then answer question 27*
*Note: If you use more than one form of cannabis then complete all of the associated questions listed above.***If responses to questions 15 or 16 = A (Marijuana) then answer questions 17-21 below.*

Please use the image below to refer to various quantities of marijuana. The image is not to scale; the dollar bill is included to help provide size perspective.

For questions 17 to 19 below, clearly indicate the number of grams of marijuana you use with a number between 0 – 100. Do NOT include other forms of cannabis you may use (such as concentrates). You may use up to 3 decimals to indicate amounts under 1 gram.

Note: 1/8 of a gram = 0.125 grams, ¼ of a gram = 0.25 grams, ½ of a gram = 0.5 grams, ¾ of a gram = 0.75 grams. 1/8 of a ounce = 3.5 grams, ¼ of an ounce = 7 grams, ½ ounce = 14 grams, 1 ounce = 28 grams

17. In a typical session, how much marijuana do you personally use? _____

18. On a typical day you use marijuana, how much do you personally use? _____

19. In a typical week you use marijuana, how much marijuana do you personally use? _____

20. On a typical day you use marijuana, how many sessions do you have? _____

21. What is the average THC content of the marijuana you typically use? Leave blank if you do not know.

1 = 0 – 4%
2 = 5 – 9%
3 = 10 – 14%
4 = 15 – 19%
5 = 20 – 24%
6 = 25 – 30%
7 = greater than 30%

***If response to questions 15 or 16 = B (Concentrates) then answer questions 22-26 below*

22. In a typical session you use cannabis concentrates, how many hits do you personally take? __

23. On a typical day you use cannabis concentrates, how many hits do you personally take? ____

24. How many hits of cannabis concentrates did you personally take yesterday? _____

25. On a typical day you use cannabis concentrates, how many sessions do you have?
    _____

26. What is the average THC content of the concentrates you typically use? Leave blank if you do not know.
    1 = 0 – 9% 6 = 50 – 59%
    2 = 10 – 19% 7 = 60 – 69%
    3 = 20 – 29% 8 = 70 – 79%
    4 = 30 – 39% 9 = 80 – 90%
    5 = 40 – 49% 10 = greater than 90%

***If response to questions 15 or 16 = C (Edibles) then answer question 27 below*

27. When you eat edibles how many milligrams of THC do you personally ingest in a typical session? _____

28. What is your current age? _____

29. How many years in total have you used cannabis? _____

30. How old were you when you FIRST tried cannabis? _____

31. Has there been any time in your life when you used cannabis regularly (2 or more times per month for 6 months or longer)?
    0 = No
    1 = Yes*

    **If response = 1 (Yes) then answer questions 31b and 31c below*

    31b. How old were you when you FIRST STARTED using cannabis regularly (2 or more

times/month)? _____

31c. Has there been any time in your life when you used cannabis on a daily or near daily basis for 6 months or longer?

0 = No
1 = Yes*

**If response = 1 (Yes) then answer question 31ci below*

31ci. How old were you when you FIRST STARTED using cannabis on a daily or

near daily basis? _____

32. Which of the following best captures the average frequency that you used cannabis before the age of 16?

0 = more than once a day medicinal) purposes?
1 = once a day
2 = 5 – 6 times a week _____
3 = 3 – 4 times a week
4 = twice a week
5 = once a week
6 = 2 – 3 times a month
7 = once a month
8 = once every 2 months (6 times/yr.)
9 = once every 3-6 months (2-4 times/yr.)
10 = once a year
11 = less than once a year
12 = n

33. Do you have a physician's recommendation to use cannabis for medicinal purposes?

0 = No
1 = Yes*
2 = Yes, but I use it for both medicinal and recreational purposes*

**If response = 1 or 2 (Yes) then answer questions 33b and 33c*

33b. Which medical condition(s) do you use cannabis for?

_____
_____
_____

33c. What percentage of the time do you use cannabis for recreational (rather than

MMQ

INSTRUCTIONS: Listed below are 25 reasons people might be inclined to use marijuana. Using the four-point scale below, decide how frequently your own marijuana use is motivated by each of the reasons listed.

I use Marijuana…
1. Never/Almost Never
2. Sometimes
3. Often
4. Almost always/Always

1. To forget my worries
2. Because my friends pressure me to use marijuana
3. Because it helps me enjoy a party
4. Because it helps me when I feel depressed or nervous
5. To be sociable
6. To cheer me up when I am in a bad mood
7. Because I like the feeling
8. So that others won't kid me about not using marijuana
9. Because it is exciting
10. To get high
11. Because it makes social gatherings more fun
12. To fit in with the group I like

13. Because it gives me a pleasant feeling

14. Because it improves parties and celebrations

15. Because I feel more self-confident and sure of myself
16. To relax

17. To forget about my problems

18. Because it is fun

19. To be liked

20. So I won't feel left out

21. To know myself better

22. Because it helps me be more creative and original

23. To understand things differently

24. To expand my awareness

25. To be more open to experiences

26. Because it makes me feel as good as I do from exercise

27. To get high, like I get from exercise

28. Because I miss the high I get from exercise

29. To simulate the feeling I get from exercise

30. As a way to feel like I do when I exercise

31. As a way to simulate the high I get from exercise

32. As a way to replace the high I get from exercise on a day off from exercise

33. When I'm not exercising, I feel low

34. When I'm not exercising, I need to feel that rush

35. To mimic the high from exercise

Daily Diary Survey

Please answer the following according to the past 24-hour period:

1. Did you use cannabis?
2. How much did you use in grams? (pictures are provided to aid in estimation of amount)
3. What cannabis did you use? (enter strain name and THC potency, as indicated on all dispensary packaging)
4. When did you use cannabis? (input: “start time”, “end time”)
5. Did you exercise in the last 24 hours? (yes/no)
6. When did you exercise? (input: “start time”, “end time”).
7. How many total minutes did you spend exercising today?
8. What exercise did you do? (Choose all that apply, plus “other” write-in option).
9. During the time you spent exercising, were you under the influence of cannabis or experiencing any effects from using cannabis earlier in the day? (yes/no)
10. Why did you decide to use cannabis in conjunction with exercise (check all that apply, plus “other” write-in option).
11. What was your experience of combining cannabis with exercise (1= much better than expected to 7= much worse than expected).
12. How do you feel about the exercise you did over the last 24 hours? (1= I enjoyed it to 7= I hated it).
13. Did you meet your exercise goals during your workout? (1= Yes, completely to 7= No, not at all).

14. This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and indicate to what extent you feel the emotion described in the last

24 hours. (1=very slightly/not at all, 2=a little, 3=moderately, 4=quite a bit, 5=extremely)

Happy

Upset

Calm

Nervous

Irritable

Lively

Bored