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Examining Motivational Pathways from Adult ADHD Symptoms to Cannabis: Results from a Prospective Study of Veterans

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Abstract

Attention deficit hyperactivity disorder (ADHD) is linked prospectively to cannabis; however, no study has examined mechanisms underlying this comorbidity. We examined five cannabis motives (i.e., coping with negative affect, sleep, social anxiety, perceived low risk of cannabis, and altered perception) as mediators of the prospective ADHD-cannabis relation. Veterans reporting lifetime cannabis use (*N*=361; 93% male; 80% White) completed three semi-annual assessments. Prospective mediation models using structural equation modeling analyzed the indirect effects of baseline ADHD symptoms on 12-month cannabis use and problems via each motive at 6-months. Zero-inflated negative binomial (ZINB) models were employed for both manifest outcomes and ADHD symptoms and motives were each modeled as one-factor latent variables. Sleep motives was a robust mediator for cannabis use frequency in single mediator models and was marginally significant when examined simultaneously with other motives after accounting for baseline cannabis use, demographics, other substance use, and other psychopathology. Coping with negative affect was the only significant mediator of ADHD symptoms and subsequent cannabis problem severity. Among veterans with ADHD symptoms, sleep disturbance is a salient motive for cannabis use, whereas coping with negative affect is a proximal predictor of cannabis problems. Findings support addressing sleep disturbance in adults with ADHD symptoms and converge with extant literature demonstrating robust associations between coping motives and substance use problems.

Keywords

Adult ADHD; cannabis; Veterans; sleep; coping

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Author Note

Jane Metrik and Brian Borsari designed the project that collected the data for the current study. Angela Stevens conducted the literature search and analyzed and interpreted the data with guidance from Jane Metrik and Kristina Jackson. Angela Stevens wrote the first draft of the manuscript with significant contribution from all authors, who have approved the final manuscript.

Attention-deficit hyperactivity disorder (ADHD) is a prevalent psychiatric disorder among children (Faraone, Sergeant, Gillberg, & Biederman, 2003), with some cases persisting into adulthood (Faraone & Biederman, 2005; Faraone, Biederman, & Mick, 2006). ADHD is characterized by the endorsement of six or more symptoms related to inattention (e.g., making careless mistakes) and/or hyperactivity (e.g., restlessness), whereas five or more symptoms required for adults (American Psychiatric Association [APA], 2013). Recent research also supports that adult ADHD symptoms can occur without experiencing ADHD symptoms in childhood (Caye et al., 2016; Moffitt et al., 2015). Prevalence rates of adult ADHD range from 2% to 5% in the general population (Asherson, Buitelaar, Faraone, & Rohde, 2016; Moffitt et al., 2015) with inattention symptoms typically increasing with age (Biederman, Mick, & Faraone, 2000; Kessler et al., 2010). Poor social and academic coping are experienced by children and adolescents with ADHD symptoms, as well as greater mood dysregulation (Harpin, 2005; Klimkeit et al., 2006; Wehmeier, Schacht, & Barkley, 2010). Adults with ADHD symptoms continue to experience profound functional impairment in many areas, often resulting in a propensity for negative affect and emotion dysregulation (Katzman, Bilkey, Chokka, Fallu, & Klassen, 2017). Research is limited on ADHD symptoms in veterans, though a greater prevalence of ADHD symptoms has been found (i.e., 7% reported an ADHD diagnosis; Kessler et al., 2014; Shura, Denning, Miskey, & Rowland, 2017).

Prospective studies have identified childhood ADHD as an important risk factor for later substance use (Charach, Yeung, Climans, & Lillie, 2011; Groenman, Janssen, & Oosterlaan, 2017; Lee, Humphreys, Flory, Liu, & Glass, 2011; Molina et al., 2018; Wilens et al., 2011). Other studies suggest gender and oppositional behavior may explicate this longitudinal relation (National Academies of Sciences, Engineering, and Medicine, 2017). Adult ADHD symptoms are also consistently linked to problematic substance use (Biederman et al., 1995; Breyer, Lee, Winters, August, & Realmuto, 2014; Faraone et al., 2007; Vogel et al., 2016), as well as higher rates of polysubstance use, difficulties reducing use, and poorer substance use disorder treatment outcomes (Katzman et al., 2017).

Cannabis use may be particularly relevant to adult ADHD symptoms, as cannabis use rates continue to rise among adults in the general population, likely due to recent policy changes (Budney, Sofis, & Borodovsky, 2019), more accepting cannabis attitudes (Sarvet et al., 2018), and increased cannabis availability (Hasin, 2018). This same trend is apparent for veterans, with veterans viewing cannabis as relatively low risk (Bonn-Miller, Harris, & Trafton, 2012; Wilkinson, Schalkwyk, Davidson, & D'Souza, 2016). A meta-analytic review of prospective studies examining childhood ADHD as a precursor to substance involvement found children with ADHD, compared to children without ADHD, are nearly three times more likely to endorse later cannabis use and nearly twice as likely to receive a cannabis use disorder (CUD) diagnosis in adulthood (Lee et al., 2011). In a nonclinical sample of young adults, ADHD symptoms were cross-sectionally linked to cannabis use, craving, cannabis-related problems, and cannabis dependence after adjusting for internalizing and externalizing psychopathology (Bidwell, Henry, Willcutt, Kinnear, & Ito, 2014). Prevalence rates of ADHD were also greater among adults seeking treatment for CUD (i.e., 36–46%) compared to the general population (Notzon et al., 2016), which supports the ADHD-cannabis link. Prospective studies on adult ADHD symptoms and cannabis in the general

population are limited. One study, to our knowledge, has examined adult ADHD and cannabis use 15-months later in a sample of young adult men, with findings suggesting adult men with ADHD maintain heavier cannabis use over time compared to men without ADHD, and have greater odds of initiating cannabis use across 15-months after adjusting for conduct disorder (Vogel et al., 2016).

The ADHD-cannabis link is concerning, given ADHD symptoms and cannabis use are independently associated with poorer educational and occupational functioning (Hasin, 2018; Katzman et al., 2017). These deleterious outcomes are especially relevant to post-9/11 veterans (i.e., Operation Enduring Freedom, Operation Iraqi Freedom, and Operation New Dawn [OEF/OIF/OND]), as post-911 G.I. Bill educational and vocational support continually increased from 2011 to 2016 (Department of Veterans Affairs, 2016). Thus, veterans who experience ADHD symptoms and use cannabis may be at heightened risk for consequences related to education and employment. Despite the prospective relation between ADHD symptoms and subsequent cannabis involvement, as well as research suggesting veterans endorse higher rates of both (Bonn-Miller et al., 2012; Kessler et al., 2014), no study has examined relations between ADHD symptoms and cannabis in veterans.

Cannabis Use Motives and ADHD

Despite evidence linking ADHD with problematic cannabis use, there is growing perception that cannabis use may be therapeutic for ADHD symptoms (e.g., Strohbeck-Kuehner, Skopp, & Mattern, 2008), and adults with ADHD symptoms have reported using cannabis for many reasons (Mitchell et al., 2016; Mitchell et al., 2018), such as improved mood, sleep, social anxiety, hyperactivity, and cognitive processing (Mitchell et al., 2016, Supporting Information). There also appears to be a substance-specific expectancy about cannabis and mood, such that individuals with ADHD (compared to a matched control group) are more likely to endorse the effectiveness of cannabis, but not alcohol or tobacco, in improving negative mood and irritability (Mitchell et al., 2018). Reasons for cannabis use in veterans with ADHD symptoms have yet to be examined, though veterans have reported using cannabis for a range of physical and mental health conditions (Davis, Lin, Ilgen, & Bohnert, 2018). Such qualitative findings shed light on the perception that cannabis is therapeutic for ADHD symptoms and converge with related quantitative literature on cannabis use motives.

Coping with Negative Affect Motives

Emotion dysregulation is linked with both ADHD (Barkley, 2015; Martel, 2009) and cannabis use and related problems (Lopez-Vergara, Jackson, Meshesha, & Metrik, 2019); thus, one conceivable pathway from ADHD symptoms to cannabis use involves using cannabis to acutely improve negative affect. This pathway is also supported by the affective-motivational model of substance use, which emphasizes the importance of short-term reductions in negative affect on developing and maintaining problematic substance use (Baker, Piper, McCarthy, Majeskie, & Fiore, 2004). Indeed, coping motives are robustly and differentially related to substance use problems cross-sectionally and prospectively (e.g., Blevins et al., 2018; Cooper, Kuntsche, Levitt, Barber, & Wolf, 2016). This pattern is also

evident for cannabis coping motives and cannabis problems cross-sectionally in the general population (e.g., Bonn-Miller & Zvolensky, 2009; Buckner, Walukevich, & Lewis, 2019; Buckner, Bonn-Miller, Zvolensky, & Schmidt, 2007; Farris, Metrik, Bonn-Miller, Kahler, & Zvolensky, 2016) and in veterans (e.g., Boden, Babson, Vujanovic, Short, & Bonn-Miller, 2013; Metrik et al., 2016), as well as prospectively in an adult sample of frequent cannabis users (van der Pol et al., 2013).

Sleep Motives

Adults with ADHD symptoms may use cannabis to improve sleep, as ADHD symptoms are disproportionately associated with sleep disturbance (Walters, Silvestri, Zucconi, Chandrashekariah, & Konofal, 2008; Van Veen, Kooji, Boonstra, Gordijn, Van Someren, 2010). Cannabis sleep motives have received less attention compared to other motives, but preliminary findings indicate this motive is linked to cannabis use, related problems, and CUD (Bonn-Miller, Babson, & Vandrey, 2014; Metrik et al., 2016). Recent research also indicates insomnia symptoms are associated with hazardous cannabis use and CUD (Wong, Craun, Bravo, & Pearson, 2019), although it is unclear whether cannabis sleep motives are differentially associated with cannabis use versus problems.

Social Anxiety Motives

Using cannabis for social anxiety is also relevant to ADHD symptoms. Children with ADHD experience more interpersonal difficulties and these experiences can manifest as social anxiety in adulthood (Harpin, 2005). Adults with ADHD are highly affected by social anxiety disorder (SAD), with 30% also meeting criteria for SAD (vs. 8% without ADHD; Kessler et al., 2006). This comorbidity places adults with ADHD symptoms at greater risk for problematic cannabis use because SAD and, perhaps more importantly, using cannabis to cope in social situations are associated with cannabis use and related problems (Buckner & Zvolensky, 2014).

Perceived Low Risk and Altered Perception Motives

Using cannabis because of its perceived low risk is particularly salient for those with ADHD symptoms (Mitchell et al., 2016), and veteran cannabis users also endorse that cannabis is lower risk than other substances or medications (Wilkinson et al., 2016). This is concerning, as research consistently indicates a negative association between perceived risk of cannabis and cannabis use and, to a lesser degree, cannabis problems (Bonn-Miller, Boden, Bucossi, & Babson, 2014; Cohn, Johnson, Ehlke, & Villanti, 2016; Kilmer, Hunt, Lee, & Neighbors, 2007). Recent research has also found a reciprocal prospective relation between devaluing risks and later cannabis use, which highlights the importance of this motive in maintaining cannabis use over time (Salloum, Krauss, Agrawal, Bierut, & Grucza, 2018). Using cannabis to alter one’s perception may have specific relevance to ADHD symptoms given ADHD is linked to more cognitive processing difficulties (Katzman et al., 2017; Schatz & Rostain, 2006). This motive is unique to cannabis and little is known about its relation to other mental health conditions.

Present Study

A number of adults with ADHD symptoms perceive cannabis as therapeutic for many associated symptoms (Mitchell et al., 2016; 2018). However, motivational pathways from adult ADHD symptoms to cannabis use and cannabis problems have yet to be empirically tested. The purpose of the current study is to empirically examine five cannabis use motives (i.e., coping with negative affect, sleep, social anxiety, perceived low risk, and altered perception) as mediators of the longitudinal relation between ADHD symptoms and 12-month cannabis use and cannabis problems in a sample of returning OEF/OIF/OND veterans. To our knowledge, we are the first to examine these relations empirically, longitudinally, and in a sample of returning veterans. Our novel aims also include (1) considering mediators separately and concurrently and (2) employing a conservative, model-building strategy whereby methodologically- and etiologically-relevant covariates are added sequentially.[1]

Building on prior cross-sectional and qualitative research (Bonn-Miller et al., 2014; Buckner & Zvolensky, 2014; Metrik et al., 2016; Mitchell et al., 2016; 2018), we expected baseline ADHD symptoms would evince significant indirect effects on 12-month (1) cannabis use frequency and (2) cannabis problem severity via each cannabis motive at 6-months, after accounting for baseline cannabis use. Based on decades of prior research (see Cooper et al., 2016), we expected coping motives to be the most salient motive for cannabis problem severity when examined concurrently with other motives. No hypotheses are proffered for multiple mediator models of cannabis use given limited extant research in this area. Models adjusting for additional demographic and etiologically-relevant covariates are considered exploratory.

Methods

Sample and Procedure

Post-9/11/2001 OEF/OIF/OND veterans (N = 361) were recruited from a Veterans Health Administration (VHA) in the Northeastern United States through the VHA database of returning veterans from military service in Iraq and Afghanistan. Eligibility criteria included: (a) at least 18-years-old; (b) OEF/OIF/OND veteran; and (c) any lifetime cannabis use. Exclusion criteria were: (a) suicide risk in the past two weeks; (b) psychotic symptoms in the past month; (c) score ≤ 23 on the Mini-Mental Status Exam (Folstein, Folstein, & McHugh, 1975); or (d) active duty at baseline assessment (see Metrik et al., 2016). Veterans were screened for eligibility by telephone and were invited for a baseline visit where they signed informed consent and completed interview and self-report assessments. In-person follow-up visits were conducted at 6-months (N = 312; 86.4%) and 12-months (N = 310, 85.9%) and included a similar battery of interview and self-report assessments, with approximately 14% attrition from baseline to 6- and 12-months. A total of 15 participants withdrew from the parent study (e.g., deployment, moving out of state), whereas other participants were lost to follow-up. All study procedures were approved by the university

[1]Models employed zero-inflated negative binomial distributions to accommodate the distribution of both outcomes. For this study, we are primarily interested in the frequency of cannabis use and the severity of cannabis problems (i.e., negative binomial count models).

and local VHA Institutional Review Boards. Participants were compensated $50 per visit and an additional $50 bonus payment for completing all three visits.

Measures

Demographics were provided by participants and verified in the VHA Computerized Patient Record System (CPRS), including age, sex, race, ethnicity, and marital status.

Adult ADHD Self-Report Scale (ASRS) was used to assess past-6-month ADHD symptoms via an 18-item screening measure using a 5-point Likert-type scale with response options ranging from 0 (*never*) to 4 (*very often*; Kessler et al., 2005). Clinically-significant symptoms were scored using guidelines from Kessler et al. (2005, p. 248), with a score of nine or greater reflecting a positive ADHD screen. Twenty-nine percent of veterans screened positive on the ASRS, which is consistent with other veteran samples (Kimbrel et al., 2017). Internal consistency in this sample was good (baseline $\alpha = .81$).

Comprehensive Marijuana Motives Questionnaire (CMMQ) was used to assess 36 reasons for using cannabis reflecting 12 distinct motives (Lee et al., 2009). Response options range from 1 (*almost never/never*) to 5 (*almost always/always*). Cannabis use motives selected for mediation analyses exhibited significant bivariate correlations with ADHD symptoms and the two cannabis outcomes. Motives demonstrating statistically non-significant correlations with ADHD symptoms were not included in subsequent analyses. Coping with negative affect (e.g., “to forget your problems”), sleep (e.g., “because you are having problems sleeping”), social anxiety (e.g., “because it relaxes you when you are in an insecure situation”), perceived low risk (e.g., “because it is safer than drinking alcohol”), and altered perception (e.g., “because you want to alter your perspective”) were examined as mediators in this study. Internal consistencies were good-to-excellent across subscales in this sample (6-months $\alpha = .84–.92$).

Time-Line Follow-Back (TLFB) is a psychometrically-sound, calendar-assisted structured interview (Dennis, Funk, Godley, Godley, & Waldron, 2004; Sobell & Sobell, 1992). TLFB has high test-retest reliability and stability over periods of 180 days (Carey, 1997) and up to one year (Sobell & Sobell, 1992). TLFB covered 180 days prior to each visit and was used to derive percentage of cannabis use days (i.e., outcome variable), as well as alcohol, cigarette, and other drug use days (i.e., covariates).

Cannabis-related problems were assessed via the Marijuana Problems Scale (MPS; Stephens, Roffman, & Curtin, 2000), which is a 22-item, self-report questionnaire that assesses problems experienced in the past 90 days. The MPS exhibited excellent internal consistency in this sample (12-months $\alpha = .91$). A total count of problems was used as the outcome variable.

Structured Clinical Interview for *DSM-IV*, Non-Patient Edition (SCID-NP) was used to assess past-month *DSM-5* major depressive disorder (MDD) and panic disorder diagnoses at baseline (First, Spitzer, Gibbon, & Williams, 2002). Diagnoses were scored as ‘yes’ vs. ‘no’.

Clinician-Administered PTSD Scale (CAPS) was used to ascertain past-month *DSM-IV* PTSD diagnosis at baseline from a semi-structured interview (Blake et al., 1995). Diagnosis were scored as 'yes' vs. 'no'.

Inventory of Depression and Anxiety Symptoms – Social Anxiety (IDAS-SA) includes 5 items (e.g., "I was worried about embarrassing myself socially") rated on a 5-point Likert-type scale ranging from 1 (*not at all*) to 5 (*extremely*), assessing symptoms of social anxiety in the past two weeks (Watson et al., 2008). This subscale reflects a continuous range of social anxiety symptoms. Internal consistency was good at baseline ($\alpha = .82$).

Data Analytic Strategy

Preliminary analyses and model selection—Data management, coding, and bivariate correlations were conducted using SAS 9.4™ software (SAS Institute Inc.). Preliminary analyses involved examining predictors of attrition, as well as examining outcome distributions to select the most appropriate modeling approach. Examinations of plots revealed cannabis use and cannabis problems were positively skewed, with 65/67% and 74/77% of participants reporting no cannabis use or cannabis problems at baseline or 12-months, respectively. To determine the best fitting distribution for the non-linear outcomes, we compared model fit indices for four count distributions: poisson, zero-inflated poisson (ZIP), negative binomial, and zero-inflated negative binomial (ZINB). We selected the distribution with the lowest Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values (Burnham & Anderson, 2004). The dispersion parameters for the two outcomes were statistically significant, suggesting a violation of the assumptions of poisson regression (Agresti, 2002). Thus, we determined the ZINB was the optimal distribution for cannabis use and related problems (see Supplemental Table S1 for model comparisons). Therefore, we leveraged zero-inflated negative binomial (ZINB) regression in all models. ZINB regression is optimal for positively-skewed outcomes that contain excessive zeros (Wagner et al., 2015). This model contains two simultaneous processes: (1) zero-inflated model determining the log-odds of an observation always being zero, or in excess of what is expected from a negative binomial distribution, and (2) negative binomial model, which can also contain zero values (Cameron & Trivedi, 1998; Heilbron, 1994).[2]

Latent variable modeling—Raw data were then imported into Mplus version 8.2 to conduct prospective mediation models using structural equation modeling (SEM) and maximum likelihood estimation with robust standard errors for missing data (Muthén & Muthén, 1998–2018). First, we constructed measurement models for ADHD symptoms and cannabis motives, specifying each variable (six total) as a one-factor model; the two outcomes were treated as manifest variables. The one-factor model fit for ADHD symptoms was suboptimal[3], as determined by the comparative fit index (CFI) and Tucker-Lewis index (TLI), though the root-mean-square error of approximation (RMSEA) for this model was

[2]Outcomes from negative binomial (i.e., count) models are henceforth referred to as cannabis use frequency and cannabis problem severity to differentiate between negative binomial and zero-inflated estimates. Estimates from the zero-inflated process of the model are not of primary and thus are not reported or discussed for simplicity.

[3]A two-factor model was also considered for ADHD, reflecting the two subscales of the ASRS – inattention symptoms (9 items) and hyperactivity-impulsivity symptoms (9 items). The measurement model with two correlated ADHD factors demonstrated improved model fit compared to the one-factor model ($\chi 2(134) = 337.28$, $p < .01$; CFI = 0.90; TLI = 0.88, RMSEA = 0.07, 90% CI = 0.06,

acceptable ($\chi^2(135) = 404.10$, $p < .01$; CFI = 0.86; TLI = 0.84, RMSEA = 0.07, 90% CI = 0.07, 0.08). The unidimensional structure of each cannabis use motive fit the data well ($\chi 2(80) = 285.59$, p < .01; CFI = 0.99; TLI = 0.99, RMSEA = 0.09, 90% CI = 0.08, 0.10).

Prospective mediation models—MODEL INDIRECT specifying INTEGRATION = MONTECARLO was used to test the indirect effects of 10 single mediation models (i.e., each mediator independently and each cannabis outcome independently). Five latent cannabis motives (assessed at 6-months) were tested as mediators of relations between baseline latent adult ADHD symptoms and 12-month cannabis use frequency and cannabis problem severity. Statistically significant mediators from single mediator models were subsequently entered into a multiple mediator model. Baseline cannabis use (0=no, 1=yes), age, sex, race, ethnicity, and marital status, as well as alcohol use, cigarette use, other drug use, social anxiety symptoms, and MDD, PTSD, and panic disorder diagnoses, were considered as covariates.

All models were first examined adjusting for baseline cannabis use only (Model A). Age, sex, race, ethnicity, and marital status were then added (Model B). The final (most conservative) model also adjusted for alcohol use, cigarette use, other drug use, social anxiety symptoms, and MDD, PTSD, and panic disorder diagnoses (Model C). Mediators included in Model D were statistically significant in Model A single mediator models. Model D reflects multiple mediator models for cannabis use frequency (see Figure 1).[4] Notably, medical records in CPRS verified that 1.9% ($n = 7$) of participants in this sample were prescribed stimulant medications (i.e., methylphenidate, lisdexamfetamine dimesylate, or dextroamphetamine/amphetamine), thus prescription medications that are typically prescribed for ADHD were not considered as a covariate.

Results

Preliminary Analyses

See Table 1 for sample demographics for the overall sample, as well as stratified by cannabis user status at baseline. Age significantly predicted retention (Wald = 5.95, $p = .02$) with older participants more likely to complete the study. ADHD symptoms, MDD, PTSD, panic disorder, cannabis use, marital status, sex, ethnicity, and employment status did not predict retention. Baseline ADHD symptoms evinced small-to-moderate bivariate correlations with 12-month cannabis use and cannabis problems and small-to-moderate correlations with 6-month cannabis motives (Cohen, 1988; see Table 2).

Prospective Mediation Path Models

Cannabis use—Each cannabis use motive at 6-months significantly mediated the relation between baseline ADHD symptoms and 12-month cannabis use frequency in single mediator models after adjusting for baseline cannabis use, such that baseline ADHD

0.07). However, for some mediators (e.g., sleep motives), we did not reach convergence once adding covariates (i.e., Models B and C) when including the 2-factor ADHD variable. Thus, we included the one-factor ADHD latent variable in all analyses for the present study, with the limitation of suboptimal model fit for this variable.

[4]Given only one cannabis use motive (i.e., coping motives) was statistically significant for cannabis problem severity in Model A, no multiple mediator model was conducted for this outcome.

symptoms were linked to increased cannabis use motives at 6-months[5], which, in turn, predicted increased cannabis use frequency at 12-months (Table 3, Model A). These findings were also robust to age, sex, race, ethnicity, and marital status (Table 3, Model B). Sleep motives as a mediator remained significant after also adjusting for alcohol, cigarette, and other drug use, social anxiety symptoms, and MDD, PTSD, and panic disorder diagnoses (Table 3, Model C). A multiple mediator model simultaneously tested all five cannabis use motives that were statistically significant in Model A (see Figure 1), and sleep motives was the only marginally significant mediator when examined concurrently with other mediators and after adjusting for baseline cannabis use, age, sex, race, ethnicity, marital status, alcohol use, cigarette use, other drug use, social anxiety symptoms, and MDD, PTSD, panic disorder diagnoses (Table 3, Model D).

Cannabis problems—Coping with negative affect, but no other motives, at 6-months significantly mediated the relation between baseline ADHD symptoms and 12-month cannabis problem severity after adjusting for baseline cannabis use, such that baseline ADHD symptoms were associated with increased cannabis coping motives at 6-months, which, in turn, was linked to cannabis problem severity at 12-months (Table 3, Model A). These findings were robust to age, sex, race, ethnicity, and marital status (Table 3, Model B), as well as alcohol, cigarette, other drug use, social anxiety symptoms, and MDD, PTSD, and panic disorder diagnoses (Table 3, Model C).

Discussion

The present study extends prior research by empirically examining five cannabis motives as mediators of the ADHD symptoms-cannabis relation in a prospective sample of returning veterans. Mediators were tested after rigorously adjusting for baseline cannabis use, demographic characteristics, other substance use (i.e., alcohol, cigarette, and other drug use), and internalizing psychopathology (i.e., social anxiety symptoms and MDD, PTSD, and panic disorder diagnoses), which all share appreciable overlap with ADHD symptoms and cannabis (Harrington et al., 2012; Metrik et al., 2016). Findings suggest motivational pathways are differentially related to cannabis use frequency and cannabis problem severity. Sleep motives emerged as a mechanism underlying the prospective relation between ADHD symptoms and subsequent cannabis use frequency over and above baseline cannabis use, demographic characteristics, other substance use, and internalizing psychopathology. Sleep motives also was the only mediator to emerge as marginally significant when considered simultaneously with other correlated motives. On the other hand, coping with negative affect motives was the most prominent pathway for cannabis problem severity. These findings are the first, to our knowledge, to identify specific mechanisms explicating this longitudinal relation. These preliminary findings also converge with extant literature on cannabis and comorbid psychiatric disorders.

[5]Latent variables for motives used in mediation analyses reflect participants' cannabis use motives at 6-months and do not reflect a change in use motives from baseline to 6-months.

Sleep Motives

Sleep disturbance and ADHD symptoms frequently co-occur, with over 70% of individuals with ADHD endorsing sleep disturbance regardless of stimulant medication intake (Schredl, Alm, & Sobanski, 2007; Van Veen et al., 2010). Qualitative findings from Mitchell et al. (2016) also found sleep disturbance is a commonly reason cited for using cannabis in those with ADHD symptoms. Our findings also align with our recent cross-sectional research on veterans, with sleep motives emerging as an important mechanism between PTSD/MDD and cannabis use (Metrik et al., 2016). Extant research also indicates that sleep motives are independently associated with past-30-day cannabis use frequency (Babson, Boden, & Bonn-Miller, 2013), which supports our differential findings that sleep motives contribute to cannabis use frequency. When examined with indices of problematic cannabis involvement, Metrik and colleagues (2016) found support for sleep motives as a mechanism underlying PTSD/MDD and cannabis problems and CUD. Indeed, evidence suggests individuals develop a tolerance to short-term benefits of cannabis use on sleep, which results in increased use and increased potential for cannabis problems (Angarita et al., 2016; Babson, Sottile, Morabito, 2017). Therefore, sleep motives may emerge as a mechanism of ADHD symptoms and cannabis problems in future replication studies.

Though speculative, our findings suggest improving sleep quality may also improve treatment outcomes related to ADHD symptoms and cannabis use. Evidence-based approaches to manage sleep disturbance, such as cognitive-behavioral treatment for insomnia (CBT-I) or EEG-biofeedback, may be effective treatment options for veterans who use cannabis and have ADHD symptoms (Diaz, Sloot, Mansvelder, & Linkenkaer-Hansen, 2012; Morin et al., 2006; Perlis, Jungquist, Smith, & Posner, 2006). Addressing sleep disturbance more directly may also yield longer-term treatment gains. In fact, 65% of cannabis users cited sleep disturbance as a reason for resuming use following a cessation attempt (Budney et al., 2008), which emphasizes the potential for improved cannabis outcomes if sleep disturbance is effectively managed.

Coping with Negative Affect Motives

As expected, coping with negative affect was not as salient for cannabis use frequency as it was for cannabis problem severity. This is consistent with the extant substance use literature noting robust relations between coping and substance use problems, but not quantity and frequency (Cooper et al., 2016 for a review). Using cannabis to cope with negative affect was the only significant mediator between ADHD symptoms and subsequent cannabis problem severity. Previous research has speculated adults with ADHD symptoms use cannabis to cope (Wilens et al., 2007), and recent qualitative evidence demonstrated low mood and negative affect are commonly cited reasons for using cannabis among those with ADHD symptoms (Mitchell et al., 2016). We are the first to empirically test this notion, and this relation is supported by the affective-motivational model of substance use (Baker et al., 2004). Interestingly, emotion dysregulation is a shared feature of both ADHD and cannabis (Barkley, 2015; Lopez-Vergara et al., 2019), and using cannabis to cope likely perpetuates the cycle of emotion dysregulation, maladaptive coping, and subsequent cannabis problems. Future research in this area is needed to determine whether effective coping skills for

negative affect (e.g., distress tolerance; Linehan, 1993) could improve outcomes for both ADHD symptoms and cannabis problems.

Social Anxiety Motives

Using cannabis to manage social anxiety was also supported as a pathway from ADHD symptoms to cannabis use frequency, though this motive was not significant after adjusting for other substance use and internalizing psychopathology. Previous research indicates notable overlap between ADHD, social anxiety, and cannabis use, as SAD is the most comorbid anxiety disorder in adults with ADHD (Kessler et al., 2006). This comorbidity likely arises from interpersonal difficulties associated with childhood ADHD that contribute to negative affect in social situations in adulthood (Katzman et al., 2017). SAD is also closely linked with problematic cannabis use (e.g., Buckner, Ecker, & Dean, 2016; Buckner, Schmidt, Bobadilla, & Taylor, 2006; Buckner & Zvolensky, 2014). Our findings indicate future research on ADHD symptoms, social anxiety, and cannabis use is warranted, particularly among veterans (Kashdan, Julian, Merritt, & Uswatte, 2006), with treatment targets related to effective coping in social situations being potentially useful for improving ADHD symptoms and reducing cannabis use.

Perceived Low Risk Motives

Our findings indicate devaluing risks is also pertinent to cannabis use frequency, which is consistent with research in this area (e.g., Cohn, Johnson, Ehlke, & Villanti, 2016); however, this mechanism was not supported after adjusting for other substance use and internalizing psychopathology. Nevertheless, attitudes toward cannabis have shifted in favor of cannabis, with an increasing perception that cannabis use carries minimal risk (Budney et al., 2019; Carliner, Brown, Sarvet, & Hasin, 2017). Among U.S. adults, the prevalence of perceived cannabis risk decreased from 50.4% to 33.3% between 2002 and 2014, with perception of no risks associated with cannabis increasing from 5.6% to 15.1% (Compton et al., 2016). Veterans also share this belief with many viewing cannabis as relatively low risk (Wilkinson et al., 2016). However, more favorable attitudes toward cannabis are often associated with increased cannabis use (Carliner et al., 2017). Notably, a recent study examined reciprocal prospective relations of risk perception and cannabis use and supported both directional effects (Salloum et al., 2018), suggesting that intervening on perceived risk may have enduring benefits. Our findings are consistent with extant research indicating risk perception is important in maintaining cannabis use over time. Our preliminary findings indicate risk perception is differentially related to cannabis use (vs. cannabis problems).

Altered Perception Motives

After adjusting for internalizing psychopathology and other substance use, altered perception was not a significant mediator of ADHD symptoms and cannabis use frequency. Given that few studies have examined this cannabis motive, particularly with psychiatric comorbidities and among veterans, more research is needed to glean when and for whom this motive is important.

Strengths and Limitations

The present study has several strengths, including being the first to empirically and prospectively test motivational pathways from ADHD symptoms to cannabis use frequency and cannabis problem severity among returning veterans. A strength of using prospective mediation is the ability to discern the temporal ordering of relations (MacKinnon & Fairchild, 2009). We used an SEM approach that reduces measurement error and also rigorously adjusted for demographics, other substance use, social anxiety symptoms, MDD, PTSD, and panic disorder diagnosis – all of which share considerable overlap with ADHD and cannabis use. Though more replication studies are needed, our findings identified malleable underlying mechanisms of ADHD symptoms and cannabis indices that could improve treatment outcomes. Building on this work and that of others (e.g., Salloum et al., 2018), future research also should examine the reciprocal relations among ADHD symptoms, motives, and cannabis use and related problems over time using a cross-lagged panel design (e.g., Hamaker et al., 2005).

Findings from the present study should be interpreted considering limitations. Our sample of returning OEF/OIF/OND veterans was predominantly male and predominantly White, limiting generalizability across sexes, races, ethnicities, nonveterans, and veterans from other war eras. Despite the strengths of our modeling approach, observational data precludes our ability to draw causal inferences. Though we employed a prospective design, age of onset of ADHD symptoms was not assessed in this sample, thus we are unable to confirm ADHD symptoms preceded cannabis use in this sample, though this ordering has been documented elsewhere (e.g., Lee et al., 2011; Molina et al., 2018). Formal ADHD diagnoses were also not assessed in the present study. However, assessing symptom count is often considered more informative and even preferred (Bidwell et al., 2014; Frazier et al., 2007). More research is needed to determine whether our findings generalize to a clinical sample of adults diagnosed with ADHD, particularly given ADHD symptoms, including those assessed in the present study, could be a result of other mental health symptoms or substance use. The present study also did not consider mode of cannabis use, cannabis quantity, or information regarding cannabis potency or strain, which could differentially relate to ADHD symptoms, cannabis motives, and cannabis indices. Model fit for the one-factor ADHD measurement model was suboptimal, as determined by CFI and TLI; however, we were unable to reach model convergence when modeling ADHD as a two-factor structure. We recommend that future studies, potentially with larger samples, consider modeling ADHD as a two-factor structure, given we demonstrated improved model fit for this measurement model, relative to the one-factor structure. Finally, the multiple mediator model exhibited signs of suppression effects likely due to this being a complex model with six highly intercorrelated latent variables, numerous covariates, and a zero-inflated negative binomial outcome. Thus, estimates from this model require additional replication with a larger sample.

Conclusions

Our findings clarify underlying mechanisms of adult ADHD symptoms and subsequent cannabis use frequency and cannabis problem severity in returning veterans. Sleep disturbance appears to play a vital role in maintaining cannabis use frequency over time. Addressing sleep using evidence-based strategies may improve treatment outcomes for

individuals with both ADHD symptoms and cannabis use. Using cannabis to cope with negative affect is robustly linked to cannabis problems in veterans with ADHD symptoms, which is consistent with the affective-motivational model of substance use. Evidence-based coping strategies to improve mood and increase distress tolerance are recommended to potentially improve treatment outcomes for ADHD symptoms and cannabis problems alike.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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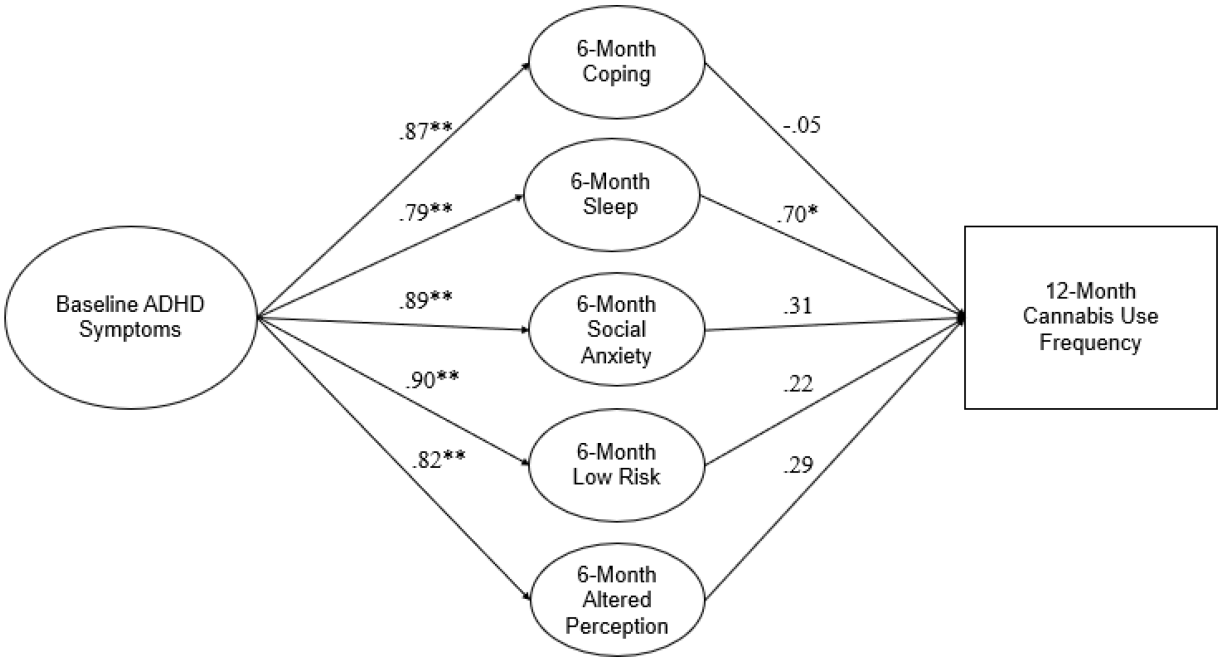

Figure 1.

Prospective mediation analysis for ADHD symptoms and cannabis use frequency

Note. Figure 1 reflects a prospective multiple mediator model from baseline ADHD symptoms to 12-month cannabis use frequency via 6-month cannabis motives. Circles reflect latent variables; squares reflect manifest variables. Mediators included in multiple mediator analyses were statistically significant in Model A of single mediator models. Age, sex, race, ethnicity, marital status, alcohol use, cigarette use, other drug use, social anxiety symptoms, and MDD, PTSD, and panic disorder diagnoses were included as covariates for both zero-inflated and negative binomial processes of the model, but also not included for simplicity. Estimates reflect standardized betas. *$p < .05$; **$p < .01$

Table 1

Sample demographics, diagnostic, and military service-related characteristics

	Overall Sample (*N*=361)	Baseline Cannabis Users (*N*=346)	Baseline Cannabis Non-Users[e] (*N*=15)
Variable		***n* (%)**	
Gender[a]			
Male	337 (93)	323 (93)	14 (93)
Race[a]			
White	289 (80)	278 (81)	11 (73)
Black/African American	16 (4)	15 (4)	1 (7)
Asian	6 (2)	6 (2)	-
Native Hawaiian/Pacific Islander	2 (1)	2 (<1)	-
American Indian/Alaska Native	2 (1)	1 (<1)	1 (7)
Multiracial	17 (4)	17 (5)	-
Other	26 (8)	24 (7)	2 (13)
Ethnicity[a]			
Hispanic/Latino(a)	48 (13)	45 (13)	3 (20)
Marital Status[a]			
Single/Never married	116 (32)	114 (33)	2 (13)
Married/Living with partner	173 (48)	165 (48)	8 (54)
Divorced/Separated	72 (20)	67 (19)	5 (33)
Employment Status[ab]			
Employed	283 (78)	274 (79)	9 (60)
Unemployed/Homemaker	67 (19)	66 (19)	1 (7)
Student	87 (24)	82 (24)	5 (33)
Military Service	101 (28)	99 (29)	2 (13)
Combat Operation(s) served in[ab]			
Operation Enduring Freedom (OEF)	223 (62)	212 (62)	11 (73)
Operation Iraqi Freedom (OIF)	74 (21)	71 (21)	3 (20)
Operation New Dawn (OND)	46 (13)	45 (13)	1 (7)
Positive ADHD screen[d]	105 (29)	102 (29)	3 (20)
Major Depressive Disorder, current (BL)	53 (15)	51 (15)	2 (13)
Posttraumatic Stress Disorder, current (BL)	47 (13)	47 (14)	-
Panic Disorder, current (BL)	30 (8)	28 (8)	2 (13)
Cannabis Use Disorder, current (BL)	53 (15)	53 (15)	-
New cannabis user at 12-months[e]	15 (4)	-	-
		Mean (SD)	
Age[a]	33.56 (9.44)	33.48 (9.44)	35.67 (9.58)
Years of education completed[a]	13.73 (2.11)	13.71 (2.11)	14.20 (2.21)

	Overall Sample (*N*=361)	Baseline Cannabis Users (*N*=346)	Baseline Cannabis Non-Users[e] (*N*=15)
Variable		***n* (%)**	
Number of deployments post-9/11/2001[a]	1.88 (1.15)	1.89 (1.16)	1.53 (0.83)
Years since last deployment[a]	3.95 (2.79)	3.89 (2.74)	5.20 (3.67)
% alcohol use days[a]	25.13 (28.83)	24.96 (28.78)	29.15 (30.67)
% cannabis use days[a]	16.23 (32.85)	16.94 (33.38)	-
% cigarette use days[ac]	76.98 (34.40)	77.79 (33.86)	59.68 (44.05)
% other drug use days[a]	4.07 (15.02)	3.90 (14.62)	8.19 (22.79)
% other tobacco use days[ac]	11.16 (25.92)	10.99 (25.41)	14.76 (37.60)
Cannabis problems, baseline	1.07 (2.71)	1.12 (2.76)	-
Coping motives, baseline	1.59 (0.99)	1.60 (0.99)	1.49 (0.95)
Sleep motives, baseline	1.90 (l.28)	1.91 (1.29)	1.51 (0.83)
Social anxiety motives, baseline	1.61 (0.95)	1.62 (0.97)	1.29 (0.53)
Perceived low risk motives, baseline	2.00 (1.19)	2.01 (1.20)	1.89 (0.96)
Altered perception motives, baseline	1.93 (1.17)	1.92 (1.16)	2.04 (1.30)

Note. BL=baseline assessment, YR=12-month follow-up assessment

[a]Baseline assessment reported

[b]Multiple responses permitted

[c]Tobacco users only (n = 157)

[d]Positive ADHD screen ascertained by endorsement of nine or more clinically-significant symptoms at baseline on the World Health Organization (WHO) Adult ADHD Self-Report Scale (Kessler et al., 2005).

[e]Determined by endorsing no current cannabis use at baseline but reporting current cannabis use at the 12-month assessment.

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Table 2

Zero-order correlations among study variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
1. Age	-																			
2. Sex	−.02	-																		
3. Race	−.04	.00	-																	
4. Ethnicity	.14	.07	−.09	-																
5. Marital status	.29*	−.00	−.02	.04	-															
6. Alcohol use	.18*	−.09	.06	.06	−.00	-														
7. Tobacco use	−.15*	−.04	−.00	.01	.06	.01	-													
8. Other drug use	−.07	−.02	.04	.03	.11*	−.08	.21*	-												
9. PTSD diagnosis	−.06	−.00	−.03	.08	.08	−.11*	.12*	.06	-											
10. MDD diagnosis	−.02	.14*	.04	.05	.08	−.06	.07	.09	.35*	-										
11.Panic disorder diagnosis	−.04	.08	.07	−.00	.11	−.02	.05	−.07	.15*	.19*	-									
12. Social anxiety symptoms	−.13*	−.06	.02	.05	.06	−.05	.10	.08	.35*	.40*	.22*	-								
13. ASRS	−.12*	−.01	.07	−.00	.08	.01	.10	.06	.29*	.31*	.10	.50*	-							
14. Coping	−.13*	−.02	−.00	−.04	.06	−.12	.22*	.13*	.30*	.25*	.17*	.28*	.27*	-						
15. Altered perception	−.19*	−.11	−.07	−.07	−.00	−.09	.17*	.16*	.26*	.10	.06	.18*	.19*	.56*	-					
16. Social anxiety	−.12*	.00	.01	−.07	.06	−.06	.23*	.07	.28*	.20*	.11*	.29*	.17*	.68*	.59*	-				
17. Perceived low risk	−.24*	.07	−.05	.01	−.01	−.13*	.19*	.06	.28*	.19*	.13*	.20*	.20*	.48*	.62*	.59*	-			
18. Sleep	−.29*	.02	.07	−.04	.03	−.10	.29*	.15*	.35*	.22*	.15*	.24*	.24*	.57*	.52*	.61*	.63*	-		
19. Cannabis use	−.18*	−.01	.08	.04	−.03	−.08	.26*	.13*	.33*	.19*	.15*	.21*	.19*	.41*	.37*	.45*	.47*	.66*	-	
20. Cannabis problems	−.05	−.05	−.05	.04	.07	−.07	−.01	.05	.10	.20*	−.01	.09	.23*	.29*	.26*	.21*	.21*	.28*	.39*	-
M/%	33.56	93.35%	80%	13.30%	48%	25.13	33.48	4.07	13.02%	14.68%	8.31%	10.48	6.24	1.48	1.89	1.55	1.94	1.84	16.58	.93
SD	9.47	−	-	-	-	28.83	44.42	15.02	-	-	-	4.63	3.93	.93	1.18	.98	1.24	1.25	32.94	2.45

Note. *N* = 361 at baseline; *N* = 312 at 6-months; *N* = 310 at 12-months. Sex = % male; race = % White; ethnicity = % Hispanic/Latino(a); marital = % married/living with partner. Alcohol, tobacco, other drug = % use days at baseline; PTSD = baseline past-year PTSD diagnosis; MDD = baseline past-year major depressive disorder diagnosis; Panic disorder diagnosis = baseline past-year panic disorder diagnosis; social anxiety symptoms = IDAS social anxiety subscale sum score. ASRS = count of clinically significant ADHD symptoms at baseline; Coping, altered perception, social anxiety, perceived low

risk, and sleep = cannabis motives at 6-months. Cannabis use = % cannabis use days at 12-months; cannabis problems = continuous cannabis-related problems at 12-months. Pearson correlations reported for bivariate correlations between continuous variables. Correlations between continuous and categorical variables are point-biserial.

* $p < .05$.

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Table 3

Indirect Effects from Prospective Mediation Models for Count Outcomes

	Model A = Base Model		**Model B = Demographics**		**Model C = Demographics+Etiology**		**Model D[a] = Multiple Mediators**	
Cannabis motives	**IE**	**(SE)**	**IE**	**(SE)**	**IE**	**(SE)**	**IE**	**(SE)**
Cannabis Use Frequency								
Coping								
Total indirect	**.05**	**(.02)**	**.06**	**(.02)**	.03	(.02)	−.02	(.24)
Sleep								
Total indirect	**.12**	**(.04)**	**.14**	**(.04)**	**.11**	**(.04)**	.25	(.14)
Social Anxiety								
Total indirect	**.04**	**(.02)**	**.05**	**(.02)**	.03	(.02)	.12	(.20)
Perceived low risk								
Total indirect	**.06**	**(.03)**	**.07**	**(.03)**	.07	(.04)	.09	(.36)
Altered perception								
Total indirect	**.05**	**(.02)**	**.07**	**(.03)**	.05	(.03)	.11	(.16)
Cannabis Problem Severity								
Coping								
Total indirect	**.10**	**(.04)**	**.12**	**(.05)**	**.10**	**(.04)**	-	-
Sleep								
Total indirect	−.03	(.07)	−.06	(.07)	.01	(.08)	-	-
Social Anxiety								
Total indirect	.01	(.02)	.02	(.03)	.06	(.04)	-	-
Perceived low risk								
Total indirect	−.04	(.04)	−.04	(.04)	−.04	(.03)	-	-
Altered perception								
Total indirect	.03	(.02)	.04	(.05)	.06	(.06)	-	-

Note. IE = indirect effect; SE = standard error. All estimates reported are standardized. Model A represents single mediator models from baseline ADHD symptoms to frequency of cannabis use or severity of cannabis problems at 12-months after adjusting for baseline cannabis use. In all models, ADHD symptoms were modeled as a single latent variable; cannabis use motives were modeled as single latent variables; and cannabis use frequency and cannabis problem severity were treated as manifest variables. Model B also includes age, sex, race, ethnicity, and marital status. Model C also includes alcohol use,

cigarette use, other drug use, social anxiety symptoms, and MDD, PTSD, panic disorder diagnoses. Model D reflects path analysis with multiple mediators adjusting for all covariates. Significant indirect effects ($p < .05$) are in bold typeface.

[a]Given the exploratory nature of Models B and C, statistically significant mediators from the base model (Model A) were selected for the multiple mediator model (Model D).