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Negative mood as a mediator of the association between insomnia severity and marijuana problems in college students

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Abstract

Insomnia symptoms have been linked to problematic marijuana use among young adults, but the mechanism underlying this association and whether sex differences exist, remains unclear. Using cross-sectional data, this study examined negative mood as a mediator of the association between insomnia and marijuana problems among male and female college students. Undergraduate students (n = 267; 61% female) reporting marijuana use in the past month completed an online survey assessing insomnia symptoms, negative mood and marijuana problems. Controlling for relevant covariates, negative mood was examined as a mediator of the association between insomnia and marijuana problems using bootstrapped significance tests for indirect effects (n-boot = 1,000). Results indicated that higher levels of insomnia were associated with greater levels of negative mood (regardless of sex), which in turn were associated with greater marijuana-related problems. In conclusion, insomnia symptoms are associated with more negative mood among college students who use marijuana, and this effect on negative mood accounts for a large part of the association of insomnia symptoms with marijuana-related problems. Research is needed to determine if these associations are maintained prospectively.

KEYWORDS

anxiety, cannabis, college students, depression, mediation, sleep problems

1 | INTRODUCTION

Young adults attending college are at higher risk of initiating marijuana use than their non-attending peers (Miech, Patrick, O'Malley, & Johnston, 2017). In fact, marijuana is the most commonly used substance among college students other than alcohol, with 48.5% reporting lifetime marijuana use (Johnston, O'Malley, Bachman, Schulenberg, & Miech, 2015). This is concerning because marijuana use is associated with a variety of negative consequences that inhibit academic performance, including cognitive impairment, physical harm and poor psychological functioning (Arria, Caldeira, Bugbee, Vincent, & O'Grady, 2015; Buckner, Ecker, & Cohen, 2010; Suerken et al., 2016). This may explain, in part, why marijuana use during

college is associated with increased dropout, lower GPA, less time studying, and poorer performance in examinations and tests (Arria et al., 2015; Suerken et al., 2016).

Sleep problems are also common in college students (Taylor et al., 2011), with approximately 62% of students reporting clinically relevant sleep difficulties (Becker et al., 2018) and 70% of students indicating at least mild severity of insomnia (Gress-Smith, Roubinov, Andreotti, Compas, & Luecken, 2015). Poor sleep quality has been linked to marijuana use and associated problems among adolescents (Mike, Shaw, Forbes, Sitnick, & Hasler, 2016) and young adults (Wong, Craun, Bravo, & Pearson, 2019), both cross-sectionally and longitudinally. In fact, individuals often report using marijuana to assist with sleep (Walsh et al., 2013), and sleep difficulties occurring both before and after marijuana cessation are associated with relapse and treatment failure (Bolla et al., 2008; Budney, Hughes, Moore, & Vandrey, 2004).

In addition to sleep problems, stressors commonly associated with college life (e.g., academic work and finances) are linked to stress and negative mood among college students (American College Health Association, 2013; Beiter et al., 2015). For example, 32%-47% of students exhibit mental health symptoms, such as depression and anxiety (Acharya, Jin, & Collins, 2018; Eisenberg, Hunt, & Speer, 2013). Notably, insomnia symptoms are also associated with increased risk of other mental health symptoms (Biddle, Kelly, Hermens, & Glozier, 2018).

Both sleep problems and negative mood have been linked to marijuana use and problems in young adults (Lee, Neighbors, Hendershot, & Grossbard, 2009; Walters, Bulmer, Troiano, Obiaka, & Bonhomme, 2018). For example, college students report using marijuana to cope with negative affect and manage sleep difficulties. After controlling for overall frequency of marijuana use, Lee et al. (2009) found that students who reported using marijuana to help them cope with college and for sleep-related reasons experienced more consequences related to their marijuana use than students using it for other reasons. Likewise, in patients taking medical marijuana for post-traumatic stress disorder (PTSD), coping with mood-related difficulties and improving sleep appeared to be the primary motivations for using marijuana (Bonn-Miller, Babson, & Vandrey, 2014).

Despite their independent associations with marijuana problems, the effect of the relationship and interplay between poor sleep and mood on the consequences of marijuana use is unclear. For example, young adult daily marijuana users report more sleep disturbance and insomnia severity than their non-daily-using peers; however, after accounting for negative mood symptoms (e.g., depression and anxiety), this relationship is no longer significant (Conroy, Kurth, Strong, Brower, & Stein, 2016), suggesting that negative mood may play a role in the association between insomnia symptoms and marijuana use. Similarly, among adults who use marijuana for medical reasons (i.e., with physician recommendation), high levels of depression are related to problematic marijuana use, but only in the context of good perceived quality of sleep (Babson, Boden, & Bonn-Miller, 2013). Although these findings are counterintuitive, almost half of this sample was recommended marijuana for insomnia; thus, the authors speculate that those with negative mood symptoms might use marijuana (and experience higher rates of marijuana problems) because of the perceived benefits of marijuana for the quality of sleep (Babson et al., 2013). This implies that insomnia symptoms contribute to negative mood, which in turn may encourage marijuana use and increase the risk of marijuana-related harm.

Despite these findings, the unique relationship between insomnia, mood and marijuana use and problems in college students remains unclear. With some states recommending the use of medicinal marijuana for sleep-related difficulties (National Academies of Sciences, Engineering, & Medicine, 2017), the influence of these variables on the experience of problems related to marijuana use is important to understand and disentangle. Hence, the purpose of the current study was to examine the associations among insomnia severity, negative mood and marijuana-related problems utilizing a cross-sectional dataset. Given the association between insomnia symptoms and negative mood (Babson, Sottile, & Morabito, 2017; Biddle et al., 2018) and, in turn, the association between negative mood and marijuana-related problems (Lee et al., 2009), we hypothesized that negative mood would help explain (mediate) the association between insomnia symptoms and marijuana-related problems among young adults attending college. Moreover, because women tend to report more insomnia (Auer, Frauscher, Hochleitner, & Hogl, 2018) and negative mood (Bromet et al., 2011) and may differ from men in the extent to which their coping strategies involve marijuana use and/ or problems (Ali, Seitz-Brown, & Daughters, 2015; Bujarski, Norberg, & Copeland, 2012), we hypothesized that sex would moderate the indirect effect of insomnia symptoms on marijuana problems through negative mood, consistent with a moderated mediation model.

2 | METHOD

2.1 | Participants and procedures

Eligible participants were 267 undergraduate students from a large southeastern university (61% female, 67% white, ages 18–25 years) who reported using marijuana at least three times in the past month. Students were recruited via email, flyers and online advertisements. Interested participants contacted the researchers via email or phone and were given the link to the screening survey. Eligible participants provided informed consent and completed an online assessment that took approximately 60 min to complete. Participants were compensated with a \$20 VisaTM card. All procedures were approved by the University of Florida Institutional Review Board.

2.2 | Measures

2.2.1 | Demographic information

Participants provided information regarding their biological sex, age and race/ethnicity.

2.2.2 | Marijuana use

Participants reported their frequency of marijuana use with a single item asking: In the past month, on how many days did you use marijuana?

2.2.3 | Marijuana-related problems

Participants were asked to report how many times in the past 30 days they experienced any of 26 consequences (e.g., having low motivation or problems following through on things) while using marijuana or as a result of their marijuana use (Lee et al., in prep.; Patrick, Fairlie, & Lee, 2018). Responses were scored from 0 (0 times) to 4 (more than 10 times) and were summed to create one consequence score.¹

2.2.4 | Mood-related symptoms

Negative mood was assessed using the Depression, Anxiety, and Stress Scale (DASS-21; Parkitny & McAuley, 2010). The DASS-21 consists of seven items and three subscales measuring symptoms of depression, anxiety and stress in the past week. Responses ranged on a 4-point Likert scale from 0 (Did not apply to me at all) to 3 (Applied to me very much, or most of the time). The DASS is a reliable and valid measure of depression, anxiety and stress in college students (Mahmoud, Hall, & Staten, 2010). Internal consistency (Cronbach's alpha) for this scale and subscales (depression, anxiety and stress) in this sample was 0.94, 0.91, 0.82 and 0.84 respectively.

2.2.5 | Insomnia severity

Symptoms of insomnia were measured using the seven-item Insomnia Severity Index (ISI; Bastien, Vallières, & Morin, 2001), which assesses difficulties in sleep onset, sleep maintenance, daytime functioning and sleep dissatisfaction and any other distress associated with sleep problems in the past 2 weeks. Response options ranged from 0 (none) to 4 (very severe) and were summed to create a continuous variable, with higher scores indicative of more severe sleep difficulties. Internal consistency (Cronbach's alpha) for the ISI in this sample was 0.87. For descriptive purposes, a cut-off score \geq 10 was used to characterize participants as screening positive versus negative for insomnia (Morin, Belleville, Belanger, & Ivers, 2011).

2.3 | Data screening and analysis

Analyses were conducted in IBM SPSS Statistics 25. Data were screened for missing values, normality and selection bias prior to analysis. Of the 310 participants, 267 provided data on the primary outcome variable (marijuana problems) and were included in the data analytic sample (see Table 1 for sample descriptions). Skewness and kurtosis estimates for all variables were within the acceptable range (Tabachnick & Fidell, 2013). There were no significant differences between participants included versus those excluded from analyses in terms of age, sex, frequency of marijuana use, insomnia severity or negative mood. Zero-order correlations between study variables are presented in Table 2. Moderated mediation was examined using PROCESS Model 59, which generates bootstrapped significance tests

TABLE 1 Sample demographics (N = 267)

Variable	n (%)		
Male birth sex	102 (38%)		
Positive insomnia screen	113 (42%)		
Ethnicity			
White/Caucasian	179 (67%)		
Black/African American	15 (5.6%)		
Asian	44 (16.5%)		
Hispanic/Latino	67 (25%)		
Other	10 (3.7%)		
	M (SD)		
Age	M (SD) 19.9 (1.4)		
Age Frequency of marijuana use	M (SD) 19.9 (1.4) 10.3 (7.9)		
Age Frequency of marijuana use Negative mood (DASS)	M (SD) 19.9 (1.4) 10.3 (7.9) 31.2 (26.3)		
Age Frequency of marijuana use Negative mood (DASS) DASS-Depression	M (SD) 19.9 (1.4) 10.3 (7.9) 31.2 (26.3) 10.1 (10.6)		
Age Frequency of marijuana use Negative mood (DASS) DASS-Depression DASS-Anxiety	M (SD) 19.9 (1.4) 10.3 (7.9) 31.2 (26.3) 10.1 (10.6) 8.7 (8.7)		
Age Frequency of marijuana use Negative mood (DASS) DASS-Depression DASS-Anxiety DASS-Stress	M (SD) 19.9 (1.4) 10.3 (7.9) 31.2 (26.3) 10.1 (10.6) 8.7 (8.7) 12.3 (9.6)		
Age Frequency of marijuana use Negative mood (DASS) DASS-Depression DASS-Anxiety DASS-Stress Insomnia severity	M (SD) 19.9 (1.4) 10.3 (7.9) 31.2 (26.3) 10.1 (10.6) 8.7 (8.7) 12.3 (9.6) 8.9 (5.8)		

Abbreviation: DASS, Depression Anxiety Stress Scale.

 $(n_{\text{boot}} = 5,000)$ to estimate indirect effects while simultaneously modelling conditional associations on all pathways (see Figure 1; MacKinnon, Lockwood, & Williams, 2004). In the hypothesized model, negative mood was examined as a mediator of the concurrent association between insomnia severity and marijuana problems, and sex was examined as a moderator of all the paths in this model (e.g., direct and indirect associations between insomnia and marijuana problems were examined separately for men and women). Because we were unable to account for the temporal precedence of the independent and mediator variables in these cross-sectional data, we then altered the temporal ordering of variables, such that (a) insomnia severity was also modelled as a mediator of the association between negative mood and marijuana problems and (b) negative mood was modelled as the mediator of the association between marijuana problems and insomnia severity. All analyses controlled for age and frequency of marijuana use.² In all models, the indirect path (mediated effect) was considered significant if the 95% confidence interval did not include zero.

3 | RESULTS

3.1 | Hypothesized model: insomnia > mood >marijuana problems

First, we examined negative mood as a mediator of the association between insomnia severity and marijuana problems (see Figure 1

¹"Trouble sleeping" was included as an item on the marijuana-related problems scale. Because this represents a potential confound between predictor and outcome variables, analyses were conducted both including and excluding the "trouble sleeping" item. Exclusion of this item did not alter the pattern of results; given this finding, the "trouble sleeping" item was retained in the measure to maintain the integrity of the scale.

²In post hoc analyses, we did not find significant direct or indirect associations between insomnia severity, negative mood, and frequency of marijuana use.

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TABLE 2 Zero-order correlations between study variables (N = 267)

		1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	Male sex	_								
2.	Age	0.09	-							
3.	Frequency of marijuana use	-0.05	0.22***	_						
4.	Negative mood (DASS)	-0.10	-0.01	-0.02	_					
5.	DASS-Depression	-0.05	0.03	-0.002	0.90***	_				
6.	DASS-Anxiety	-0.09	-0.01	-0.01	0.91***	0.69***	_			
7.	DASS-Stress	-0.13*	-0.06	-0.04	0.92***	0.72***	0.81***	-		
8.	Insomnia severity	-0.12*	0.02	0.05	0.50***	0.48***	0.41***	0.47***	_	
9.	Marijuana problems	0.06	0.03	0.12*	0.54***	0.45***	0.54***	0.50***	0.33***	_

Abbreviation: DASS, Depression Anxiety Stress Scale.

*p < .05, ***p < .001.



FIGURE 1 Conceptual diagram for moderated mediation models. Inconsistent associations are depicted in grey. Non-significant associations are depicted by dashed lines

and Table 3). There was a positive association between insomnia severity and negative mood (a-path effect = 2.43, SE = 0.30, p < .001; 95% CI = 1.85, 3.01), and sex did not significantly moderate this association (X^*W effect = -0.60, SE = 0.52, p = .25; 95% CI = -1.62, 0.42). There was also a positive association between negative mood and marijuana problems (b-path effect = 0.22, SE = 0.04, p < .001; 95% CI = 0.14, 0.30); however, sex significantly moderated this association (M^*W effect = 0.19, SE = 0.07, p = .01; 95% CI = 0.06, 0.32). Follow-up tests of simple slopes indicated that negative mood was associated more strongly with marijuana problems among men (effect = 0.40, SE = 0.05, p < .001; 95% CI = 0.30, 0.51) than women (effect = 0.22, SE = 0.04, p < .001; 95% CI = 0.14, 0.30). The direct and indirect association between insomnia severity and marijuana problems also differed as a function of sex. Specifically, insomnia symptoms were associated directly with marijuana problems among women (effect = 0.42, SE = 0.19, p = .02; 95% CI = 0.06, 0.79), but not men (effect = -0.11, SE = 0.24, p = .66; 95% CI = -0.59, 0.37). In line with this finding, negative mood helped explain more of the association between insomnia severity and marijuana problems among men (effect = 0.74, SE = 0.29; 95% CI = 0.30, 1.29) than women (effect = 0.53, SE = 0.15; 95% CI = 0.27, 0.84).

3.2 | Alternative model 1: marijuana problems > mood > insomnia

Given the potential bidirectional association between insomnia severity and marijuana problems, we then examined a model with reverse predictor and outcome variables. Specifically, we examined negative mood as a mediator of the association between marijuana problems and insomnia severity (see Table 3). Similar to the hypothesized model, there was a positive association between marijuana problems and negative mood (a-path effect = 1.07, SE = 0.13, p < .001; 95% CI = 0.82, 1.32); however, sex did not significantly moderate this association (X*W effect = -0.15, SE = 0.18, p = .42; 95% CI = -0.51, 0.21). There was also a positive association between negative mood and insomnia severity (b-path effect = 0.10, SE = 0.02, p < .001; 95% CI = 0.07, 0.13), and again, sex did not significantly moderate this association (M^*W effect = -0.01, SE = 0.03, p = .78; 95% CI = -0.07, 0.05). There was a direct association between marijuana problems and insomnia severity (effect = 0.08, SE = 0.03, p = .02; 95% CI = 0.02, 0.15) that was marginally moderated by sex (X*W effect = -0.10, SE = 0.05, p = .06; 95% CI = -0.20, 0.004). The direct association between marijuana problems and insomnia severity was significant for women (effect = 0.08, SE = 0.03, p = .02; 95% CI = 0.02, 0.15), but not for men (effect = -0.01, SE = 0.04, p = .71; 95% CI = -0.09, 0.06). However, marijuana problems were associated with insomnia severity indirectly through negative mood for both men (effect = 0.08, SE = 0.03; 95% CI = 0.03, 0.14) and women (effect = 0.11, SE = 0.03; 95% CI = 0.06, 0.16).

3.3 | Alternative model 2: mood > insomnia > marijuana problems

Finally, to examine the possibility of alternative temporal ordering, we examined insomnia severity as a mediator of the

TABLE 3 Statistics for hypothesized and alternative mediation models (N = 267)



	Coeff.	B _{SE}	LLCI	ULCI
Insomnia > Mood > MJ problems				
Constant	5.62	10.86	-15.76	27.00
Age	-0.12	0.55	-1.20	0.97
MJ frequency	0.27	0.10	0.08	0.46
Male sex	2.77	2.89	-2.92	8.46
Negative mood (<i>b</i> -path)	0.22	0.04	0.14	0.30
Negative mood by sex (M*W)	0.19	0.07	0.06	0.32
Insomnia severity by sex (X*W)	-0.53	0.31	-1.13	0.07
Insomnia direct effect (c'-path)				
Men	-0.11	0.24	-0.59	0.37
Women	0.42	0.19	0.06	0.79
Insomnia indirect (mediated) effect				
Men	0.74	0.25	0.30	1.29
Women	0.53	0.15	0.27	0.84
MJ problems > Mood > Insomnia				
Constant	2.12	4.56	-6.85	11.09
Age	0.12	0.23	-0.33	0.57
Marijuana frequency	0.02	0.04	-0.06	0.10
Male sex	0.98	1.06	-1.12	3.06
Negative mood (<i>b</i> -path)	0.10	0.02	0.07	0.13
Negative mood by sex (<i>M</i> *W)	-0.01	0.03	-0.07	0.05
MJ problems by sex (X^*W)	-0.10	0.05	-0.20	0.004
MJ problems direct effect (c'-path)				
Men	-0.01	0.04	-0.09	0.06
Women	0.08	0.03	0.01	0.15
MJ problems indirect (mediated) effect				
Men	0.08	0.03	0.03	0.14
Women	0.11	0.03	0.06	0.16
Mood > Insomnia > MJ problems				
Constant	5.62	10.86	-15.76	27.00
Age	-0.12	0.55	-1.20	0.97
Marijuana frequency	0.27	0.10	0.08	0.46
Male sex	2.77	2.89	-2.92	8.46
Insomnia severity (b-path)	0.42	0.19	0.06	0.79
Insomnia severity by sex (M*W)	-0.53	0.31	-1.13	0.07
Negative mood by sex (X*W)	0.19	0.07	0.06	0.32
Negative mood direct effect (c'-path)				
Men	0.40	0.05	0.30	0.51
Women	0.22	0.04	0.14	0.30
Negative mood indirect (mediated) effect				
Men	-0.01	0.03	-0.07	0.06
Women	0.05	0.02	0.01	0.09

Note: Bold font indicates significance (p < .05).

Abbreviations: LLCI, lower limit confidence interval; MJ, marijuana; ULCI, upper limit confidence interval.

association between negative mood and marijuana problems (see Table 3). Consistent with the other models, there was a positive association between negative mood and insomnia severity (*a*-path effect = 0.12, SE = 0.01, p < .001; 95% CI = 0.09, 0.15), and sex did not significantly moderate this association (X*W effect = -0.04, SE = 0.03, p = .15; 95% CI = -0.08, 0.01). There

was also a positive association between insomnia severity and marijuana problems (*b*-path effect = 0.42, *SE* = 0.19, *p* = .02; 95% CI = 0.05, 0.793), and sex did not significantly moderate this association (M^*W effect = -0.53, *SE* = 0.31, *p* = .08; 95% CI = -1.13, 0.07). The association between negative mood and marijuana problems was moderated by sex (X^*W effect = 0.19, *SE* = 0.07, *p* = .01; 95% CI = 0.06, 0.32). As noted for the hypothesized model, negative mood was associated more strongly with marijuana problems among men (effect = 0.40, *SE* = 0.05, *p* < .001; 95% CI = 0.30, 0.51) than women (effect = 0.22, *SE* = 0.04, *p* < .001; 95% CI = 0.14, 0.30). Insomnia severity helped explain the association between negative mood and marijuana problems among women (effect = 0.05, *SE* = 0.02; 95% CI = 0.01, 0.09) but not men (effect = -0.01, *SE* = 0.03; 95% CI = -0.07, 0.06).

4 | DISCUSSION

The purpose of this study was to determine whether negative mood mediated the relationship between insomnia severity and marijuanarelated problems among men and women using a cross-sectional dataset. Results indicated that higher levels of insomnia were associated with greater levels of negative mood (regardless of sex), which in turn were associated with greater marijuana-related problems, but more strongly so for men. These findings extend prior work by suggesting that negative mood may underlie the association between sleep difficulties and marijuana-related problems.

Consistent with our hypothesis, we found that mood partially mediated the relationship between insomnia symptoms and marijuana-related problems. Our results extend prior research by examining the relationship between sleep difficulties and both mood and marijuana-related outcomes among women and men, thus uncovering a potential pathway leading to the experience of marijuana-related problems. Specifically, our findings indicated that insomnia severity was more strongly associated with marijuana problems among women compared to men, whereas negative mood was more strongly associated with marijuana problems among men than women.

Notably, based on the small and marginally significant regression coefficients, our alternative model suggests that insomnia seems to play less of a role in explaining the association between negative mood and marijuana problems in this sample. Despite the cross-sectional nature of this study, this seems to indicate that insomnia symptoms may precipitate negative mood, as opposed to vice versa. Moreover, the lack of a direct association between insomnia symptoms and marijuana problems among men suggests that insomnia symptoms may be associated with marijuana problems because of their influence on negative mood.

There are several potential explanations for the mediating role of negative mood in the association between insomnia symptoms and marijuana problems. First, negative mood has been associated with marijuana-related coping motives, which have been linked directly to marijuana problems in college-aged adults (Bonn-Miller et al., 2014; Simons, Gaher, Correia, Hansen, & Christopher, 2005). Thus, it is possible that individuals with more severe insomnia were using marijuana to cope with the associated negative mood, and this coping motivation led to worse marijuana-related problems. Second, given research suggesting associations between negative mood, negative urgency (tendency to engage in rash action due to negative affect) and marijuana problems (Gunn, Jackson, Borsari, & Metrik, 2018), it is possible that negative mood as a result of more severe insomnia may have predisposed individuals to act more impulsively, leading to more consequences related to their marijuana use. Finally, neuroimaging findings have linked both insomnia and marijuana use with reductions in prefrontal activity (Babson & Bonn-Miller. 2014; Drummond, Smith, Orff, Chengazi, & Perlis, 2004), which has been shown to be associated with decreased top-down control of the amygdala, disrupted mood regulation and persistence of negative affect (for a review see Palagini, Bastien, Marazziti, Ellis, & Riemann, 2019). This dysregulated neural system has been associated with poor decision making and problem behaviours in individuals with insomnia (Palagini et al., 2019). Thus, it is possible that these alterations in associated brain regions play a key role in the manifestation of marijuana-related problems and may provide an additional explanation for our findings.

Alternatively, it may be that marijuana problems lead to insomnia, again in part due to their influence on negative mood. Prior studies have shown that marijuana can decrease sleep onset latency in young adults (Nicholson, Turner, Stone, & Robson, 2004). Because both models examined in this study (insomnia > marijuana problems and marijuana problems > insomnia) were significant, research is needed to determine which of these variables precedes the other or if there is a bidirectional effect. Regardless, data from this study indicate that negative mood seems to play a role in the relationship between insomnia and marijuana problems.

Collectively, our findings have several implications for the aetiology and treatment of problematic marijuana use. First, these results are clinically significant as the negative affect experienced as a result of insomnia may increase the likelihood of college students using marijuana as a coping mechanism. This, in turn, places them at increased risk of experiencing problems related to its use (Simons et al., 2005) and the development of marijuana-use disorder (Moitra, Christopher, Anderson, & Stein, 2015). Thus, individuals who use marijuana may benefit from intervention programmes that target negative mood as well as sleep. Additionally, results from the current study have implications for the proper use of medical marijuana for sleep difficulties and how the potential risks and benefits of its use are communicated to prospective patients. Although some reports suggest that marijuana has beneficial effects on sleep, the effect of marijuana on sleep depends on a number of variables (e.g., composition of the plant, timing and mode of administration), and tolerance of the sleep-enhancing effects of marijuana develops quickly (Babson et al., 2017). If tolerance develops, individuals may be tempted



to use more marijuana to get the sleep-enhancing effects, which may increase their risk of marijuana-related problems (Babson et al., 2017). Together, data from this study and others suggest that certain forms of marijuana use may be contraindicated for insomnia, based not only on their sleep effects but also on their potential effect on mood.

This study had several relevant limitations. First, although examination of alternate temporal ordering of predictor variables provides some potential insight into directionality of the relationship between our variables, true directionality cannot be determined because of the cross-sectional nature of the study. Thus, future prospective research is needed to evaluate these constructs across time. Second, the results may not be representative of young adults who are not in college. Third, the assessment measures used had varying time frames (e.g., marijuana problems in the past month, insomnia symptoms in the past 2-weeks), which may hinder interpretation of our proposed pathways. Finally, given that data collected on marijuana use, problems, mood and insomnia were assessed via self-report measures, it may be important for future work to assess objective measures of these constructs.

The present study suggests that marijuana problems may be in part related to insomnia-related negative mood. Given that sleep difficulties are a common symptom of marijuana withdrawal (Babson & Bonn-Miller, 2014; Budney et al., 2004) as well as a risk factor for poor response to marijuana interventions (Babson & Bonn-Miller, 2014), results highlight the importance of considering the potential consequences of marijuana use in college students with insomnia. Furthermore, results suggest that individuals with insomnia may be at greater risk of negative consequences associated with marijuana use and should be monitored for potential risk of marijuana-use disorder. This may be especially important when working with men. Prospective studies are needed to further explore specific temporal relationships between insomnia, negative mood and marijuana-related problems among men and women. Studies examining marijuana problems as a function of insomnia-related motives for use, impulsivity and neurocognitive dysfunction are encouraged.

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CONFLICT OF INTEREST

No conflicts of interest declared.

AUTHOR CONTRIBUTIONS

AY designed the original study and wrote the protocol. AY and RP implemented the research plan. AY conducted literature searches, wrote the introduction and prepared the manuscript for final submission. RP wrote the first draft of the methods and formatted the references. MBM conducted the statistical analysis, wrote the first draft of the data analysis plan, the results and the tables and figures. AC wrote the first draft of the discussion and provided edits on the full manuscript. CM provided oversight and final edits. All authors contributed to and have approved the final manuscript.

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