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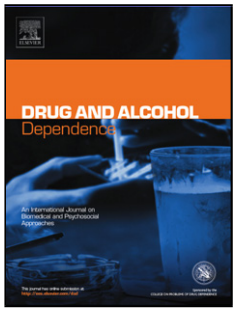

Is time elapsed between cannabis use and sleep start time associated with sleep continuity? An experience sampling method

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Is time elapsed between cannabis use and sleep start time associated with sleep continuity? An experience sampling method

Running Head: sleep and cannabis use

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Highlights:

- Shorter time elapsed between cannabis use and sleep associated with shorter SOL
- No association found between cannabis use and number of awakenings
- More evidence for cannabis effects on sleep is needed

Abstract

Background: A substantial proportion of people using cannabis report using it to improve sleep. Yet, little research exists on the associations between the timing of cannabis use and sleep. This study examines the time elapsed between cannabis use and sleep start time and its association with two of the main indicators of sleep continuity: (1) sleep onset latency (SOL) and (2) number of awakenings (NOA) throughout the night.

Methods: Each morning, for 7 consecutive days, daily cannabis users (n = 54) reported on the timing of previous night's cannabis use and sleep indicators on their smartphones. Mixed effects models examined the relations of within- and between-subjects' time elapsed between previous night cannabis use and sleep start time, with (1) SOL and (2) NOA.

Results: Within subjects, shorter time elapsed between cannabis use and sleep start time was associated with shorter SOL ($\beta = 0.519$, $p = 0.010$), but not NOA ($\beta = -0.030$, $p = 0.535$). Furthermore, between individuals, the time gap between the previous night cannabis use and sleep start time was not associated with SOL or NOA ($p > 0.05$).

Conclusions: It is possible that cannabis use proximal to bedtime is associated with shorted sleep onset latency but not continuous sleep. Cannabis users should be informed about both the potential sleep aid effects of cannabis and its limitations. Pending further evidence of the effects of cannabis on sleep, cannabis users experiencing sleep problems should be provided with evidence-based alternatives to improve sleep, e.g., pharmacological and behavioral treatments.

Keywords: cannabis; sleep; insomnia; sleep onset latency; nightly awakenings; experience sampling method

1.1 Introduction

Poor sleep is a common complaint in adults. In a large U.S. survey, sleep disturbances, defined as difficulty falling asleep / maintaining sleep or sleeping too much, were reported by about 15% of men and 20% of women, with highest rates in the younger age groups (Grandner, Martin, Patel, Jackson, Gehrman, Pien, Perlis, Xie, Sha, Weaver and Gooneratne, 2012). Insomnia is a prevalent public health concern affecting about 10% of the population (Ohayon, 2002), characterized by sleep discontinuity including difficulty falling and/ or staying asleep, and lasting at least 3 days per week for over 3-months (DSM-5). Despite the efficacy and safety of short term use of common prescription drugs to aid sleep (benzodiazepines and benzodiazepine receptor agonists), they are not recommended for long term use due to the development of tolerance and an increased risk of dependency (Riemann, Nissen, Palagini, Otte, Perlis and Spiegelhalder, 2015). Cognitive behavioral therapy for insomnia (CBT-I) is considered first line treatment (Riemann, Baglioni, Bassetti, Bjorvatn, Dolenc Groselj, Ellis, Espie, Garcia-Borreguero, Gjerstad, Goncalves, Hertenstein, Jansson-Frojmark, Jennum, Leger, Nissen, Parrino, Paunio, Pevernagie, Verbraecken, Weess, Wichniak, Zavalko, Arnardottir, Deleanu, Strazisar, Zoetmulder and Spiegelhalder, 2017), yet its dissemination and availability remain limited, and remission rates are only 40% (Morin, Vallieres, Guay, Ivers, Savard, Merette, Bastien and Baillargeon, 2009).

A growing body of research shows that cannabis users, both recreational and medical, report use of cannabis to improve sleep (Bonn-Miller, Babson and Vandrey, 2014; Walsh,

Callaway, Belle-Isle, Capler, Kay, Lucas and Holtzman, 2013) suggesting that cannabis plays a role in the regulation of sleep, including its initiation and maintenance. Yet, few studies have been conducted in this area. A systematic review of studies examining the effects of cannabis on sleep in humans included 39 studies (Gates, Albertella and Copeland, 2014). Findings from both objective and subjective measures of sleep latency in recreational cannabis users were inconsistent (see Karacan, Fernandez-Salas, Coggins, Carter, Williams, Thornby, Salis, Okawa and Villaume, 1976; Nicholson, Turner, Stone and Robson, 2004), whereas none found effects on nighttime awakenings (e.g. Chait, 1990).

A total of 28 studies reviewed were related to medicinal use of cannabis, most of them in the realm of pain and most examined the effect of the administration of synthetic analogues of THC and/or CBD. Of these, 20 studies showed an improvement to sleep (e.g. Bedi, Foltin, Gunderson, Rabkin, Hart, Comer, Vosburg and Haney, 2010; Berman, Symonds and Birch, 2004; Bestard and Toth, 2011) yet in two studies improvement was no longer significant at the end of the study (Bedi, Foltin, Gunderson, Rabkin, Hart, Comer, Vosburg and Haney, 2010; Brady, DasGupta, Dalton, Wiseman, Berkley and Fowler, 2004). Finally, six studies did not find a significant association between medicinal cannabis use and sleep (e.g. Collin, Ehler, Waberzinek, Alsindi, Davies, Powell, Notcutt, O'Leary, Ratcliffe, Novakova, Zapletalova, Pikova and Ambler, 2010; Frank, Serpell, Hughes, Matthews and Kapur, 2008). Most of the studies with medicinal users did not use validated sleep questionnaires and did not measure different aspects of sleep problems. Of the studies that did, two studies reported on sleep latency with one finding an improvement on high cannabis dose only (Ware, Wang, Shapiro, Robinson, Ducruet, Huynh, Gamsa, Bennett and Collet, 2010), while the other showed no effect (Ware, Fitzcharles, Joseph and Shir, 2010). Two studies reported on night

time awakenings and neither showed an effect (Åkerstedt, Schwarz, Gruber, Lindberg and Theorell-Haglöw, 2016; Ware, Wang, Shapiro, Robinson, Ducruet, Huynh, Gamsa, Bennett and Collet, 2010).

An updated literature review was published in 2017 with similarly mixed results (Babson, Sottile and Morabito, 2017) leading to the overall conclusion that at present the results of human studies are mixed in terms of the effects of cannabis on sleep. Furthermore, and as pointed out by the authors of the literature review (Gates, Albertella and Copeland, 2014), conclusions drawn from the literature are only tentative due the fact that the studies in this area include a number of methodological issues. Furthermore, most of the studies in this area are based on clinical samples who use cannabis to treat medical symptoms and conditions, most in the context of the pain relief.

It is possible that the effect of cannabis on sleep is fully or partly mediated by the effects that cannabis has on pain or other medical symptoms in these clinical samples. It also needs to be mentioned that long-term effects are rarely studied in RCTs. This is particularly problematic in light of studies that have shown that chronic administration of THC is related to tolerance to the potential sleep promoting effects of cannabis (Menefee, Anderson, Doghramji, Cohen, Frank and Lee, 2001; Vaughn, Denning, Stuhr, de Wit, Hill and Hillard, 2010).

Further limitations of the extant literature is that most of the RCTs that have examined the effects of cannabis on sleep have examined the exposure to orally administrated synthetic cannabinoids (Babson, Sottile and Morabito, 2017; Gates, Albertella and Copeland, 2014). While this is informative as an initial step, most cannabis users (medical and recreational users) administer cannabis by smoking the whole plant which includes inhaling more than

500 compounds (Elsohly and Slade, 2005) of which at least 144 are classified as phytocannabinoids (Hanus, Meyer, Munoz, Taglialatela-Scafati and Appendino, 2016). Different phytocannabinoids exhibit diverse pharmacological and biological activities and they act on multiple targets (Russo, 2011). Therefore phytocannabinoids and combinations of cannabinoids can excerpt differential effects on sleep beyond THC and CBD. This process, called the *entourage effect* (De Petrocellis, Ligresti, Moriello, Allara, Bisogno, Petrosino, Stott and Di Marzo, 2011) is a process of synergy in which, for instance, the activity of one minor component diminish adverse effects of cannabinoid administrations. Research supporting CBD as a synergist to THC has been summarized (Russo and Guy, 2006). Specifically, research shows that CBD reduces potential anxiety and psychotic producing effects of THC. It is possible that other cannabis components offer additional synergetic effects (Russo, 2011) but we are not aware of any research that have attempted to examine differential cannabinoid components and synergy effects on sleep beyond THC/CBD. Nevertheless, the potential for an entourage effect of whole plant cannabinoids suggest that findings from extant RCTs that examine synthetic THC/CBD extracted medicines are not good indications of the association between cannabis use and sleep in the daily lives of typical cannabis users exposed to herbal cannabis.

A final critical limitation of the extant literature is that cannabis use and sleep are commonly assessed retrospectively as global outcomes based on only one aggregate assessment (e.g. how would you rate the quality of your sleep during the last month, how many times per week do you typically use cannabis before going to bed). This is problematic because research has shown that self-reported retrospective measures of cannabis use are unreliable (van der Pol, Liebregts, de Graaf, Korf, van den Brink and van Laar, 2013) and

individual's sleep tend to vary from night-to-night (Molzof, Emert, Tutek, Mulla, Lichstein, Taylor and Riedel, 2018). Moreover, this kind of aggregation means that we can only examine the associations between variables at the between-person and not at the within-person level. This is critical, because between-person associations can often differ substantially from within-person associations (Hamaker, 2012) and they can even be in the opposite direction, a phenomenon known as Simpson's Paradox (Kievit, Frankenhuis, Waldorp and Borsboom, 2013; Simpson, 1951). As an illustrative example, due to cannabis dependence or craving, heavy cannabis users may report more sleep difficulties than occasional cannabis users, but on days when heavy users consume cannabis right before going to bed their sleep may be better than when more time elapses between cannabis use and sleep time.

In order to test within-person hypotheses, and distinguish within- and between-person associations, we need to collect multiple assessments from individuals. Experience sampling method (ESM) is a data capture technique that involves repeated sampling across multiple days of momentary experiences (e.g. sleep, cannabis use), as close in time to the experience as possible in the naturalistic environment (Shiffman, Stone and Hufford, 2008). The method reduces many of the methodological problems that arise with aggregate retrospective measures (e.g. recall bias, generalization of sleep quality experiences) (Konjarski, Murray, Lee and Jackson, 2018; Trull and Ebner-Priemer, 2013). While reporting on events in near-real time may still reflect some degree of inaccuracy, naturalistic assessment enables more ecologically valid observations of sleep parameters and cannabis use in real world contexts compared with laboratory studies (Carney, Buysse, Ancoli-Israel, Edinger, Krystal, Lichstein and Morin, 2012; Tournier, Sorbara, Gindre, Swendsen and Verdoux, 2003). The primary

advantage, however, is that intensive within-person assessments gathered in ESM have the potential to shed light on the within-person associations between sleep and cannabis use (Shiffman, 2009).

1.1.1 The current study

This study examines associations between cannabis use and sleep continuity. More specifically, we examine *within-person variation in time elapsed between cannabis use and sleep start time* and its association with two main indicators of sleep continuity (APA, 2013): (1) difficulty falling asleep and (2) difficulty maintaining sleep throughout the night. We hypothesized that there would be a sleep promoting association between cannabis use and sleep measures in that when a person smokes cannabis closer in time to sleep start time (compared to when s/he reports longer time between cannabis use and sleep start time) s/he will report (1) less time for falling asleep and (2) fewer night awakenings.

1.2 Materials and Methods

1.2.1 Sample and Procedures

The institutional review board (IRB) of the Faculty of Social Welfare & Health Sciences, University of Haifa approved the study protocol. A sample of 802 frequent cannabis users (used cannabis at least 4 times per week) were recruited from a popular Hebrew language internet website dedicated to cannabis use (Israeli cannabis magazine; http://www.קנאביס.com). The website moderator posted messages about the study and links to the online baseline survey on the website and associated Twitter and Facebook accounts. Interested participants clicked on a link that asked for participant consent before they could complete the baseline online survey that assessed demographic background and inclusion criteria (being at least 18 years of age, typically use cannabis at least 3 times

per week, report mainly administrating cannabis through smoking, and in possession of a smartphone with an internet connection). Next, respondents were asked if they wanted to participate in the ESM part of the study which involved answering 3 surveys per day (09:00 AM, 03:00 PM, 09:00 PM) for 7 consecutive days (Monday through Sunday) on their smartphones. Respondents could answer the survey prompts within a 2.5 hour window after they were sent. Despite being relatively short, a 7-day study period, was chosen in order to avoid over-burdening participants. To encourage participation, respondents had the opportunity to enter a lottery of 12 vouchers of 500 NIS that could be used in a variety of stores across Israel.

Questions about last night sleep and last night cannabis use was only asked in the first prompt of the day and thus only the morning daily reports were used for the current analyses. Of all the participants who filled in the baseline survey (n=802), 138 eligible participants agreed to participate in the ESM. Of these, we excluded 84 individuals who answered less than 30% of all reports as research has shown that data from individuals with less than 30% completed reports might be unreliable (Delespaul, 1995).

Included participants (n = 54) completed a mean of 3.5 daily morning assessments (S.D. = 1.87). There were no significant differences in terms of education, sex or daily cannabis use rates between included and excluded individuals. However, included respondents were significantly older than excluded respondents (mean 29.30 vs. 25.54, p. = 0.002). The statistical models adjust for age. Non-response was more prevalent in the latter part of the study, akin to response fatigue, but we did not detect any systematic non-response patterns regarding the time of day of the assessments.

1.2.2 Measures:

Dependent variables: the following sleep measures were recorded each morning: number of minutes it took to fall asleep (sleep onset latency, SOL) and number of times the respondents woke up (number of awakenings, NOA) during the previous night. Both dependent variables were transformed (square root) after a ladder of powers tests indicated that this transformation allowed the variables to approximate the normal distribution more closely and also minimizing the possibility of encountering Type II errors.

Independent variables: Each morning respondents were asked if they smoked cannabis during the previous evening/night. Respondents answered in the affirmative 95% of the time. Respondents were then asked to report the time (hh:mm) of last cannabis use during the previous evening/night and the time (hh:mm) they fell asleep. The differences between these two time points were then calculated as a measure of time from cannabis use to sleep start time. A between-subjects version of this variable was created by person-mean centering the variable (*between cannabis to sleep start time*) and a within-subjects version of the variable was creating by subtracting the person mean variable from the raw scores (*within cannabis to sleep start time*). The between-subject variable focus on the covariation in mean levels of time elapsed from cannabis use to sleep start time in the sample. In other words, the *between-subject measure of cannabis to sleep start time* tests whether individuals who on average report a relatively short time period between evening cannabis use and sleep start time fall asleep quicker and wake up less during the night compared to individuals who on average report a relatively long time period between cannabis use and sleep start. The within-subjects variable examines covariation between cannabis use and sleep start time within the subjects. Specifically,

this variable measures whether individuals report falling asleep more quickly (short sleep onset latency) and fewer nightly awakenings on nights when cannabis use occurs relatively close to sleep start time compared to when the same person reports longer time between cannabis use and sleep start time.

Covariates: age and sex (0 = male, 1 = female) were measured at baseline. Since work/study obligations may influence both sleep and cannabis use patterns we controlled for whether participants were in fulltime work, study (part time/fulltime) or unemployed. We also controlled for number of alcoholic drinks consumed during the previous evening/night as alcohol may have an influence on both sleep and cannabis use. Sleep and cannabis use may be related to a persons' average bedtime as well as a person's deviation from his or her average bedtime. Therefore, based on respondents' report of nightly sleep start time we created the following variables: a between-subjects version by person-mean centering the variable (*between sleep start time*) and a within-subjects version of the variable was created by subtracting the person's mean variable from the raw scores (*within sleep start time*).

Models also included a linear time variable ranging from 1-7 for each day of the survey and an indicator of whether cannabis and sleep measures were collected on a weekend or weekdays. Continuous variables were grand mean centered.

1.2.3 Statistical analyses

Means, standard deviations and proportions were used to describe the sample. Mixed effects models estimated the associations between the independent variables (between- and within-subjects time lapse between cannabis use and sleep start times, between- and within-subjects sleep start time, sex, age, occupation, time, alcohol use,

weekday/weekend) on each of the dependent variables using the xtmixed commands in Stata (StataCorp, 2011). Mixed effects models take the interdependence that occurs with multiple repeated measures within the same individual into account. We estimated random intercepts and slopes models using a first-order autoregressive covariance structure to account for autocorrelation in the repeated measures.

1.3 Results

1.3.1 Sample descriptive:

Respondents were 29 years on average (S.D. 7.99) and 31.5% were female. Over 60% reported working full time, 24% reported studying and 15% were unemployed. On average, during the 7 day study period respondents reported 1.48 (S.D. = 1.89) hours between cannabis use and sleep start time. Additionally, and on average per night, respondents reported that it took them approximately half an hour (27.88 min, S.D. = 38.09) to fall asleep and they reported 1.55 (S.D. = 1.23) nightly awakenings during the study period.

[Table 1]

1.3.2 Sleep onset latency (SOL)

In the first mixed effects model, SOL (minutes) was entered as the outcome variable. Within-subject measure of time elapsed between cannabis use and sleep start time was significant (see Table 2, model 1). This indicates that when an individual reported longer time elapse between cannabis use and sleep start time, s/he also reported longer SOL compared to when the same individual reported less time elapse between cannabis use and sleep start time. None of the other variables in the model were significantly associated with SOL.

1.3.3 Number of awakenings (NOA)

In the second model the number of times respondents reported waking up last night was entered as the outcome variable. Model 2 in Table 2 shows that females were more likely to report nightly awakenings. None of the other predictors were related to nightly awakenings including the variables measuring time between cannabis use and sleep start time.

[Table 2]

1.4 Discussion

The current study of daily cannabis users shows that shorter time between cannabis use and sleep start time is associated with shorter sleep onset latency but not less nightly awakenings. SOL is an important indicator of insomnia and is common in young adults. In a large study of Norwegian university students ages 18-35, mean SOL on weekdays and weekends was 48 and 35 minutes, respectively, with 66% of the sample reporting a SOL >30-minutes (Sivertsen, Vedaa, Harvey, Glozier, Pallesen, Aaro, Lonning and Hysing, 2019). Typically, a SOL that exceeds 30 minutes is considered a sleep problem that warrants treatment (Perlis, Smith, Orff, Enright, Nowakowski, Jungquist and Plotkin, 2004). In the present study, the average SOL was about 30 minutes, indicating that some participants exceeded the 30-minutes cutoff. Previous studies in recreational and medical cannabis users have reported mixed results regarding SOL (Gates, Albertella and Copeland, 2014).

In the current sample no between-subjects association was found between cannabis use and sleep start time and SOL. This suggests that the observed within-subjects association between cannabis and sleep is not related to broader between-subjects differences associated with both sleep and cannabis use such as cannabis use disorders or sociodemographic factors not measured yet more research with larger samples are needed to confirm this.

This study did not find any association between time elapsed between cannabis use and sleep start time and nightly awakenings. Also the studies reviewed in Gates et al., (2014) did not report on significant effects of cannabis use and nightly awakenings This may be because nightly awakenings occur later in the night when potential sleep promoting effects of cannabis have worn off. We are not aware of research examining the duration of acute effects of cannabis on sleep. To the extent that research from other areas examining acute effects of cannabis is any indication, research suggest that that we can expect the strongest effects of cannabis of sleep to be in the first hour post use, yet effects can last as long as 8 hours. Indeed, research examining acute effects of cannabis on performance impairment has mainly been based on occasional users and has found that impairment is maximal during the first hour after smoking cannabis and sharply declines over 2-4 hours after cannabis use (Curran, Brignell, Fletcher, Middleton and Henry, 2002; Ramaekers, Kauert, van Ruitenbeek, Theunissen, Schneider and Moeller, 2006). Yet, research has also found that infrequent cannabis users report feeling stoned up to 8 hours after THC administration (Curran, Brignell, Fletcher, Middleton and Henry, 2002). Some (Ramaekers, Kauert, Theunissen, Toennes and Moeller, 2009), but not all studies (Ramaekers, van Wel, Spronk, Toennes, Kuypers, Theunissen and Verkes, 2016) have found that heavy users build tolerance to the acute behavioral impairment effects of cannabis.

It is not clear how long acute effects of cannabis exerts its effects on sleep, in occasional or heavy users. Much more detailed and controlled experimental studies are needed in this area. It is also important to mention that in addition to interpreting the results as indications that cannabis has little or no association with nightly awakenings,

the lack of association found between cannabis use and NOA may be due to a floor effect, i.e., the low number of nightly awakenings in this sample (<2) left little or no room for changes related to cannabis use. Indeed, nighttime awakenings and difficulty staying asleep are more characteristic of sleep problems in older adults (Åkerstedt, Schwarz, Gruber, Lindberg and Theorell-Haglöw, 2016) while the current sample is relatively young. Future research with older samples are needed to better understand whether cannabis is association with NOA. Indeed, inclusion of older individuals in research on sleep and its association with sleep is particularly needed because sleep problems are common in older populations (Klink, Quan, Kaltenborn and Lebowitz, 1992) and medical and recreational cannabis use is increasing in older population (Boehnke, Gangopadhyay, Clauw and Haffajee, 2019; Han, Sherman, Mauro, Martins, Rotenberg and Palamar, 2017; Hasin, Saha, Kerridge, Goldstein, Chou, Zhang, Jung, Pickering, Ruan, Smith, Huang and Grant, 2015; Hazekamp, Ware, Muller-Vahl, Abrams and Grotenhermen, 2013; Kerr, Lui and Ye, 2018).

1.4.1 Strengths and Limitations

This study has clear strengths. While, ESM does not enable the type of causal inference that RCTs would, it enables investigation of stimulus-response type relations in the natural environment of respondents (Bolger and Laurenceau, 2013). This study constitutes a considerable advance from extant RCTs related to cannabis and sleep as this study enabled an investigation of within-person associations between cannabis use and sleep while controlling for between-person associations. The study also includes exposure to naturalistic cannabis use patterns among a sample of recreational cannabis users, including use of the whole plant, as opposed to exposure to cannabis products and patterns dictated by research protocols. As

such, the study has higher ecological validity and increased accuracy compared with extant and the growing body of RCTs examining the effects of cannabis on sleep.

Despite these advantages, the study has limitations that need to be mentioned and considered. Firstly, while we did collect data on alcohol intake, and because of the need to keep daily reports as brief as possible to not overload participants, we did not collect data on other legal and illegal stimulant use (e.g. caffeine, tea, amphetamines) and sleep aid use. We also lack data on motivations for cannabis use, and mental health indicators which may be confounding as well as explanatory or mediating factors for the associations found between cannabis use and sleep onset latency. Concretely, it is possible that respondents use cannabis to reduce negative affect (and/or to improve sleep) and that this mood altering effect explains the associations between cannabis use and sleep onset latency. Understanding the mechanisms underlying the relation between cannabis and sleep onset latency is imperative and future research with more detailed data on potential mediator and further explanatory variables is urgently needed. Furthermore, cannabinoid concentration, dose, and route of administration may have differential effects on sleep quality and insomnia symptoms. This study was unable to control for these factors. Additionally, the sample is relatively small. The power is enhanced for our main variable of interest measuring within-person variations due to multiple measurements per individual. Nevertheless, the power is much lower for variables measuring between-person variation which may account for the insignificant results for variables at this level.

It also needs to be mentioned that in order to reduce participant burden, a relatively short time period was studied (7 days). Future, controlled prospective studies are needed

to better characterize the impact that specific components of cannabis use have on sleep (e.g. different modes of administration and cannabinoid concentrations) and include a longer study period.

Previous research has suggested that tolerance to potential sleep-promoting effects of cannabis occurs after long term and heavy use of cannabis. The current study is based on a sample of daily users in which one would expect such tolerance to have occurred, yet we still detected an association between cannabis use and sleep onset latency. As such, our results suggest that at least complete tolerance has not occurred among these participants. In order to study potential tolerance effects in the future there is a need to collect data from cannabis users with different cannabis use patterns and history (e.g. light users vs heavy users, recent onset use vs. long term use) or collect data over a much longer time-trajectory (e.g. from onset to frequent use). This would greatly help in reaching a better understanding of the potential development of tolerance towards the sleep aid effects of cannabis.

1.5 Conclusions

With caution, our results suggests that a shorter time between cannabis use and sleep start time is associated with a shorted sleep onset latency but not continuous sleep throughout the night in young adults. In the current climate of growing support for medical cannabis policies and a booming medical cannabis and recreational cannabis industry the public is increasingly exposed to information about the therapeutic effects of cannabis, including sleep aid effects (Lewis and Sznitman, 2019). Research has found that the cannabis industry are making various claims of therapeutic and beneficial health effects of cannabis that remain

unsupportive by research evidence (Bierut, Krauss, Sowles and Cavazos-Rehg, 2017). Within this context it may be particularly important to inform cannabis users about both the potential sleep aid effects of cannabis and its limitations. Based on the current study, cannabis should be informed that while it is possible that cannabis induces sleep it may not help maintain sleep. Pending further evidence of the effects of cannabis on sleep, cannabis users with sleep problems should be provided with evidence-based alternatives to improve sleep, e.g., pharmacological and behavioral treatments.

Clinical trial registration details: not applicable

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Conflict of Interest: No conflict declared

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Table 1: Participant characteristics and daily attributes

Participant characteristics	**N=54**
Age in years, (Mean, S.D.)	29.30 (7.99)
Female, N (%)	17 (31.5)
Work fulltime, N (%)	33 (61.1)
Study (full time or part time), N (%)	13 (24.1)
Unemployed, N (%)	8 (14.8)
Daily Attributes	
Cannabis use to sleep start time, mean hours (S.D.)	1.48 (1.89)
Sleep onset latency, mean minutes (S.D.)	27.88 (38.09)
Number of awakenings, mean (S.D.)	1.55 (1.23)

Table 2. Results from mixed effects models predicting sleep onset latency (model 1) and number of awakenings (model 2)

	Model 1: Sleep onset latency					Model 2: number of awakenings				
	Estimate	**SE**	**z**	**p**	**95% CI**	**Estimate**	**SE**	**z**	**p**	**95% CI**
Fixed effects										
Age	0.031	0.047	0.660	0.508	-0.006, 0.124	0.019	0.013	1.500	0.134	-0.006, 0.045
Female	0.205	0.811	0.250	0.801	-1.385, 1.759	**0.446**	**0.221**	**2.020**	**0.043**	**0.014, 0.879**
Work fulltime (referent)										
Study (fulltime or part time)	-1.324	0.882	-1.500	0.133	-3.053, 0.405	-0.256	0.242	-1.060	0.290	-0.729, 0.218
Unemployed	1.230	0.999	1.230	0.218	-0.727, 3.187	-0.076	0.272	-0.280	0.780	-0.609, 0.457
Number of alcoholic drinks last night	-0.038	0.149	-0.250	0.799	-0.329, 0.253	0.015	0.044	0.350	0.727	-0.071, 0.101
Survey day	0.040	0.046	0.880	0.380	-0.050, 0.130	-0.005	0.014	-0.350	0.725	-0.033, 0.023
Weekend	-0.883	0.487	-1.810	0.070	-1.837, 0.071	-0.026	0.147	-0.180	0.860	-0.314, 0.262

Between sleep start time	-0.019	0.015	-1.290	0.198	-0.048, 0.010	-0.008	0.004	-1.970	0.049	-0.016, 0.000
Within sleep start time	0.001	0.005	0.150	0.881	-0.010, 0.011	-0.001	0.002	-0.840	0.401	-0.004, 0.002
Between cannabis to sleep start time	0.513	0.349	1.470	0.142	-0.171, 1.197	0.097	0.095	1.010	0.310	-0.090, 0.284
Within cannabis to sleep start time	**0.519**	**0.202**	**2.570**	**0.010**	**0.123, 0.915**	-0.030	0.049	-0.620	0.535	-0.126, 0.066
Intercept	**4.502**	**0.958**	**4.700**	**0.000**	**2.624, 6.380**	**0.841**	**0.262**	**3.210**	**0.001**	**0.327, 1.354**
Note: CI = Confidence Interval, SE = Standard Error										