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Daily diary study of associations between alcohol, cannabis, co-use and sleep quality in individuals with intentions to use cannabis to cope with anxiety

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Abstract

Introduction: Sleep problems and anxiety conditions are common comorbidities and may be influenced by cannabis and alcohol use. This study examined daily within-person variation in subjective sleep quality among individuals with anxiety symptoms after cannabis or alcohol were used alone, and after co-use.

Methods: A total of 347 individuals with intentions to use cannabis to cope with anxiety reported their cannabis and alcohol use in the previous 24 h and their previous nights' sleep quality for 30 consecutive days. Mixed-effects models examined whether the within-person daily variation in use of cannabis and alcohol (alone and co-use) was associated with subjective sleep quality. Models also examined whether daily cannabis and alcohol use associations with sleep were moderated by frequency of cannabis, alcohol and co-use during the study period.

Results: Compared to non-use, participants reported better sleep after cannabis-use-only and after co-use, but not after alcohol-use-only. People who more frequently use alcohol and cannabis reported sleeping better after cannabis-use-only days compared to those who use cannabis and alcohol less frequently.

Discussion and Conclusions: The study's utilisation of naturalistic data among individuals with anxiety symptoms replicated previously reported experimental findings among individuals without sleep and anxiety problems that overall, cannabis is associated with higher subjective sleep quality. The results expand upon other research to suggest that more frequent use of alcohol and cannabis may moderate daily associations of cannabis use and sleep, potentially through pharmacokinetics and cross-sensitisation.

KEYWORDS
alcohol, anxiety, cannabis, co-use, sleep

1 | INTRODUCTION

Alcohol and cannabis are psychoactive substance that are widely used [1] and co-used (e.g., use of both substances within the last 24 h, but not necessarily simultaneously) [2, 3]. Both substances are commonly used for sleep assistance [4–6] and this is particularity notable among individuals with anxiety disorders who often suffer from

sleep disturbances [7]. Sleep disturbances and co-use of alcohol and cannabis link to mental health issues, including anxiety [8], making it an important area of research given the high prevalence of anxiety disorders in the general population [9].

Alcohol, when used without cannabis, can aid falling asleep and reduce early sleep awakenings, but it tends to worsen sleep disturbances later in the night [10]. Cannabis may temporarily enhance sleep quality [11] but long-term and frequent use of both substances can lead to diminished sleep-inducing effects [12]. Withdrawal-related sleep issues have also been observed [13]. Only one experimental study has tested the effects of simultaneous use of cannabis and alcohol on sleep in humans, with simultaneous use of alcohol and cannabis showing worse sleep outcomes compared to separate use [14].

Regarding the prolonged combined impact of alcohol and cannabis, research has proposed that persistent or lingering effects of cannabis could result in cross-tolerance to certain impairing alcohol effects (sleep outcomes not examined, [15, 16]). Conversely, a recent study discovered that cannabis users experienced decreased negative feelings following alcohol consumption compared to non-cannabis users [17], indicating possible cross-sensitisation.

With limited human research on the interplay of cannabis-alcohol co-use and its sleep effects, insights can be gained from animal studies. One study showed that administering Tetrahydrocannabinol (THC) and ethanol to rodents increased sleep duration compared to ethanol alone [18]. Animal investigations have also suggested mutual cross-tolerance between alcohol and cannabis effects [19–22].

Experimental sleep research in this realm is constrained as the conditions tested deviate from typical alcohol-cannabis use and regular sleep settings. This underscores the need for investigations in natural settings. Daily diary studies capture real-world fluctuations in alcohol-cannabis use and sleep, offering ecologically valid insights. However, findings from daily diary studies on alcohol and cannabis's sleep impact have been mixed. Participants in some daily diary studies report poorer sleep quality after drinking alcohol [23–25] or no effect of alcohol on sleep disturbance [26]. Conversely, daily diary studies suggest that cannabis use is associated with improved sleep quality [27], fewer nightmares [28], decreased sleep latency [29], longer sleep duration and fewer awakenings [5]. A recent diary study focusing on cannabis for anxiety demonstrated better sleep quality post-use, particularly in individuals with greater emotional challenges [30]. A sole study with objective data, a 5-day actigraphy study, revealed heightened cannabis intake linked to quicker sleep onset but reduced sleep efficiency [31].

Two diary studies have explored the link between combined alcohol and cannabis use and sleep. Both suggest that any potential sleep improvements from cannabis use are counteracted by alcohol's negative effects [32, 33]. Due to the scant research in this area, it is crucial to verify and apply findings to diverse populations. This is particularly vital for high-risk groups with sleep issues or substantial alcohol-cannabis usage.

1.1 | Current study

This study aimed to examine how cannabis and alcohol (used alone or together) relate to self-reported sleep quality in individuals using cannabis for anxiety relief, using a 30-day daily diary approach. A prior study with the same participants revealed better sleep after cannabis use, especially in those with higher initial emotional symptoms [31]. This study expands on these findings, focusing on comparing alcohol's effects to cannabis and exploring co-use effects on sleep, while considering baseline anxiety levels. Additionally, we investigate whether daily cannabis and alcohol use associations with sleep are moderated by frequency of cannabis, alcohol and co-use. Despite widespread expectations of sleep enhancement from cannabis and alcohol, limited knowledge persists, emphasising the need for further investigation.

We predicted that, compared to non-use days, sleep quality would be worse after alcohol-only days and better after cannabis-only days. We also expected this positive cannabis-sleep association to weaken when combined with alcohol. We explored if the associations between daily cannabis/alcohol use and sleep quality were moderated by use frequency. As no prior research examined these variables on daily sleep variation, we did not have predefined hypotheses for moderation. However, more frequent use was considered a proxy measure of tolerance, cross-tolerance and cross-sensitisation. More specifically, evidence of a negative interaction term where daily use of a substance is associated with poorer sleep in those who use more frequently compared to less frequently would be interpreted as the presence of tolerance to the sleep effects. A significant negative interaction terms between daily use of one substance (i.e., cannabis) and frequency of use of another substance (i.e., alcohol) would indicate cross-tolerance to sleep effects. In contrast, a positive interaction term between daily use of one substance (i.e., cannabis) and frequency of use of another substance (i.e., alcohol) indicates that people who use alcohol more frequently may develop cross-sensitisation to sleep effects of cannabis. These proxy measures are untested and we thus see the moderation analyses as

exploratory, uncovering potential future research directions in this realm.

2 | METHODS

2.1 | Sample

Data originated from an ongoing longitudinal study exploring the interplay of cannabis use, stress and inflammation [31]. A first report of the findings from this study has been published elsewhere [31]. The sample comprised 347 individuals with at least mild anxiety according to the Generalised Anxiety Scale [34]. Participants were recruited from Boulder, Colorado via social media, flyers and mailings. Eligibility was determined by trained research assistants using phone conversations or confidential online surveys. All participants, in this Institutional Review Board-sanctioned study [31], met these criteria: (i) age: 21–70 years; (ii) anxiety: Generalised Anxiety Scale-7 score ≥5; (iii) cannabis use: past use and intent to employ cannabis for anxiety relief; (iv) no psychotropic drugs (e.g., attention-deficit/hyperactivity disorder medications), no anti-viral medication, nor other drug use for 72 h, confirmed via negative urine toxicology and blood alcohol content; and (v) treatment: no ongoing or recent substance use, psychotic, bipolar or major depressive disorders, or history of such conditions (Figure 1).

2.2 | Procedure

After screening, eligible participants attended an in-person laboratory session for baseline and practice daily diary assessments. Participants self-selected the form of cannabis (64.8% chose flower, 35.2% selected edibles) that they would use during the study and were randomly allocated to THC-dominant, CBD-dominant or balanced THC/CBD ratio groups. The assigned product was acquired at a local dispensary (https://thefarmco.com/). While we control for the experimental part in the models, it is not the main focus since: (i) participants also used non-study, non-verified cannabis; and (ii) the current analyses mainly explored co-use, sleep and frequency moderation, while cannabinoid ratios are the prime focus of other ongoing analyses, beyond the current scope. After baseline, participants completed daily diary assessments using scheduled REDCap [35] emails, one every 24 h for 30 days, each taking 2–3 min. Surveys were sent in the morning and could be answered during a 24-h window, accommodating diverse daily routines influenced by work, weekends and holidays. This flexibility averted survey fatigue and sustained engagement across the study. Materials and analysis code for this study are available upon request. This study was not preregistered.

2.3 | Measures

2.3.1 | Baseline assessment

Demographic factors. Sex, age, race and ethnicity, education and employment status were controlled for as these variables may influence sleep [36–39] and cannabis and alcohol use patterns [40].

Affective symptoms. The anxiety subscale of the Depression Anxiety Stress Scales, 21 item [41] was used.

Sleep. The Pittsburgh Sleep Quality Index [42], a 19-item self-rated questionnaire, was used to assess sleep quality and disturbance over the previous month.

2.3.2 | Daily diary assessments

Daily sleep quality (dependent variable). This was measured using a daily question where participants rated last night's sleep quality relative to their usual pattern (0 = worst sleep, 10 = best sleep). Preliminary analysis confirmed the sleep quality variable's normal distribution. A single-item measure was preferred over multiple sleep assessments to maintain a concise daily questionnaire and prevent respondent fatigue across the 30-day study. Similar single-item sleep measures have previously shown acceptable reliability and validity [43, 44].

Daily cannabis and alcohol use (independent variables). These were based on data from daily surveys asking participants whether they had used their verified cannabis product (yes/no), other (non-study, non-verified) cannabis (yes/no) and whether they had used alcohol (yes/no) during the previous 24 h. Dummy within-person daily variables were created: cannabis-only, alcohol-only, co-use and non-use. Between-person frequency of use variables were computed by totalling daily reports of cannabis-only, alcohol-only and co-use days. Two participants who reporting no cannabis or alcohol use were excluded as their data lacked variability in key independent variables. To ensure manageable surveys and prevent fatigue across 30 days, no queries on simultaneous vs. concurrent use were included. Given uncertainties about accurate self-reporting of detailed cannabis dose/potency measures [45], we opted against collecting such granular substance use data.

Other covariates. These included: (i) cannabis form (flower vs. edible) and CBD:THC ratio (THC dominant and balanced vs. CBD dominant); (ii) a linear time-trend variable; (iii) a contrast indicator concerning whether sleep reports were recorded on weekends (1 = Friday,

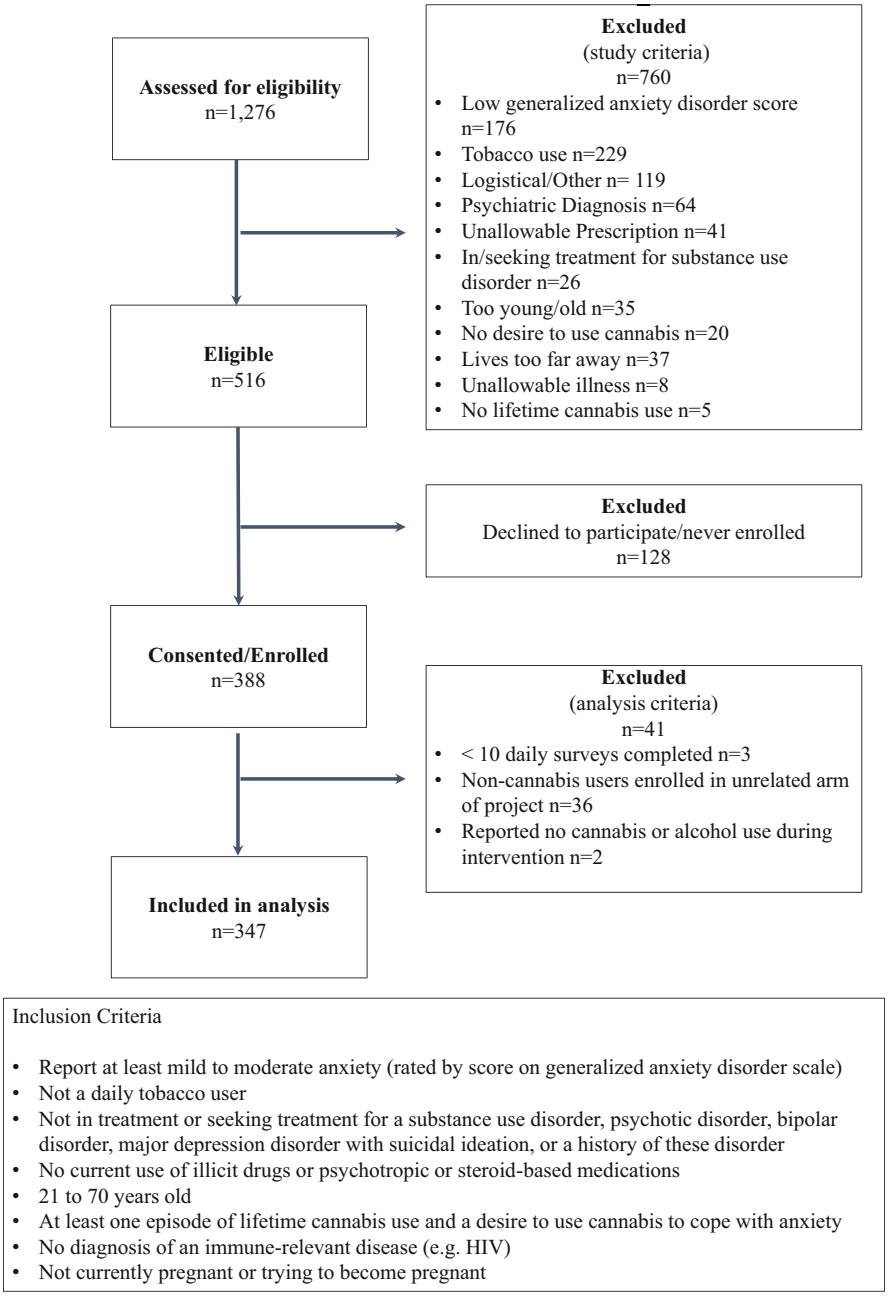

FIGURE 1 Recruitment flow.

Saturday, 0 = Sunday–Thursday); and (iv) whether daily reports were recorded in the evening (1 = PM reporting, 0 = AM reporting) as these factors may relate to cannabis and alcohol use, and sleep patterns. Average time of day for survey response was 11:43 AM.

2.4 | Statistical analyses

Descriptive statistics were calculated (means, standard deviations, proportions). Then, linear mixed effects models were calculated which included random intercepts to account for subject-level clustering and per-participant autocorrelated (order 1) error structures for days since baseline. Models were run in Stata using the xtmixed command [46]. The intraclass correlation coefficient for the outcome variable (sleep quality) was 0.28, showing substantial variance within individuals.

To explore alcohol and cannabis effects on daily sleep, within-person models compared non-use days to: (i) cannabis-only days; (ii) alcohol-only days; and (iii) co-use days. Bonferroni adjusted post-hoc analyses then assessed differences among all other use day combinations. Between-person variation in total cannabis-only,

alcohol-only and co-use days was controlled for to ensure genuine within-person alcohol and cannabis use variations. Furthermore, we controlled for the following between-person variables: age, gender, education, employment, ethnicity, cannabis form, CBD:THC ratio, sleep issues and anxiety symptoms. Time-varying control variables were linear time trend (days 1–30), AM–PM reporting and weekday/weekend distinctions.

Following the main effect model, an additional model was executed with cross-level interactive effects of within-person daily alcohol only, cannabis only and co-use days combined with between-person counts of alcohol-only, cannabis-only, and co-use days. Listwise deletion of observations with missing values was used.

To explore whether prior night's sleep influenced subsequent substance use, three lagged analyses were conducted. Each lagged daily substance use variable (cannabis-only, alcohol-only, co-use) served as an outcome in separate logit mixed-effect models. The predictor was the prior day's sleep quality reports, accompanied by covariates.

3 | RESULTS

3.1 | Sample descriptives

The flow of participants from recruitment to study inclusion is presented in Figure 1. Of the 347 participants, average age 33.15 (SD = 13.22), 64% were female and 80% were White. Sample descriptives are presented in Table 1.

3.2 | Daily data descriptives

The 30-day average sleep quality rating was 5.65. Participants reported not using any alcohol or cannabis on 32% of the days, while they reported alcohol-use-only, cannabis-use-only and co-use on 44%, 10% and 14% of the days, respectively (Table 1).

3.3 | Mixed effect model results

Compared to non-use days (Model 1A), participants reported better sleep after cannabis-use-only (β: 0.510, $p < 0.001$) and after co-use (β: 0.342, $p < 0.001$) days, but not after alcohol-use-only days (β: 0.039, $p = 0.560$). Post-hoc analysis (Table 3) also showed that participants reported lower sleep quality after alcohol use days compared to cannabis use days (β: −0.472, $p < 0.001$) and co-

TABLE 1 Sample demographics, baseline characteristics and daily attributes ($N = 347$).

Demographics	
Female, *n* (%)[a]	221 (63.7)
Age, mean (SD)[b]	33.15 (13.22)
Ethnicity, *n* (%)[c]	
American Indian or Alaska Native	1 (0.3)
Asian	12 (3.5)
African American or Black	6 (1.6)
Hispanic or Latino	17 (4.9)
Two or more races/ethnicities	21 (6.1)
White	278 (80.1)
Prefer not to answer	12 (3.5)
Education, *n* (%)[d]	
Less than high school	1 (0.02)
High school diploma	13 (3.8)
Some college	99 (29.0)
Associates degree	28 (8.1)
Bachelors degree	143 (41.0)
Masters degree	57 (16.4)
Doctoral degree	6 (1.7)
Work full- or part-time, *n* (%)[e]	285 (81.90)
Baseline survey characteristics	
Depression, Anxiety, Stress, mean (SD)[f]	43.1 (1.11)
Generalised Anxiety Disorder-7, mean (SD)[g]	11.7 (4.06)
Sleep quality (PSQI), mean (SD)[h]	7.32 (3.14)
Daily survey attributes[i]	
Daily survey response rate, mean (SD)	26.16 (6.23)
Daily survey response rate, median (SD)	29 (6.23)
Rating of sleep quality (0–10) in last 24 h, mean (SD)	5.65 (1.82)
Average time of day for responders (AM) (%)	11:43 (63.00)
No use events in entire sample, *n* (%)	2911 (31.99)
Cannabis use events in entire sample, *n* (%)	3972 (43.65)
Alcohol use events in sample, *n* (%)	904 (9.94)
Co-use events in entire sample, *n* (%)	1312 (14.42)

[a]Male vs. female.
[b]Age (continuous in years) at the time of baseline.
[c]Race and ethnicity that participant considers themselves to be, including when multiple categories were selected.
[d]Highest level of education obtained.
[e]Employment status (full- or part-time employment vs. all others).
[f]Composite score of the Depression, Anxiety, and Stress Scale—21 items [41, 47] contains three subscales, each with seven items and a severity response scale of 0–3 (0-Did not apply to me at all, up to 3-Applied to me very much, or most of the time) assessing baseline negative affect.
[g]Composite score of Generalised Anxiety Disorder-7 [34] contains seven items, each with a severity response scale of 0–3 (0-Not at all, up to 3-Nearly every day) assessing baseline score for mild to severe anxiety.
[h]Composite score of the Pittsburgh Sleep Quality Inventory (PSQI) assessing baseline sleep quality.
[i]Mean/median daily survey response rate, average daily online survey diary sleep quality rating, time of response (AM) and response rate, total no-use, cannabis, alcohol, and co-use events endorsed over for 30 days.

TABLE 2 Mixed effects of daily cannabis/alcohol use predicting daily sleep quality rating ($N = 349$).

	Model 1A (no interactions)				Model 1B (with interactions)			
	Estimate	**SE**	***z***	***p***	**Estimate**	**SE**	***z***	***p***
Fixed effects—within person (no use = referent)								
Alcohol only use (within-person)	0.039	0.066	0.580	0.560	0.300	0.225	1.340	0.181
Cannabis only use (within-person)	**0.510**	**0.045**	**11.380**	**<0.0001**	0.196	0.138	1.420	0.155
Co-use (within-person)	**0.342**	**0.062**	**5.530**	**<0.0001**	0.128	0.224	0.570	0.568
Survey day (1–30)	**0.008**	**0.002**	**4.400**	**<0.0001**	**0.008**	**0.002**	**4.290**	**<0.0001**
Survey day of the week (weekend)	0.018	0.044	0.400	0.689	0.019	0.044	0.440	0.661
PM reporting (vs. AM reporting)	**−0.176**	**0.042**	**−4.210**	**<0.0001**	**−0.176**	**0.042**	**−4.200**	**<0.0001**
Fixed effects—between person								
Sum alcohol use only days	−0.003	0.016	−0.210	0.832	−0.009	0.018	−0.500	0.615
Sum cannabis use only days	−0.003	0.009	−0.360	0.718	−0.014	0.010	−1.350	0.177
Sum co-use days	−0.013	0.012	−1.140	0.253	−0.013	0.015	−0.860	0.392
Cannabis form (flower vs. edibles)	−0.093	0.119	−0.780	0.436	−0.095	0.119	−0.800	0.424
Cannabis ratio (THC vs. CBD)	−0.071	0.130	−0.550	0.583	−0.072	0.130	−0.550	0.580
Cannabis ratio (THC + CBD vs. CBD)	−0.150	0.128	−1.170	0.240	−0.153	0.128	−1.200	0.231
Male vs. female	−0.038	0.114	−0.340	0.736	−0.041	0.114	−0.360	0.722
Age	0.004	0.005	0.840	0.400	0.004	0.005	0.860	0.392
Race/ethnicity (White vs. other)	0.116	0.147	0.790	0.430	0.111	0.147	0.760	0.450
Education (university degree vs. all others)	0.202	0.117	1.730	0.084	0.203	0.117	1.730	0.083
Employment (full- or part-time employment vs. all others)	0.015	0.148	0.100	0.917	0.020	0.148	0.130	0.894
[a]Baseline anxiety (DASS)	0.011	0.008	1.320	0.186	0.011	0.008	1.360	0.175
[b]Baseline sleep quality (PSQI)	**−0.123**	**0.019**	**−6.610**	**<0.0001**	**−0.123**	**0.019**	**−6.600**	**<0.0001**
Interactions								
Alcohol only use (within-person) × sum alcohol use only days (between-person)					−0.015	0.017	−0.870	0.384
Cannabis only use (within-person) × sum alcohol use only days (between-person)					**0.036**	**0.017**	**2.190**	**0.029**
Co-use (within-person) × sum alcohol use only days (between-person)					0.001	0.019	0.040	0.965
Alcohol only use (within-person) × sum cannabis use only days (between-person)					−0.018	0.018	−0.980	0.327
Cannabis only use (within-person) × sum cannabis use only days (between-person)					**0.020**	**0.009**	**2.380**	**0.018**
Co-use (within-person) × sum cannabis use only days (between-person)					0.017	0.013	1.320	0.188
Alcohol only use (within-person) × sum co-use days (between-person)					−0.009	0.016	−0.550	0.583
Cannabis only use (within-person) × sum co-use days (between-person)					0.001	0.013	0.050	0.964
Co-use (within-person) × sum co-use days (between-person)					0.006	0.015	0.380	0.701
Intercept	**5.984**	**0.307**	**19.510**	**<0.0001**	**6.099**	**0.313**	**19.480**	**<0.0001**

Note: Significant associations are in bold.

[a]Composite score of the Anxiety Depression, Anxiety, and Stress Scale (DASS) sub scale [41, 47] with seven items and a severity response scale of 0–3 (0-Did not apply to me at all, up to 3-Applied to me very much, or most of the time) assessing baseline anxiety symptoms.

[b]Composite score of the Pittsburgh Sleep Quality Inventory (PSQI) assessing baseline sleep quality.

use (β: −0.304, $p < 0.001$), and they reported better sleep quality after cannabis use only days compared to co-use days (β: 0.168, $p = 0.023$).

Table 2 also shows that more baseline sleep problems related to poorer daily quality of sleep (β: −0.123, $p < 0.001$). As the study progressed, participants reported better sleep (β: 0.008, $p < 0.001$). PM reporting was also associated with worse sleep (β: −0.176, $p < 0.001$).

The moderation analysis (Table 2, Model 1B) shows that the total number of alcohol use only days and total number of cannabis use only days moderated the associations between cannabis-use-only days and sleep (β: 0.036, $p = 0.029$ and β: 0.020, $p = 0.018$, respectively). These results are plotted in Figure 2, which shows that compared to after non-use days, people who more frequently use alcohol and people who more frequently use cannabis slept better after cannabis-use-only days (Figure 2a,b). A simple slope analysis showed that none of the slopes depicted in Figure 2 were significantly different from zero.

Sensitivity analyses examined potential weekend sleep pattern variations on results. Similar models to those above were tested with different weekend indicators: Friday to Sunday, Thursday to Saturday, Thursday to Sunday, Saturday to Sunday. These covariates were not significantly related to sleep quality and did not alter main model results (detailed results available upon request).

Results from the lagged analyses testing whether sleep quality reports from the night before influence next day substance use indicated that sleep quality was not related to subsequent alcohol, cannabis or co-use (results available upon request).

TABLE 3 Bonferroni adjusted post hoc analysis of differences in sleep quality by each of the different daily alcohol, cannabis and co-use daily variations.

		Estimate	SE	*t* value	Adj *p*
Alcohol only	No use	0.039	0.066	0.580	1.000
Cannabis only	No use	0.510	0.045	11.380	<0.0001
Co-use	No use	0.342	0.062	5.530	<0.0001
Alcohol only	Cannabis	−0.472	0.068	−6.940	<0.0001
Alcohol only	Co-use	−0.304	0.075	−4.060	<0.0001
Cannabis only	Co-use	0.168	0.058	2.890	0.023

4 | DISCUSSION

This study contributes to the limited literature by ecologically assessing within-person associations of combined and separate alcohol-cannabis use and their impact on subjective sleep quality. A sizable sample allowed testing average alcohol-cannabis use frequency moderations. This extends prior research by investigating these associations and moderations in individuals using cannabis to

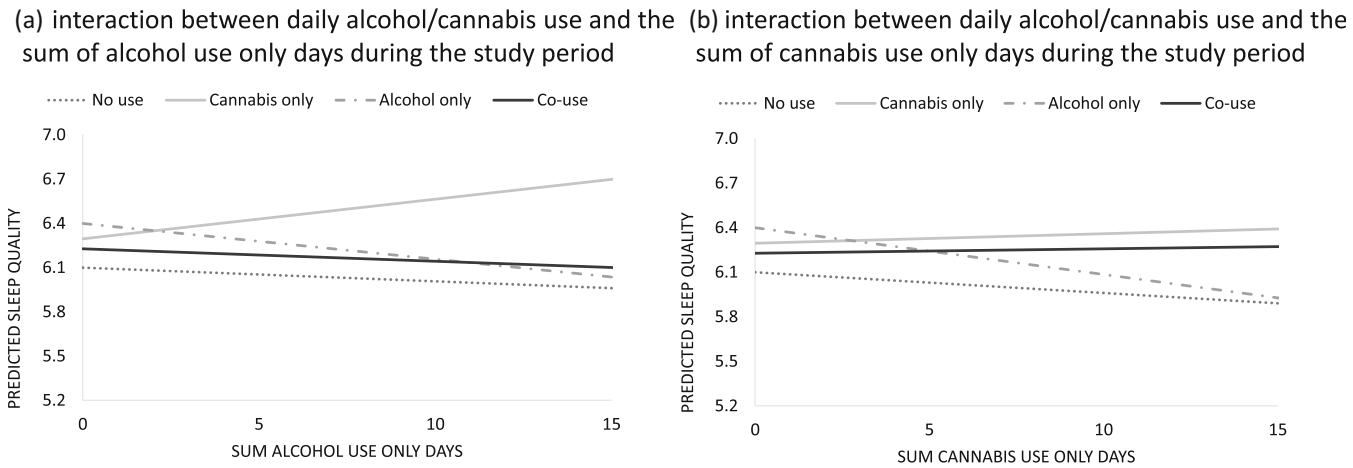

FIGURE 2 Interaction plots for predicted daily sleep quality. (a) Line graph displaying predicted daily sleep quality (*y*-axis) as a function of daily cannabis/alcohol use (lines) moderated by sum of alcohol use only days during the study period (*x*-axis) in the sample ($n = 347$). (b) Line graph displaying predicted daily sleep quality (*y*-axis) as a function of daily cannabis/alcohol use (lines) moderated by sum of cannabis use only days during the study period (*x*-axis) in the sample. Data points account for mixed effects model covariates (age, sex, education, employment, ethnicity, cannabis form, CBD:THC ratio, linear time trend, AM-PM reporting, weekday/weekend, baseline sleep problems and anxiety symptoms, and the sum of co-use days during the study period. Sum of co-use days was also interacted with daily cannabis/alcohol use variables but interactions were not significant and thus not depicted in the graph).

cope with anxiety, a group with heightened sleep issues and alcohol-cannabis use prevalence [7].

Our first hypothesis, expecting worse sleep quality with alcohol use alone compared to non-use, was not substantiated. This contrasts with previous daily diary studies indicating alcohol-related awakenings in college students [28] and worse sleep in young adults [32]. Factors like lower alcohol use levels and varying measurement methods between studies might contribute to this inconsistency. The null result could also relate to recruiting individuals with anxiety symptoms. Past research notes higher anxiety linked to greater tension reduction with alcohol [48], which might enhance sleep disturbances improvement post-alcohol use for those with anxiety symptoms. Additional research is vital to validate these null findings concerning sleep and alcohol among individuals with anxiety symptoms.

Our hypotheses about cannabis and sleep were confirmed. Cannabis use and co-use were linked to higher perceived sleep quality versus non-use. Sleep quality was notably better after cannabis-only days compared to co-use days. These findings add to the emerging evidence of cannabis's sleep-enhancing properties [11].

The moderation outcomes contrast typical expectations tied to tolerance and cross-tolerance effects. Specifically, no sign of weakened sleep effects on cannabis-use days occurred in frequent alcohol or cannabis users. In fact, results suggest a contrary pattern: better sleep quality post-cannabis use days (compared to non-use days) among those frequently using cannabis. This could be due to higher doses used by frequent users [49], potentially tied to better sleep. However, understanding various cannabis combinations and ratios' sleep effects remains limited [50], requiring further research. Unfortunately, our study did not capture daily cannabis doses, preventing deeper investigation into this matter.

The simple slope analysis showed that none of the slopes differed from zero, and thus that there was no difference in sleep quality after no-use days across those who use cannabis more and less frequently. This refutes an alternative interpretation of the interaction effect, namely that people who use cannabis more frequently experience withdrawal-related sleep problems after non-use days.

We also observed heightened subjective sleep quality after cannabis-only days in individuals who use alcohol more frequently. This could suggest a level of cross-sensitisation, where alcohol use frequency potentially influences cannabis's acute sleep effects. Alternatively, those using alcohol more might consume higher cannabis doses or more potent products on cannabis-use days [49], potentially linking to better sleep. Yet, and as noted above, comprehensive understanding of cannabis dosing's impact on sleep is limited. Additionally, hypothesising cross-sensitisation effects of cannabis and alcohol on sleep (against other explanations) remains speculative. No study has supported comparable moderation effects as studied here, warranting further investigation. Future research should delve into dose-specific cross-substance effects, their dependence on distinct sleep outcomes and potential moderation by individual differences.

Lastly, over the study's duration, participants reported improved sleep, possibly attributed to systematic changes in sleep quality due to repeated assessment. Consistently answering queries about sleep quality, alcohol, and cannabis use daily might influence participants' responses and experiences [51].

4.1 | Limitations

This study's strengths encompass its naturalistic design, sizable sample, affording ample statistical power for between-person moderator variable testing. However, there are limitations. Daily diary studies are demanding for participants, creating a need to keep questionnaires short. While this curtails the amount of data that can be collected, it likely enhances reliability and decreases dropout rates. Our daily diaries lack granular data on cannabis and alcohol consumption timing within the past 24 h. Most reports were morning-submitted, reflecting prior day/evening experiences, and we controlled for AM/PM reporting to compensate for lack of more specific data.

We cannot differentiate concurrent from simultaneous cannabis and alcohol use, although research suggests concurrent use predominates [52] with minimal meaningful differences in sleep between concurrent and simultaneous use [32]. However, exploring sleep distinctions between co-use and simultaneous use is valuable, needing further study. We similarly do not know the daily quantity/frequency of alcohol or cannabis consumed. Only one subjective sleep outcome was measured, the study is thus lacking sleep duration and other vital sleep-related factors. Additionally, subjective and objective sleep measures (e.g., actigraphy) might assess different sleep aspects [53]. Collecting both types in future studies could clarify which measurements are more relevant to cannabis and alcohol use and ultimately lead to a better understanding of how use relates to sleep.

Although participants were randomised to specific cannabinoid concentration groups, there were 802 incidences of self-bought cannabis use for which THC and CBD concentrations are unknown. To maximise all data points, and because the experimental design was not the

main focus of the current paper, we retained these data. This prevented testing if findings were specific to certain cannabinoid concentrations. Controlled clinical trials are necessary to probe causal hypotheses and relative effects concerning cannabinoid concentration. Our sample was primarily White, necessitating more diverse and representative participation for further research. The sample was selected based on self-reported cannabis use for anxiety coping, potentially limiting generalisability. This could result in stronger sleep expectations from cannabis compared to alcohol, influencing the reported results. However, data on sleep expectancies for cannabis, alcohol and co-use were lacking. Future studies should encompass detailed assessments of such expectancies for a nuanced understanding of their effects. Including these comprehensive measures would provide valuable insights into cannabis and alcohol's sleep impact. This will enable a more accurate interpretation of the results and contribute to a broader understanding of the relationship between substance use, anxiety and sleep.

5 | CONCLUSION

There is an urgent need for experimental studies investigating the effects of cannabis and alcohol on sleep. Our study suggests that cannabis may exert positive effects on subjective sleep quality among individuals intending to use cannabis to cope with anxiety. Day-to-day alcohol use may have less of an impact on sleep in this population when used without cannabis, and when co-used with cannabis, alcohol may mitigate positive sleep effect of cannabis. Further research is needed to investigate the moderating role of frequency of cannabis and alcohol use on more immediate associations between sleep and substance use. This is particularly pressing in populations seeking to use cannabis to cope with anxiety as this population may be prone to alcohol and cannabis misuse and sleep problems.

AUTHOR CONTRIBUTIONS

SS was responsible for data analysis, interpretation and writing the paper. RMW was responsible for data quality and management, supporting the analysis, and writing and reviewing the article. WHM was responsible for data collection, data quality and management, supporting the analysis, writing and reviewing the article. HCK was responsible for data collection, data quality and management, supporting the analysis, writing and reviewing the article. CB was responsible for conceptualising the study, study oversight, results interpretation, as well as writing and reviewing the article.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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