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A Latent Class Approach to Understanding Longitudinal Sleep Health and the Association with Alcohol and Cannabis Use During Late Adolescence and Emerging Adulthood

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Abstract

Objective: Sleep is a multi-dimensional health behavior associated with elevated risk of substance use. This is the first study to utilize a latent class approach to characterize sleep health across multiple dimensions and across time from late adolescence to emerging adulthood, and to examine associations with alcohol and cannabis use trajectories.

Methods: The sample included 2995 emerging adults (mean ages = 18 to 24 years across six waves of data collection; 54% female) who provided data on sleep dimensions (quality, duration, and social jetlag) and frequency and consequences of alcohol and cannabis use. Longitudinal latent class analysis (LLCA) models characterized participants according to the three sleep dimensions. Latent growth models examined trajectories of frequency and consequences of alcohol or cannabis use over time among emergent sleep classes, with and without controlling for covariates.

Results: LLCA models identified four sleep classes: *good* sleepers (n= 451; 15.2%); untroubled poor sleepers (n= 1024; 34.2%); troubled, moderately good sleepers (n=1056; 35.3%); and *suboptimal* sleepers (n= 460; 15.4%). Good sleepers reported significantly lower levels of alcohol or cannabis use and consequences, and less of an increase in alcohol consequences as compared to suboptimal sleepers.

Conclusions: Persistent poor sleep health was associated with higher levels of alcohol and cannabis use and consequences, and greater increases in alcohol-related consequences during the transition from late adolescence to emerging adulthood. Findings have important clinical

implications, highlighting that addressing multi-dimensional sleep health may be an important, novel target of intervention to reduce substance use frequency and consequences.

Keywords

sleep; alcohol; marijuana use; longitudinal; adolescents; emerging adulthood

1. INTRODUCTION

Emerging adulthood (typically defined as ages 18–24) is a critical period of development characterized by increased independence from parents, changes in biology and behavior, and development of health behaviors that may influence well-being into adulthood^{1,2}. For example, substance use increases during this time^{3,4}, and is associated with negative consequences across the lifespan, including risk of substance use disorders, mental and physical health morbidity, and premature mortality^{5–9}. Sleep is also a critical health behavior that undergoes substantial changes during adolescence and emerging adulthood and is consistently associated with multiple indicators of health and functioning, including risk of substance use, depression, suicide, and cardiometabolic dysregulation^{10–18}. Given that emerging adulthood is a time of increased flexibility in schedules, less parental involvement, and removal of early high school start times (a primary constraint to sufficient sleep in adolescent years)^{19,20}, this represents a critical period for identifying profiles of sleep health and how such profiles may be associated with alcohol and cannabis use trajectories over time.

Evidence suggests that alcohol and cannabis use may negatively affect sleep and bidirectional associations may exist²¹; however, a greater understanding is needed of how sleep health profiles over time associate with alcohol and cannabis use, as addressing sleep health may serve as a novel target of intervention to reduce substance use and associated consequences. Considerable longitudinal evidence suggests that poor sleep health may be a risk factor for substance use in childhood, adolescence, and adulthood^{22–31}. To date, however, few studies have addressed sleep health and substance use in emerging adulthood. This gap is notable given that sleep undergoes dramatic changes during this period³², and rates of alcohol and cannabis use increase^{33,34}.

Given that substance use peaks during emerging adulthood, studying this period affords the opportunity to investigate more clinically relevant substance use outcomes, including changes in frequency of use and consequences, whereas in younger samples it is often infeasible to investigate such outcomes due to low base rates of use⁴. For example, in our prior work with the current sample, we assessed sleep and substance use trajectories when youth were ages 14 to 16 and continuing for 6 annual waves of data (up to age 21); however, these analyses focused on presence or absence of *any* alcohol or cannabis use in the past month due to low base rates at younger ages. Thus, there remains a need to investigate how longitudinal sleep health associates with other clinically relevant outcomes, including frequency and consequences of use.

Moreover, prior research (including our own²⁸) has focused on sleep or circadian rhythm disturbances, viewed in isolation, in association with substance use, thereby demonstrating

that isolated symptoms including short sleep duration, insomnia or poor sleep quality, and “social jetlag” (i.e., discrepancy between weekday and weekend sleep timing) are cross-sectionally and longitudinally associated with substance use^{35–41}. However, specific phenotypes of sleep disturbances (e.g., combination of insomnia and short sleep duration) are more strongly associated with adverse health outcomes than either sleep disturbance examined in isolation^{42–44}. Further, sleep and circadian disturbances often co-occur^{10,45}, and are considered a transdiagnostic process that underlies other health issues, including problematic substance use⁴⁶. In fact, a growing body of sleep research suggests that a multi-dimensional approach to conceptualizing sleep health may better reflect clinically-relevant sleep disturbances, and may elucidate common mechanisms and novel targets for intervention^{46–48}.

As articulated by Buysse⁴⁷, “[S]leep health is a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being.” Buysse’s definition simultaneously highlights the potential role of sleep health in contributing to key health outcomes, and reflects awareness that the specific patterns or profiles of sleep-wakefulness and their association with specific health outcomes are influenced (i.e., “adapted”) by multi-level factors, including the developmental stage of the individual.

Guided by this framework and with an eye towards intervention⁴⁷, the current study conceptualizes sleep health as a dynamic and multi-dimensional construct comprised of different dimensions of sleep and circadian functioning that may be more or less relevant across various stages of development. This approach may be clinically useful as it may help to identify individuals who suffer from a constellation of sleep and circadian disturbances and may facilitate tailored treatment approaches to specific needs of a given developmental stage^{45,49}. This is particularly salient among adolescents and emerging adults, where insufficient sleep duration and erratic sleep-wake patterns are highly prevalent, but not necessarily indicative, in isolation, of clinically relevant symptoms.

The present study is the first to utilize a longitudinal latent class approach to conceptualize a multi-dimensional sleep health construct, comprised of key sleep health dimensions salient among emerging adults (i.e., sleep duration, quality, and social jetlag), in association with longitudinal trajectories of alcohol and cannabis use frequency and consequences, in a large and diverse sample of late adolescents and emerging adults. We selected these dimensions as prior research has demonstrated that short and long sleep duration⁵⁰, poor sleep quality⁵¹, and social jetlag are longitudinally associated with substance use outcomes, undergo considerable changes from late adolescence through emerging adulthood^{52,53}, and can be measured via survey assessments. Other constructs, such as variability in sleep timing are also relevant for these developmental periods and are consistent with the sleep health framework, but are more difficult to measure via surveys⁴⁷. The current work builds upon and extends prior research and our prior longitudinal work in this cohort²⁸ by 1) examining frequency of use and consequences associated with use, as opposed to presence or absence of use 2) considering sleep health as a multidimensional construct, versus a set of individual symptoms, 3) examining these associations into early adulthood, and 4) applying a longitudinal latent class approach, which yields novel information concerning

patterning of specific sleep health dimensions over time and their association with substance use outcomes. We hypothesized that those in the poorest sleep health class would have the greatest frequency and consequences of alcohol and cannabis use.

2.0 METHODS

2.1 Participants

This study utilized six waves of data from wave 8 (June 2015 to May 2016) to wave 13 (July 2020 to July 2021) from a large multi-wave study of participants in southern California. The sample included 2,995 participants (mean age 18.3 at Wave 8 and 23.6 at Wave 13) enrolled when participants were in 6th and 7th grades (ages 11 to 13) in 2008 for a one-year substance prevention program, CHOICE. Participants were representative of the 16 middle schools in southern California from which they were recruited⁵⁴. Participants transitioned to over 200 different high schools and were re-contacted and re-consented to complete annual web-based surveys. Average retention rate across waves 1–13 is 85%, with 82% of the sample completing 4 or more waves between wave 8–13. Participants were paid \$50 for completing each survey. The study has a Certificate of Confidentiality, and all procedures were approved by the [BLIND] Human Subjects Protection Committee.

2.2 Measures

2.2.1 Sleep Health Dimensions—The sleep health composite measure was derived at 6 waves (waves 8 to 13) from three dichotomous indicators of sleep, based on the following dimensions: sleep quality, sleep duration, and social jetlag. This approach is consistent with prior research using a sleep health framework^{48,55} and has clinical utility as it provides meaningful distinctions among groups. We dichotomize each dimension into “good” (1) versus “suboptimal” (0) categories.

Sleep quality was assessed with an item from the 15-item Patient Health Questionnaire (PHQ) Somatic Symptom Severity Scale measure⁵⁶ asking “during the past 4 weeks, how much have you been bothered by trouble sleeping?”, with responses ranging from “not bothered at all” to “bothered a lot”. A response of “not bothered at all” was categorized as *good* in the dichotomous indicator for sleep quality, and responses of “bothered a little” and “bothered a lot” were categorized as *suboptimal*.

Sleep duration was calculated by taking the difference between self-reported bed and wake times for weekdays and weekends separately. Given that this calculated measure does not account for wakefulness during the sleep period, it is actually a measure of “time in bed”. However, to be consistent with the literature, which has used similar methods⁵⁷ and to facilitate interpretability, we refer to this variable as “sleep duration”. Based on established recommendations for sleep duration in adolescents and young adults which recognize that there may be health consequences associated with both short and long duration^{58,59}, sleep duration was considered “*good*” if the time between bed and wake time was between 8 and 10 hours, inclusive; sleep duration less than 8 hours or greater than 10 hours was deemed “*suboptimal*”.

Social jetlag was calculated as the absolute difference between the mid-point of sleep during weekdays and the mid-point of sleep during weekends. Mid-point of sleep was calculated as the half-way point between self-reported bed and wake times. Larger discrepancies in weekday versus weekend sleep midpoint is indicative of greater circadian misalignment. Based on prior research^{60,61}, we set thresholds for *good* social jetlag (having < 2 hours of difference between weekday and weekend mid-sleep) and *suboptimal* social jetlag (>2 hours of difference between weekday and weekend mid-sleep).

2.2.2 Alcohol and Cannabis Use Outcomes—Alcohol and cannabis use were assessed with separate items asking “during the past month (30 days), how many days did you use [at least one drink of alcohol]/[marijuana (pot, weed, grass, hash, bud, sins)]?” At waves 8–10, response options ranged from 1 = 0 days to 7 = 20–30 days. Items were re-coded such that the mid-point was taken for responses with ranges (e.g., 3–5 days re-coded to 4 days) and response values represented actual number of days used (e.g., 0 days coded as 0), resulting in a range of 0–25 days. At waves 11–13, respondents entered a value from 0–30; these responses were re-coded to match the range from the earlier waves (e.g., responses between 3–5 days were re-coded to 4).

Alcohol and cannabis use consequences were assessed (waves 8–13) by asking respondents how often in the past year things happened to them because of drinking alcohol or using marijuana (e.g., missed school or work or other obligations). Response options ranged from “never” to “20 or more times.” Items were dichotomized to indicate that the consequence happened one or more times in the past year versus never; dichotomous indicators were summed to create consequence scores, with ranges of 0–5 (alcohol) and 0–4 (marijuana).

2.2.3 Covariates—Respondents reported age, sex assigned at birth (male or female), race and ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic/Latinx/o, Asian, and other/multi-racial), and maternal education (dichotomized as associate degree/college or higher vs some college/high school or less). Given strong associations between mental health and sleep and substance use⁶², mental health was included as a covariate using the validated Mental Health Inventory (MHI-5)⁶³, comprised of five items assessing past month anxiety and depression symptoms. Finally, we controlled for middle school intervention status.

2.3 Analytic Plan

The analytic strategy was comprised of two steps: 1) identify longitudinal latent classes based on multidimensional sleep health measures; and 2) estimate and compare trajectories of alcohol and cannabis frequency and consequences by multi-dimensional sleep classes. First, we conducted a longitudinal latent class analysis (LLCA), a type of mixture model focused on modeling patterns across time rather than scaled change as is typical of growth mixture models. In a traditional growth mixture model, a given number of classes might emerge wherein each class is defined by a distinct intercept and slope. LLCA classifies individuals based on patterns over time and as such do not assume any growth function (e.g., linear or quadratic). Thus, class assignment is based on similar item response patterns. LLCA models were estimated in Mplus version 8.0⁶⁴ using the manual three-step approach

⁶⁵. We included all sleep health measures across waves in the model and estimated a series of LLCAs until converging on an optimal solution. We determined the optimal class solution for the multi-dimensional sleep health measure by evaluating the combination of several fit indices including: negative two log likelihood ($-2LL$), Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), the sample size adjusted Bayesian Information Criteria (aBIC), the Vuong-Lo-Mendell-Rubin adjusted likelihood ratio test (VLMR), and the Lo-Mendell-Rubin (LMR) adjusted likelihood ratio test. For all log likelihood measures ($-2LL$, AIC, BIC, and aBIC), lower values indicate better fit ⁶⁶. Likelihood ratio testing (VLRM and LMR) provides a significance test evaluating the improvement of an additional class (e.g., 4 versus 5 classes) ⁶⁶. We also considered the theoretical interpretation and sample size of the emergent classes. Thus, both statistical and theoretical rationale, concerning typical clinical presentation of sleep profiles, guided our final model selection⁶⁷.

Second, we used logits for the classification probabilities for the most likely latent class membership obtained from the LLCA model and then estimated growth models across latent classes. We repeated this process for each longitudinal use or consequence measure. We estimated intercept, linear (slope), and non-linear (quadratic) growth factors for each model and tested for statistical differences between classes (e.g., do slopes differ between classes?) using a Wald test. For all growth models, we included the set of covariates listed previously. Finally, although analyzing racial/ethnic or gender differences in the longitudinal sleep health classes is beyond the scope of this paper, it is important for descriptive purposes. We therefore provide this information in supplemental Table 1.

3.0 RESULTS

3.1 Sample Description

The sample was on average 18.3 years old ($SD = 0.8$) at wave 8, 53.7% female, 20.4% non-Hispanic White, 2.2% non-Hispanic Black, 45.9% Hispanic, 19.9% Asian, and 11.5% other/multi-racial (Table 1). Table 2 reports descriptives for each sleep health dimension. The proportion of respondents with *good* sleep quality steadily decreased over time, from 56% at the first time point to 48% at the last time point. In contrast, the proportion of respondents in *good* categories for sleep duration (33–44%) and social jetlag (62–74%) increased across time points. Supplemental Table 1 includes information on sociodemographic differences in the longitudinal sleep classes (e.g., Classes 2 (49%) and 4 (53%) had a significantly greater proportion of Hispanic respondents, compared to Classes 1 (40%) and 3 (42%); and Class 3 (60%) had a greater proportion of females compared to all other classes (47–54%)).

3.2 Deriving Longitudinal, Multi-dimensional Sleep Classes

Based on results from likelihood ratio tests (e.g., VLMR) from the LLCAs, in combination with theoretical consideration, a four-class solution best represented longitudinal patterns of average sleep duration, healthy social jetlag, and trouble sleeping. Model fit indices and likelihood ratio tests are presented in Table 3. All information criteria ($-2LL$, AIC, BIC, aBIC) improved as the number of extracted classes increased; however, the five-class solution was not a statistical improvement over the four-class as indicated by VLMR ($p = .1214$) and LMR ($p = .123$) likelihood ratio tests. Item probabilities across all waves and

by class are presented in Figure 1. The resulting four classes were: Class 1 (n=454, 15.2%) -- *good sleepers* (*good* across all dimensions); Class 2 (n=1024, 34.2%) -- *untroubled poor sleepers* (*good* sleep quality, but *suboptimal* sleep duration and social jetlag). Class 3 (n=1056, 35.3%) - *troubled moderately good sleepers* (*suboptimal* sleep quality, but *moderately good* sleep duration and social jetlag). Class 4 (n=460, 15.4%) -- *poor sleepers* (*suboptimal* across all 3 dimensions).

3.3 LLCA Growth Models

Using class probabilities from the LLCA, we fit growth models for alcohol use, cannabis use, alcohol consequences, and cannabis consequences to explore differences in trajectories by sleep class. Growth parameters (intercept, slope, quadratic) are presented for each longitudinal measure and for each class in Table 4. Trajectory plots by class for each longitudinal measure are presented in Figure 2. For each longitudinal measure, we tested to see if growth parameters differed across sleep health classes.

Alcohol Frequency.—Trajectories of alcohol use by sleep class are depicted in panel A of Figure 1. All sleep classes reported some level of initial alcohol use which increased over time, and then stabilized between waves 12 and 13. The *poor sleeper* class had the highest levels of initial alcohol use, and this was significantly higher than the *good sleeper* class ($\chi^2=7.01, p=.008$) and *untroubled poor sleeper* class ($\chi^2=12.17, p=.001$). Further the *troubled, moderately good sleeper* class had significantly higher initial alcohol use frequency than the *untroubled poor sleeper* class ($\chi^2=5.51, p=.019$). There were no significant differences across classes in terms of change in alcohol use over time (i.e., slopes and quadratic).

Alcohol Consequences.—Trajectories of alcohol consequences by sleep class are depicted in panel B of Figure 1. All sleep classes reported some initial alcohol consequences, which increased over time, but then started to decline at wave 12. *Poor sleepers* had greater initial alcohol consequences than both the *good sleepers* ($\chi^2=11.99, p=.001$) and *untroubled poor sleepers* ($\chi^2=36.36, p<.0001$). Similarly, *troubled, moderately good sleepers* had greater consequences than both *good sleepers* ($\chi^2=11.78, p=.001$) and *untroubled poor sleepers* ($\chi^2=31.24, p<.0001$). Regarding linear change, *poor sleepers* had a steeper increase in consequences than *good sleepers* ($\chi^2=10.18, p=.001$) and *untroubled poor sleepers* ($\chi^2=4.14, p=.04$). *Troubled, moderately good sleepers* had a steeper increase in consequences than *healthy sleepers* ($\chi^2=7.15, p=.008$). Lastly, regarding the deceleration or downturn (i.e., quadratic term), *good sleepers* had a significantly less pronounced downturn or decline in consequences than *troubled, moderately good sleepers* ($\chi^2=4.92, p=.03$) and 4 ($\chi^2=5.2, p=.023$).

Cannabis Frequency.—Trajectories of cannabis use frequency by sleep class are depicted in panel C of Figure 1. All sleep classes reported some level of initial cannabis use which increased over time, and then either stabilized or began to decelerate between waves 12 and 13. Relative to the *good sleeper* class, *troubled, moderately good sleepers* ($\chi^2=6.091, p=.014$) and *poor sleepers* ($\chi^2=3.66, p=.056$) reported greater initial cannabis

use frequency. There were no significant differences across classes in terms of change in use over time (i.e., slopes and quadratic).

Cannabis Consequences.—Trajectories of cannabis consequences by sleep class are depicted in panel D of Figure 1. All sleep classes reported some initial cannabis consequences, which increased over time (except for *troubled, moderately good sleepers*), but then started to decline at wave 12. *Unhealthy sleepers* had greater initial consequences than both the *good sleepers* ($\chi^2=4.93$, $p=.026$) and *untroubled poor sleepers* ($\chi^2=13.25$, $p=.0003$). Similarly, *troubled, moderately good sleepers* had greater consequences than both *good sleepers* ($\chi^2=7.17$, $p=.007$) and *untroubled poor sleepers* ($\chi^2=18.44$, $p<.0001$). There were no significant differences across classes in terms of change in consequences over time (i.e., slopes and quadratic).

4.0 DISCUSSION

The current study evaluated longitudinal associations between multiple dimensions of sleep health and alcohol and cannabis use and associated consequences during emerging adulthood. We examined sleep quality, sleep duration, and social jetlag as key components of sleep health in emerging adulthood,³² as these dimensions undergo considerable changes during these developmental periods and are associated with substance use outcomes^{31,52,53,68,69}. Descriptively, our findings showed interesting developmental changes, with the proportion of respondents with *good* sleep quality (based on our dichotomous definitions) steadily decreasing over time, whereas the proportion of respondents in *good* categories for sleep duration and social jetlag increased over time. This is consistent with prior evidence demonstrating that developmentally, the peak in circadian phase delay (i.e., evening preference) tends to occur in one's early 20s⁶⁹, after which it tends to shift earlier, but at the same time, social jetlag is reduced, as sleep is less constrained by early school start times⁷⁰.

Importantly, prior research has focused on individual sleep health dimensions using a variable-centered approach⁷¹. For example, in our prior work²⁸ in this sample when youth were ages 16–22, we analyzed changes in several sleep health dimensions individually over time and their longitudinal associations with *any* alcohol or cannabis use. In contrast, in the current study, using a sleep health perspective⁴⁷ and a person-centered analytic approach⁷¹, we analyzed multiple sleep health dimensions simultaneously to identify four longitudinal sleep health classes from late adolescence into emerging adulthood and examined the associations between these sleep health classes and substance use outcomes. Furthermore, given the older age range of the current sample, we were able to examine associations between longitudinal sleep health classes and the frequency and consequences of alcohol or cannabis use, as opposed to a binary outcome of “any” versus “no” use as in our prior paper.

The classes included: *good sleepers* (good across all dimensions), *untroubled poor sleepers* (good sleep quality but suboptimal for sleep duration and social jetlag), *troubled moderately good sleepers* (suboptimal sleep quality, but moderately good across other 2 dimensions), and *poor sleepers* (suboptimal across all dimensions). The majority of emerging adults were either troubled but had good sleep, or not troubled but had suboptimal sleep. Only 15%

were *good* across all dimensions or *suboptimal* across all dimensions over time. Findings highlight the considerable heterogeneity in sleep profiles and the clinical relevance of addressing the subjective experience of poor quality sleep, even in the absence of other quantitative indicators of sleep disturbance.

The *poor sleeper* class reported significantly higher frequency of alcohol use and greater linear increases as compared to *good sleepers* or *untroubled poor sleepers*. Further, troubled but otherwise good sleepers reported significantly higher frequency of initial alcohol use as compared to the untroubled, poor sleepers and significantly greater increases in alcohol use than good sleepers. Thus, the presence of insomnia-related symptoms such as poor sleep quality seem to be more strongly associated with frequent alcohol use, consistent with prior evidence demonstrating that insomnia-related symptoms are often more strongly linked with negative health outcomes than quantitative dimensions of sleep (e.g., sleep duration)^{72–74}.

We observed a similar pattern for initial frequency of cannabis use, with *good sleepers* reporting less frequent use than either *troubled*, *moderately good sleepers*, or *poor sleepers*. Similarly, regarding initial levels of cannabis use consequences, *poor sleepers* reported more consequences than *good sleepers* and *untroubled poor sleepers*, whereas *troubled*, *moderately good sleepers* reported greater initial consequences as compared to *good sleepers* or *untroubled, poor sleepers*. However, there were no sleep health class differences in trajectories of cannabis use frequency or consequences over time.

Overall, findings underscore key developmental patterns in sleep health profiles and alcohol and cannabis use and consequences over time. Consistent with a sleep health perspective, the majority of this sample of emerging adults experienced problematic sleep health on some dimensions (as opposed to being healthy across all dimensions). Further, those with more optimal sleep profiles reported less alcohol or cannabis use. Results suggest the relative importance of subjective sleep quality as a potential intervention target as the presence of poor sleep quality, alone or in combination with other poor sleep health dimensions, may portend poorer substance use-related outcomes.

Findings have important clinical implications for identifying populations that may be most at-risk, and highlight the need for deploying evidence-based, behavioral interventions that target insomnia (e.g., cognitive behavioral therapy for insomnia)⁷⁵ and transdiagnostic approaches (e.g., Trans-C⁷⁶) that also address common circadian disruptions among this age group. Given that our findings cannot rule out bidirectional associations, which have been reported in prior work⁷⁷, it is also critical for interventions to address motivations for using substances, which may include misconceptions about the soporific effects of cannabis or alcohol⁷⁸, and to provide psychoeducation concerning the effects of alcohol and cannabis on sleep.

Findings must be considered in light of limitations. First, we utilized self-report, which may have introduced common method variance or self-report bias. Furthermore, we selected sleep health dimensions a priori, based on prior research demonstrating the importance of these sleep dimensions during late adolescence and emerging adulthood and that could be measured with survey items. However, other sleep dimensions (e.g., daytime sleepiness,

snoring, variability) as well as other substance use outcomes including amount of the substance, may also be relevant. Relatedly, multi-dimensional sleep health is an evolving construct and our specific approach to operationalizing sleep health with dichotomous indicators was motivated by a clinical perspective. However, an important unanswered question is whether sleep health is more strongly associated with substance use outcomes compared to sleep measures viewed in isolation. Furthermore, there are limitations with regard to the dichotomous approach we used to characterize each dimension. Namely, there are not established guidelines for what constitutes “good” or “suboptimal” social jetlag. However, prior research suggests that social jetlag greater than two hours (as defined herein as “suboptimal”) is associated with greater depression and higher blood cortisol levels^{79,80}. In addition, even for sleep duration where published recommendations exist, there is discrepancy in recommendations, with some establishing an upper limit for sleep duration^{59,81} and others not⁸². There is also inconsistency in recommendations with regard to age cutoffs for the two developmental periods covered in the current study—adolescents and young adults. Thus, it is possible that findings regarding latent sleep health classes and their associations with substance use outcomes would be different based on different operationalizations of sleep health. Our analyses adjusted for several relevant covariates; however, other factors, such as family or social support, personality characteristics, or other sociodemographic factors may influence findings. Furthermore, our supplemental analyses suggest several sociodemographic differences in longitudinal sleep profiles. Examining how the association between longitudinal sleep health classes and substance use outcomes may differ by sociodemographic characteristics was beyond the scope of this paper but is a critically important opportunity for future research. In addition, we did not examine potential mechanisms underlying associations between sleep health and substance use levels and trajectories; however, prior research suggests that altered neural responses to reward, as well as impacts on affective and behavioral regulation may be candidate mechanisms^{83,84}. Finally, we chose to address how sleep affects trajectories of substance use; future research is needed to examine potential bidirectional associations over time, in order to determine how and when to most effectively intervene.

In sum, findings indicate that emerging adults who face a cluster of sleep and circadian disturbances may be at greatest risk for problematic alcohol and cannabis use, and that those with poor sleep quality were more likely to use substances and report consequences from use. Results highlight the importance of transdiagnostic approaches to treat poor sleep quality as well as circadian rhythm disruptions common to this age group, as a potential strategy to reduce risk of alcohol and cannabis use-related consequences and thereby decrease the likelihood of continued problems into adulthood.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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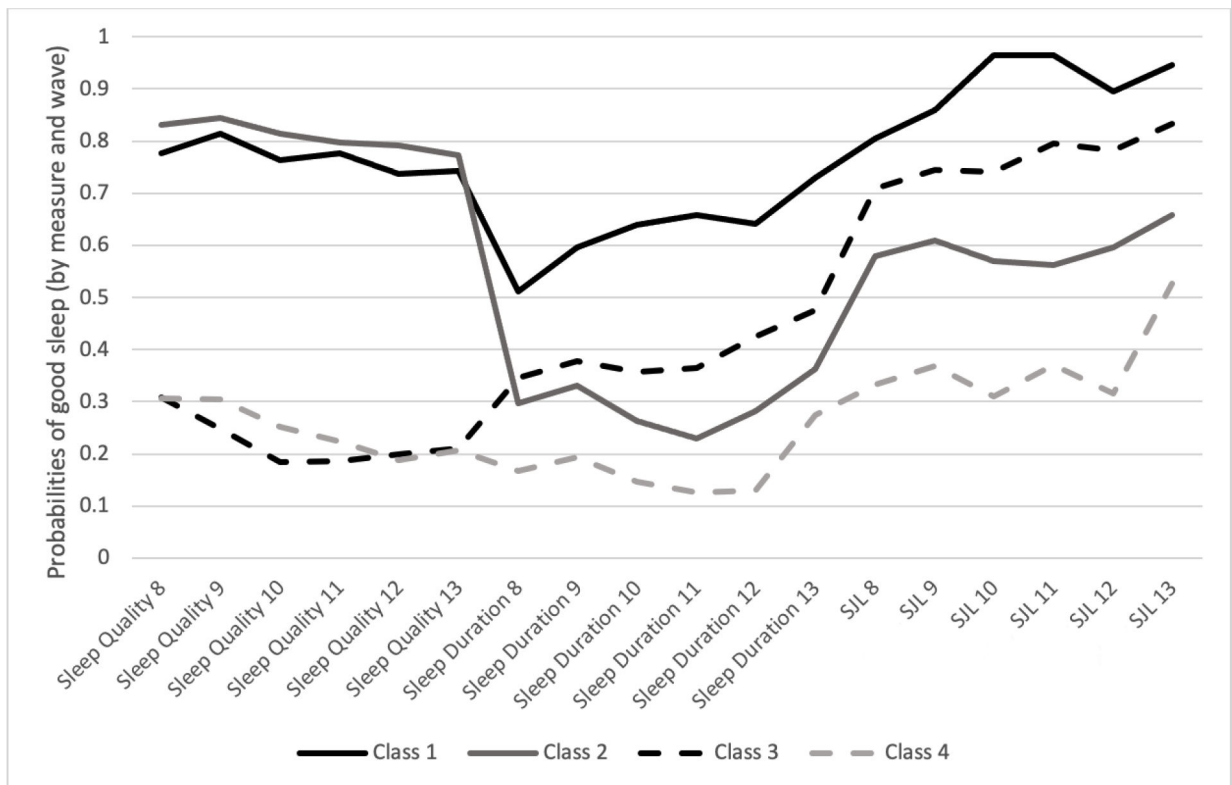
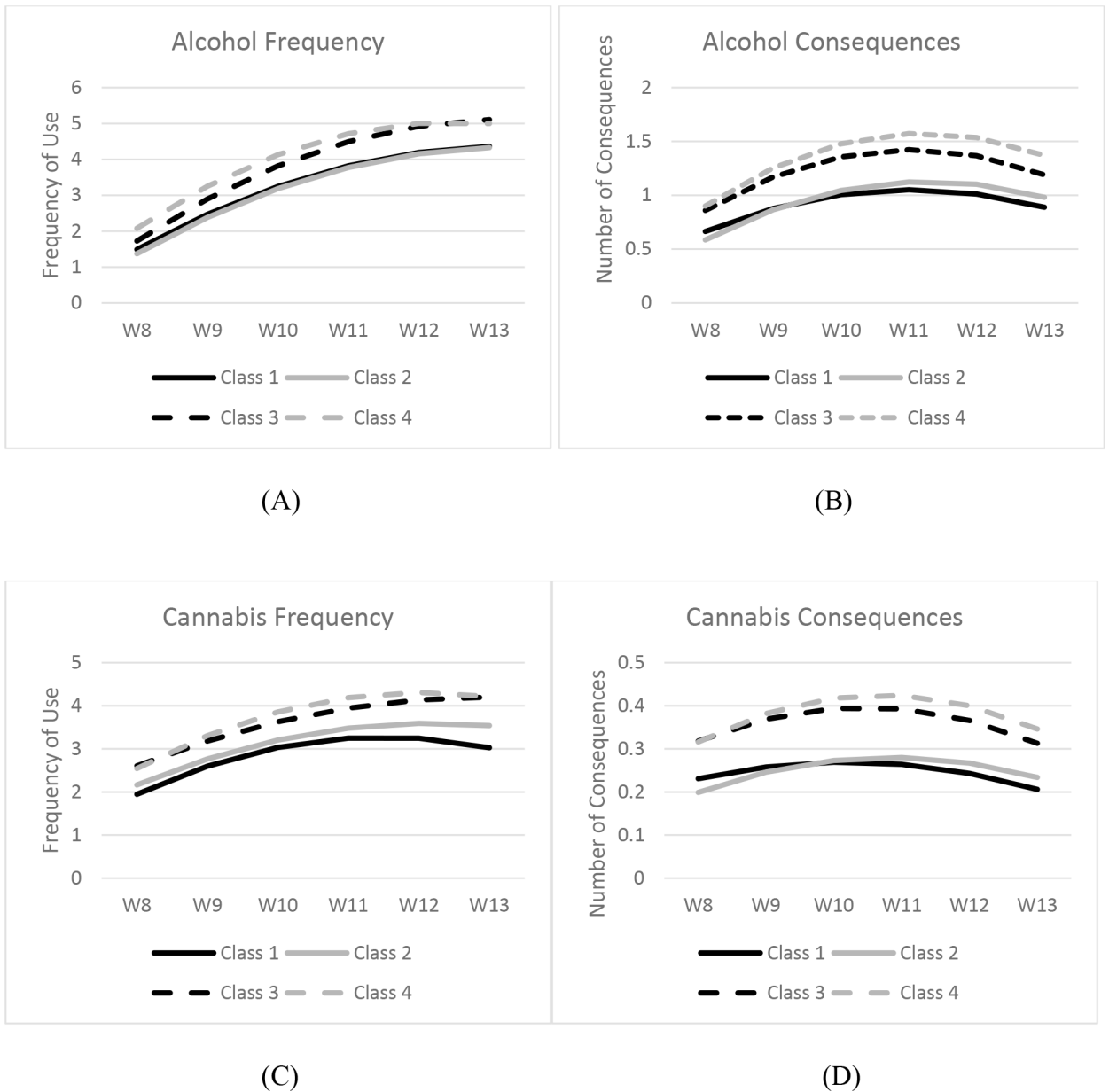


Figure 1.

Longitudinal patterns of multidimensional sleep measures.

Note. Class 1: Good sleepers (*good* across all dimensions); Class 2: Untroubled, poor sleepers (*good* sleep quality but *suboptimal* for sleep duration and social jetlag), Class 3: Troubled, moderately good sleepers (*suboptimal* sleep quality, but moderately *good* across other 2 dimensions), and Class 4: Poor sleepers (*suboptimal* across all dimensions).

**Figure 2.**

Alcohol and Cannabis use frequency and consequences over time (Wave 8–13) according to sleep health class. Mean ages at each wave were: W8: 18.3, W9: 19.4, W10: 20.7, W11: 21.6, W12: 22.6, W13: 23.6. Panel A shows the alcohol use frequency trajectories by sleep class. Panel B shows the trajectories of alcohol-related consequences by sleep class. Panel C shows the cannabis use frequency trajectories by sleep class. Panel D shows the trajectories of cannabis-related consequences by sleep class. Class 1: Good sleepers (*good* across all dimensions); Class 2: Untroubled, poor sleepers (*good* sleep quality but *suboptimal* for sleep duration and social jetlag), Class 3: Troubled, moderately good sleepers (*suboptimal* sleep quality, but moderately *good* across other 2 dimensions), and Class 4: Poor sleepers (*suboptimal* across all dimensions).

Table 1.

Sample Descriptives at Wave 8

Covariates	
Age (wave 8), <i>mean (SD)</i> , years	18.3 (0.8)
Male, <i>n (%)</i>	1,385 (46.3%)
Race/ethnicity, <i>n (%)</i>	
Non-Hispanic White	612 (20.4%)
Non-Hispanic Black	67 (2.2%)
Hispanic	1,374 (45.9%)
Non-Hispanic Asian	596 (19.9%)
Non-Hispanic Other/Multi-racial	345 (11.5%)
Maternal education, <i>n (%)</i>	
Some college/high school or less	1,236 (55.1%)
Associate degree or bachelor's degree and higher	1,007 (44.9%)
CHOICE intervention, <i>n (%)</i>	1,521 (50.9%)
MHI-5 (wave 8), <i>mean (SD)</i>	65.3 (20.4)

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Table 2. Substance Use and Sleep Health Dimensions (Continuous and Binary Indicators) from Wave 8 to Wave 13

	Wave 8	Wave 9	Wave 10	Wave 11	Wave 12	Wave 13
Alcohol Use, past month, <i>mean (SD)</i> of days	1.8 (4.1)	2.3 (4.4)	3.5 (5.2)	4.7 (6.2)	4.5 (6.1)	4.5 (6.3)
Cannabis Use, past month, <i>mean (SD)</i> of days	2.3 (6.3)	2.9 (6.9)	3.5 (7.5)	3.6 (7.6)	3.4 (7.6)	3.8 (7.9)
Alcohol Consequences, <i>mean (SD)</i>	0.8 (1.3)	1.0 (1.4)	1.2 (1.5)	1.3 (1.5)	1.3 (1.5)	1.1 (1.4)
Cannabis Consequences, <i>mean (SD)</i>	0.3 (0.7)	0.3 (0.8)	0.3 (0.8)	0.3 (0.8)	0.3 (0.7)	0.3 (0.7)
Sleep Quality *, <i>mean (SD)</i>	1.6 (0.7)	1.6 (0.7)	1.6 (0.7)	1.7 (0.7)	1.7 (0.7)	1.7 (0.7)
Good Sleep Quality, <i>n (%)</i>	1396 (55.9%)	1329 (55.1%)	1209 (49.9%)	1222 (49.2%)	1224 (48.5%)	1155 (48.1%)
Sleep Duration (hours), <i>mean (SD)</i>	8.3 (1.2)	8.3 (1.2)	8.1 (1.2)	8.1 (1.2)	8.2 (1.2)	8.3 (1.1)
Good Sleep Duration, <i>n (%)</i>	813 (32.5%)	881 (36.6%)	811 (33.7%)	808 (32.8%)	908 (36.2%)	1063 (44.4%)
Social Jetlag (hours), <i>mean (SD)</i>	1.7 (1.1)	1.6 (1.1)	1.6 (1.1)	1.6 (1.1)	1.6 (1.1)	1.4 (1.1)
Good Social Jetlag, <i>n (%)</i>	1492 (61.7%)	1540 (65.4%)	1499 (64.8%)	1618 (67.6%)	1661 (66.0%)	1771 (74.1%)

Note.

* 1 = Not bothered at all by trouble sleeping, 3 = Bothered a lot.

“Good” indicates meeting defined threshold criteria for the given sleep dimension.

Table 3.

Model Fit Statistics and Likelihood Ratio Tests for Longitudinal Latent Class Analyses

Class	-2LL	df	AIC	BIC	aBIC	VLMR	LMR
1	57701.058	18	57737.059	57845.137	57787.944	--	--
2	55237.202	37	55311.202	55533.363	55415.800	0.0000	0.0000
3	54469.358	56	54581.358	54917.603	54739.669	0.0008	0.0009
4	54074.636	75	54224.636	54674.964	54436.660	0.0001	0.0001
5	53872.094	94	54060.095	54624.505	54325.831	0.1214	0.1230

Note. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; aBIC = Sample size-adjusted BIC; VLMR = Vuong-Lo-Mendell-Rubin Likelihood Ratio Test; LMR = Lo-Mendell-Rubin Likelihood Ratio Test. (*) denotes the current class structure (k classes) was a significant improvement over the previous class structure ($k-1$ classes). (#) denote models with non-convergence perturbations.

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Table 4.

Growth parameters by class for each longitudinal substance use and consequences measures

	Class 1	Class 2	Class 3	Class 4
Alcohol Frequency				
Intercept	1.491 p<.001	1.372 p<.001	1.727 p<.001	2.079 p<.001
Slope	1.079 p<.001	1.116 p<.001	1.291 p<.001	1.319 p<.001
Quadratic	-0.101 p<.001	-0.105 p<.001	-0.123 p<.001	-0.147 p<.001
Alcohol Consequences				
Intercept	0.664 p<.001	0.586 p<.001	0.859 p<.001	0.900 p<.001
Slope	0.255 p<.001	0.329 p<.001	0.371 p<.001	0.419 p<.001
Quadratic	-0.042 p<.001	-0.05 p<.001	-0.061 p<.001	-0.065 p<.001
Cannabis Frequency				
Intercept	1.947 p<.001	2.164 p<.001	2.606 p<.001	2.545 p<.001
Slope	0.761 p<.001	0.685 p<.001	0.639 p<.001	0.869 p<.001
Quadratic	-0.109 p<.001	-0.082 p=.001	-0.064 p=.013	-0.107 p=.003
Cannabis Consequences				
Intercept	0.231 p<.001	0.199 p<.001	0.318 p<.001	0.316 p<.001
Slope	0.035 p=.078	0.057 p<.001	0.064 p<.001	0.081 p<.001
Quadratic	-0.008 p=.023	-0.01 p<.001	-0.013 p<.001	-0.015 p<.001