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# Sleep Architecture in Adolescent Marijuana and Alcohol Users during Acute and Extended Abstinence

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## Abstract

This study examined sleep changes following cessation of marijuana and alcohol use during late adolescence. Twenty-nine heavy marijuana and alcohol users and 20 matched controls were studied during a 28-day monitored abstinence period. Sleep as examined as a function of prior substance use during Nights 1–2 and Nights 27–28. On Night 2, percent Rapid Eye Movement sleep was predicted by past month alcohol use, whereas percent Slow Wave Sleep was predicted by marijuana intake. By Night 28, neither alcohol no marijuana use predicted any sleep architecture measure. However, on Night 28, indices of period limb movements (PLMs) in sleep were predicted by marijuana and alcohol intake. Results indicate that in adolescents: (1) cessation of heavy marijuana and alcohol use may influence sleep; (2) most sleep abnormalities abate within several weeks of abstinence; and (3) PLMs may increase following abstinence.

### Keywords

Polysomnography; Adolescence; Alcohol; Marijuana; Withdrawal; Sleep

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## INTRODUCTION

Alcohol is the most commonly used intoxicant among underage youth in the U.S. followed by marijuana, with 45% of teens report drinking and 18% report using marijuana in the past month (Johnston et al., 2007). Alcohol-related effects on sleep have been extensively studied in adults. Acute and subacute alcohol withdrawal (<3 weeks) have been associated with decreased Slow Wave Sleep (SWS) and higher Rapid Eye Movement (REM) pressure (Roehrs and Roth, 2001; Gann et al., 2004). Sleep continuity is also disturbed, with abstinent users showing more awakenings, increased sleep latency (SL), shortened total sleep time (TST), and lowered sleep efficiencies (SE). In chronic users, irregular sleep patterns may persist up to two years following last use (Drummond et al., 1998).

The effects of marijuana use on sleep are less well studied. Available data indicate that marijuana use is associated with changes in sleep architecture, including reduced REM sleep and increased Non-REM sleep (Barratt et al., 1974; Feinberg et al., 1975, 1976), while the reverse follows marijuana withdrawal: a reduction in SWS coupled with a REM rebound and a shortened REM onset latency (Nicholson et al., 2004; Bolla et al, 2008).

The goal of the present study was, for the first time, to characterize the effects of acute and subacute marijuana and alcohol abstinence on sleep in youth during a monitored one-month abstinence period.

## METHODS

### Participants

As part of a larger study on neural activation in youth, parents and adolescents were administered a wide range of clinical interviews collecting medical, diagnostic, and demographic information, and substance use history (Medina et al., 2007; Tapert et al., 2007). Twenty-nine marijuana and alcohol users and 20 non-using healthy controls participated. Exclusion criteria included: history of DSM-IV Axis I disorder (other than alcohol or marijuana abuse/dependence), use of psychotropic medication, learning disability, loss of consciousness >2 minutes, neurological problems, prenatal substance exposure, and parental history of any mood or psychotic disorder.

Substance users had >200 lifetime experiences with marijuana and ≤ 30 lifetime uses of other drugs. Users needed to screen positive for marijuana on Night 1 (see below), but were not informed of this to ensure against any encouragement of use. Controls had ≤ 5 lifetime experiences with marijuana, none in the past month, and no use of any other drug. Participants could not have an Apnea-Hypopnea Index ≥ 5 (on Night 1, see below).

The UCSD Human Research Protections Program approved this study. All participants provided written informed assent (16–17 years) and written parental consent or personal consent (18–21 years) for their participation.

### Procedures

All participants underwent 28 days of monitored abstinence from alcohol and drugs. As cannabis metabolites can remain reliably detectible for at least 4 days after use (Fraser et al., 2002) subjects were required to provide monitored urine samples for drug toxicology every 3–4 days throughout the 28-day period.

Each participant was studied in the sleep laboratory for two consecutive nights at the beginning of the abstinence protocol (Nights 1 and 2 of abstinence) and then again on Nights 27 and 28 (i.e., after four weeks of abstinence). The PSG recording protocol used by our laboratory has

been previously published (Ayalon et al., 2009); PSG was visually scored by trained staff blind to group status using sleep staging criteria by Rechtschaffen and Kales (1973). The first night of each pair served as (1) an adaptation night to minimize possible "first night effects," and hence these data were not used in analyses and (2) a screening night for sleep apnea. Participants determined their own bedtimes and wake times, within the limitation that (1) bedtime could not exceed 1:00am, (2) total time in bed was 7–10 hours/night, and (3) the sleep schedule chosen on the first night remained consistent for the remaining PSG nights.

### Data Analyses

Groups were compared on demographic and substance use variables with independent samples *t*-tests and chi-square tests. Due to substance use relapse in 9/29 substance users, abstainers versus non-abstainers were compared on demographic, mood, and substance use variables with chi-square and *t*-tests. Additional *t*-tests prior to primary analyses ruled out: 1) differences in Apnea-Hypopnea Index on Night 1 between the groups; and 2) gender-related differences in PSG sleep measures.

To assess group differences in sleep measures, independent-sample t-tests were run for four sleep architecture measures (REM%, SWS%, REM latency, REM density), four continuity measures (TST, SL, WASO, and SE), and two measures of periodic limb movements (PLMI and PLMAI). To assess the relationships of marijuana and alcohol use with sleep, multiple linear regressions were run for Night 2 ($N$=49) and Night 28 ($N$=40) with each of the above measures as dependent variables. Independent variables for each regression were self-reported alcohol use (#drinks) and marijuana use (#hits) for the month prior to Night 1. As participants in both groups reported some use (especially alcohol), both groups were combined for regression analyses. Interpretations of statistical significance were made if $p<.05$; unstandardized betas are reported.

## RESULTS

### Demographics and Substance Use

Substance users and controls did not significantly differ on demographics or affective symptoms (see Table 1). All users were abstinent from all drugs and alcohol for at least one day by Night 2 ($n$=29), and 20 substance users had at least 28 days of verified abstinence by the last night of the study. As expected, users reported more past month and lifetime marijuana and alcohol use than controls. Nicotine use was relatively low, and no group difference was found on nicotine dependence scores; however, past month number of cigarettes smoked was higher among users. Users reported more *lifetime* use of stimulants, opioids, ecstasy, and hallucinogens than controls and greater past *month* hallucinogen and stimulant use.

As not all users successfully completed the 28-day abstinence protocol, abstainers ($n$=20) and non-abstainers ($n$=9) were compared on demographics and substance use in the month before abstinence was requested. Groups did not differ in age, gender, socioeconomic status, ethnic background, past month marijuana or alcohol use (all $p>.25$).

### Sleep Architecture

At Night 2, REM% ($p<.04$) was predicted by past month alcohol intake ($\beta$ =.05; $p<.05$), but not by marijuana intake ($\beta$ =.003; p=.54), for all participants. A trend was also found for REM latency to be predicted by past month substance use ($p<.09$), however neither alcohol ($\beta$ =−.18 ; $p$=.39) nor marijuana use ($\beta$ =−.05 ; $p$=.17) were independent predictors. Night 2 REM density was not predicted by either marijuana or alcohol intake ($p$=.62). A trend for significance was found for Night 2 SWS% ($p<.08$) to be predicted by past month substance use, with

marijuana ($\beta$ =−.01; $p$<.03), but not alcohol intake ($\beta$ =.02; $p$=.53) serving as a significant independent predictor.

On Night 28, neither alcohol nor marijuana intake predicted any sleep architecture measure and no group differences were found for any measure for both nights (see Table 2).

### Sleep Continuity

For all participants, SL ($p$<.03) was predicted by past month alcohol use ($\beta$ =.27; $p$<.01) on Night 2. Other sleep continuity measures on Nights 2 and 28 were not predicted by past month alcohol or marijuana intake. No group differences were found for any continuity measures on either night (see Table 2).

### Period Limb Movements in Sleep

As indicated in Table 2, neither group showed a mean PLMI or PLMAI in the clinically significant range and no group differences were found on either night. Nonetheless, the degree of prior substance use did predict PLMI/PLMAI values on Night 28, specifically, previous month marijuana use predicted both PLMI ($\beta$ =.02; $p$<.001) and PLMAI ($\beta$ =.01; $p$<.001), while previous month alcohol intake also contributed to PLMAI ($\beta$ =−.02; $p$<.04) (see Table 2).

## DISCUSSION

The goal of the current study was to explore whether marijuana and alcohol use affects the sleep EEG during a 28-day monitored abstinence period in a sample of adolescents with and without recent substance use. The data suggest modest but significant sleep architecture alterations in adolescent substance users at the onset of abstinence, with most abnormalities abating within one month. In this sample, heavy drinking was linked with higher REM pressure, i.e. greater REM% and marginally shorter REM latency, and longer sleep latencies in early abstinence, whereas heavy marijuana use predicted lower SWS% in early abstinence. The effects of recent substance use on sleep did not extend to 28 days of abstinence, though. On the other hand, prior substance use, especially the amount of marijuana use, predicted indices of PLMs, but only after 28 days of abstinence. Thus, overall, our hypotheses regarding the influence of prior substance use on sleep parameters were partly confirmed.

Similar, though stronger, acute sleep alterations are consistently reported in alcohol and marijuana abusing adults, however these alterations (at least those related to alcohol) in adults sustain up to several months into abstinence (Gillin et al., 2005). Several historical and developmental factors may explain why adolescent users are less susceptible than older users to acute and ongoing substance-induced influences on sleep, such as: a) less frequent and/or less intense use pattern; b) shorter chronicity of use; and c) youth may more quickly rebound from physiological insult, leading to shorter sleep recovery times. Additional PSG studies examining acute, subacute, and long-term withdrawal in adolescents and adults are needed to ascertain the causes of this discrepancy.

Also similar to adult users, this sample of adolescents showed effects of substance abstinence on periodic limb movements (PLMs) in sleep. During protracted abstinence, but not acute cessation, heavy marijuana use predicted more PLMs, and both heavy marijuana and alcohol use predicted PLM-associated cortical arousals. These results are consistent with previous reports in the adult literature showing acute alcohol use may have a suppressant effect on PLMs, possibly followed by an unmasking effect and return to baseline or worse during subacute withdrawal (Aldrich and Shipley, 1993; Gann et al., 2002). Treatment outcome studies are

needed to further clarify whether relapse rates are higher among frequent users with a comorbid PLMS condition and whether treatment for PLMS may protect teens from relapse.

Some study limitations should be considered. Differences in sleep patterns could predate substance use onset. Further, it is possible that synergistic effects of combined alcohol and marijuana use and subsequent cessation in this sample may account for or even obscure the findings; additional studies are needed to examine the effects of alcohol and of marijuana alone. Also, a possibility remains the participants engaged in substance use during the course of the study, particularly with compounds with shorter half-lives, such as alcohol; unfortunately short of hospitalizing participants, this limitation cannot be avoided. It is unclear from these data exactly when within the 28-day abstinence period the sleep abnormalities may abate; additional research will need to examine this using more frequent assessments. Finally, results should be replicated, given large individual variability of sleep measures, modest power and lack of strict Type I error correction.

In conclusion, adolescents who are heavy users of marijuana and/or alcohol show disturbed sleep architecture, immediately upon cessation of substance use. Interestingly, adolescents may find largely improved overall sleep patterns after just four weeks of abstinence. Despite these corrections, heavier prior substance use did lead to greater rates of PLMS after 28 days, suggesting that sleep may not have completely recovered from prior use. Given the relatively frequent and erratic use pattern seen in adolescents sleep may be chronically and repeatedly disturbed, presenting potentially significant problems during this critical developmental period.

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**Table 1**

Demographic and Substance Use Characteristics by Group at Night 1

| | Controls (*n*=20) M (SD) or % [range] | Substance Users (*n*=29) M (SD) or % [range] | t-value/$\chi^2$(df) |
|---|---|---|---|
| Age | 18.4 (1.2) [16.3–21.4] | 18.2 (1.1) [16.4–20.9] | 0.84 (47) |
| Female | 40% | 24% | 1.40 (1) |
| Non-White | 40% | 48% | 4.1 (5) |
| Socioeconomic status (Hollingshead) | 29.0 (17.0) [11.0–77.0] | 29.2 (12.6) [11.0–58.0] | −0.03 (47) |
| Beck Depression Inventory-II (BDI-II) | 2.2 (2.4) [0.0–7.0] | 2.7 (2.9) [0.0–12.0] | −0.03 (47) |
| State-Trait Anxiety Inventory (STAI) | 37.5 (4.3) [30.0–49.5] | 38.2 (4.8) [30.0–47.5] | −0.72 (47) |
| Smoked cigarettes/month, past month** | 0.1 (0.2) [0.0–1.0] | 4.2 (7.5) [0.0–30.0] | −2.99 (47) |
| Apnea Hypopnea Index† | 0.5 (1.1) [0.0 – 4.2] | 0.4 (0.6) [0.0 – 2.1] | 0.20 (47) |
| Fagerstrom Test of Nicotine Dependence | 0.0 (0.0) | 0.17 (0.5) | −1.43 (47) |
| Marijuana hits/month, past month*** | 0.0 (0.0) | 204.1 (232.1) [9.0–837.0] | −3.92 (47) |
| Lifetime marijuana use episodes*** | 0.50 (1.2) [0.0–4.0] | 582.7 (382.4) [200.0–1800.0] | −6.79 (47) |
| Days since last marijuana use***‡ | 448.5 (260.5) [157.0–672.0] | 1.9 (1.6) [1.0–8.0] | 10.2 (30) |
| Drinks/month, past month*** | 2.4 (4.5) [0.0–14.0] | 39.4 (41.3) [10.0–806.0] | −3.98 (47) |
| Lifetime alcohol use episodes*** | 26.0 (46.0) [0.0–196.0] | 214.4 (207.8) [0.0–150.0] | −3.98 (47) |
| Days since last drink**‡ | 118.8 (176.7) [6.0–649.0] | 11.4 (39.3) [1.0–211.0] | 3.10 (39) |
| Other drug use/month, past month***∞ | 0.0 (0.0) | 1.1 (1.8) [0.0–9.0] | −3.05 to –2.05 (47) |
| Lifetime other drug use episodes**∞ | 0.0 (0.0) | 7.8 (8.7) [0.0–30] | −2.77 to –2.22 (47) |
| Days since last other drug use‡ | -- | 135.6 (264.8) [6.0–1203.0] | -- |

** *t* -test or chi-square $p<.01$

*** *t* -test or chi-square $p<.001$

‡ Only for those participants who reported use

∞ Includes stimulants, opioids, hallucinogens, and ecstasy

† Collected on adaptation night (Night 1) only

**Table 2**

Sleep Continuity and Architecture for Nights 2 and 28 by Group

| | Controls M (SD) [range] | | Substance Users M (SD) [range] | |
|---|---|---|---|---|
| **Night** | **2 (*n*=20)** | **28 (*n*=20)** | **2 (*n*=29)** | **28 (*n*=20)** |
| Total Sleep Time | 456.2 (51.7) [352 – 526] | 446.75 (44.2) [362 – 506] | 454.69 (52.4) [348 – 567] | 420.30 (53.9) [265 – 501] |
| Sleep Latency | 14.05 (12.0) [4 – 53] | 14.20 (13.2) [3 – 55] | 22.26 (27.7) [3 – 136] | 18.8 (20.3) [3 – 74] |
| Wake After Sleep Onset | 27.0 (28.3) [4.5 – 126.0] | 18.8 (14.4) [0.0 – 58.0] | 20.7 (15.6) [2.0 – 62.5] | 21.0 (18.4) [2.5 – 67.5] |
| Sleep Efficiency | 90.8 (5.4) [73.3 – 96.4] | 92.2 (3.2) [83.8 – 96.0] | 90.7 (5.8) [72.0 – 97.0] | 90.5 (5.9) [78.0 – 96.9] |
| Stage 1% | 4.7 (3.4) [1.5 – 13.6] | 3.7 (1.8) [0.0 – 6.9] | 4.1 (1.8) [1.7 – 7.0] | 4.6 (2.9) [1.3 – 11.3] |
| Stage 2% | 54.6 (7.0) [40.7 – 65.2] | 54.6 (8.6) [30.5 – 67.8] | 51.6 (8.0) [29.2 – 64.6] | 53.9 (6.9) [43.7 – 66.9] |
| Slow Wave Sleep % (SWS%) | 20.4 (7.3) [10.4 – 42.3] | 21.7 (9.9) [8.0 – 57.6] | 20.9 (7.6) [8.3 – 36.8] | 21.0 (5.7) [8.5 – 28.5] |
| Rapid Eye Movement Sleep % (REM%) | 20.2 (5.8) [9.5 – 33.0] | 20.0 (3.5) [11.9 – 26.3] | 23.4 (5.7) [8.3 – 35.8] | 20.6 (4.0) [12.7 – 27.9] |
| REM Latency | 87.0 (40.3) [0.0–170.0] | 88.5 (31.9) [56.0–161.5] | 77.0 (52.9) [0.0–249.5] | 102.5 (51.3) [50.0–200.0] |
| REM Density | 2.2 (0.6) [1.0–3.0] | 2.1 (0.6) [1.0–4.0] | 2.2 (0.7) [1.0–3.0] | 2.2 (0.8) [0.0–4.0] |
| Periodic Limb Movement Index | 3.8 (5.8) [0.0 – 23.7] | 3.8 (5.1) [0.0 – 16.2] | 2.6 (4.4) [0.0 – 15.9] | 3.8 (5.1) [0.0 – 17.6] |
| Periodic Limb Movement Arousal Index | 0.8 (1.5) [0.0 – 6.8] | 0.4 (0.6) [0.0 – 2.1] | 0.9 (1.4) [0.0 – 5.9] | 1.2 (2.2) [0.0 – 9.7] |