

Novel Methods of Cannabis Use and Lower Sleep Duration Among High School Students

Evan A. Winiger¹, Ming Ma²,
Ashley Brooks-Russell²

¹Department of Psychiatry, University of Colorado Anschutz Medical Campus, Aurora

²Colorado School of Public Health, Department of Community and Behavioral Health, University of Colorado Anschutz Medical Campus, Aurora

Cannabis

2022

© Author(s) 2022

researchmj.org

DOI: 10.26828/cannabis/2022.02.006



ABSTRACT

Background. The general use of cannabis in adolescence is associated with various sleep deficits. While traditional smoking remains the most common form of cannabis consumption amongst adolescents, novel methods of administration are becoming more popular and available due to legalization. The association of these novel methods of use with sleep in adolescence has yet to be studied and research is needed to inform public health initiatives. **Methods.** High school (9th-12th grade) students from the Healthy Kids Colorado Survey with current cannabis use (n= 4,637) reported on numerous demographic variables, method of cannabis use (flower, edibles, dabs, and vaporizers) and average sleep duration on weeknights. Logistic regression assessed the relationship between novel methods of use (edibles, dabs, and vaporizers) and sleep duration in comparison to cannabis flower. **Results.** Use of any edible, dab, or vaporizer product in the past 30-days was associated with being male and current tobacco use. Reporting a novel method of use as the most common mode of cannabis use was associated with current tobacco use and higher mothers' education. Students who used any novel method products in the past 30 days or reported these products as the usual mode of cannabis use, were more likely to sleep 7 hours or fewer a night. **Conclusions.** Novel methods of cannabis administration such as edibles, dabs, and vaporizers are associated with getting less sleep than recommended (7 or less hours), in comparison to those who smoked flower. Sleep outcomes should be a focus of study for novel cannabis products amongst high school adolescents.

Key words: = concentrates; marijuana; cannabis; adolescent substance use

Sleep is crucial for adolescent development and is critical for the processes of cognition, physiology, and mental health (Tarokh et al., 2016). Sleep issues are common among adolescence, with the prevalence of insomnia being as high 24% (Hysing et al., 2013) and 41% of adolescence reporting feeling tired or sleepy during the day (Kolla et al., 2019). While cannabis use is often thought to be a sleep aid among adults (Altman et al., 2019), frequent cannabis use is associated with numerous sleep deficits (Edwards & Filbey, 2021). Cannabis use during adolescence has been linked to poor sleep outcomes including higher rates of insomnia (Roane & Taylor, 2008), shorter total sleep time, later bedtimes (Troxel et al., 2015), insufficient

sleep on school nights (Kwon et al., 2020; McKnight-Eily et al., 2011), overall greater sleep problems (Zhabenko et al., 2016), and minor sleep architecture alterations during the onset of abstinence (Cohen-Zion et al., 2009). The current body of research regarding cannabis and sleep in adolescence is based on studies that have measured any use of cannabis, with no focus or distinction on the method of administration.

While smoking remains the most common mode of cannabis consumption among adolescents, alternative methods of administration (such as ingesting, vaporizing, and dabbing) that are often high in tetrahydrocannabinol (THC) (Cinnamon Bidwell et al., 2018) and have increased subjective

effects compared to flower (Spindle et al., 2018), are more widely available because of legalization (Knapp et al., 2019). A recent meta-analysis on cannabis vaping in adolescents estimate prevalence rates have increased in the last decade, estimating 13.6% for lifetime use, 13.2% for past 12-month use, and 1.6% for past 30-day use (Lim et al., 2022). Other recent studies estimate lifetime concentrate use (hash oil, wax, crumble, shatter) at 24% and past month concentrate use at 12.7% (Meier et al., 2019), as well as lifetime edible use at 21% and past 30-day edible use at 4.9% (Peters et al., 2018). The influence of these novel methods on health and behavioral outcomes in adolescence, particularly on sleep, has yet to be understood (Bidwell et al., 2021). While little is known regarding the exact relationship between these novel products and sleep in general, there is evidence to suggest that THC is associated with sleep architecture alterations (such as reduced time in rapid eye movement) (Edwards & Filbey, 2021; Schierenbeck et al., 2008) and that increased frequency of edibles could be associated with increased sleep issues in adults (Winiger et al., 2021). Due to the changing legal landscape and expansion of novel and often high THC cannabis products, research is needed to understand their relationship with sleep during adolescence, an activity critical for brain development (Telzer et al., 2015). In this study, we examined the association of novel cannabis products (edibles, vaporizers, and dabs) with sleep duration in a statewide representative sample of high school students in Colorado.

METHODS

Data are from 2019 administration of the Healthy Kids Colorado Survey (HKCS) (Colorado

Department of Public Health and Environment, 2021), a biennial cross-sectional survey conducted in Colorado that includes 9th- through 12th-grade students (n=46,537). The current study included students who reported using cannabis in the past 30 days in one of the two survey modules that included questions about mode of cannabis use (n=4,637). The HKCS uses a stratified cluster design with random sampling of public high schools. Teachers provided instructions that stated that students could choose to skip questions or not participate without consequence. Students completed the survey on paper or online, as determined by school administration. Parents were notified and could opt-out their child. This study was approved by the Colorado Multiple Institutional Review Board. Cannabis use was assessed by two questions: “During the past 30 days, how did you use marijuana? (select all that apply).” and “During the past 30 days, how did you usually use marijuana? (select only one response).” Response options included: smoked it, ate it, used a vaporizer, dabbed it, and used it in some other way. We collapsed edibles, vaporizing, and dabbing into a novel methods of use category with the flower group as the reference group. One set of analysis focused on the first question in which students could choose all methods of use. Among the 4,637 students, 1,202 reported only using flower and 860 reported using any novel use in the past 30 days, which were the two groups used in analysis. The 2,328 students who reported using flower, novel, and other products were removed (as using methods in both groups was exclusion criteria for this analysis). Furthermore, 247 students who reported using other products and did not report using either flower or novel products were removed for the any use analysis.

Table 1. *Number of Students Endorsing Each Method of Use Before Generating the Flower and Novel Methods of Use Groups for Each Analysis*

Method of cannabis use	Any use in the past 30 days	Usual method of use in the past 30 days
Smoking	3,530	2,463
Edibles	1,593	440
Vaping	1,436	389
Dabbing	2,185	809
Other way	404	86

Note. The usual method of use was a single selection whereas the use of any method allowed students to check all that apply.

Table 2. Novel Methods of Cannabis Use in the Past 30 Days by Individual Characteristics Among Current Cannabis Users; Public High School Students in Colorado, 2019 (Weighted Results, Unweighted N=4,637)

	Overall	Any novel method of use, past 30 days % (95% CI) (N = 860)	Only smoking flower, past 30 days % (95% CI)	<i>p</i>	Novel method of use as usual mode, past 30 days % (95% CI)	Smoking flower as usual mode, past 30 days % (95% CI)	<i>p</i>
N (unweighted)	4,637	860	1,202		1,638	2,463	
Sex				0.03*			0.08
Female	48.6 (47.1, 50.0)	44.9 (40.8, 49.0)	53.7 (50.5, 57.0)		46.8 (44.5, 49.0)	51.1 (48.7, 53.4)	
Male	51.4 (50.0, 52.9)	55.1 (51.0, 59.2)	46.3 (43.0, 49.5)		53.2 (51.0, 55.5)	48.9 (46.6, 51.3)	
Grade				0.31			0.34
9 th	16.6 (15.3, 18.0)	15.3 (12.8, 17.8)	18.0 (15.0, 20.9)		16.0 (13.9, 18.0)	17.2 (15.3, 19.0)	
10 th	23.2 (21.7, 24.8)	24.5 (21.2, 27.9)	19.8 (17.2, 22.4)		23.5 (21.3, 25.8)	23.0 (20.5, 25.4)	
11 th	28.3 (26.4, 30.2)	31.1 (27.4, 34.8)	30.0 (27.0, 33.1)		30.5 (27.7, 33.4)	26.7 (24.6, 28.9)	
12 th	31.8 (29.6, 34.0)	29.1 (26.1, 32.0)	32.2 (27.6, 36.8)		29.9 (27.5, 32.4)	33.2 (29.9, 36.4)	
Race/ethnicity				0.12			0.08
Non-Hispanic White	53.3 (50.3, 56.3)	54.1 (48.3, 59.9)	50.3 (45.5, 55.0)		58.3 (53.8, 62.8)	51.9 (48.3, 55.5)	
Non-Hispanic Black	4.5 (3.2, 5.8)	2.8 (1.1, 4.5)	8.0 (4.5, 11.5)		3.1 (1.9, 4.4)	5.5 (3.4, 7.7)	
Hispanic	34.7 (31.3, 38.0)	35.0 (29.6, 40.4)	33.9 (29.3, 38.6)		30.5 (26.6, 34.4)	35.0 (31.0, 39.0)	
Other/Multi-racial	7.6 (6.8, 8.4)	8.1 (6.3, 10.0)	7.8 (6.3, 9.4)		8.1 (6.8, 9.4)	7.5 (6.2, 8.8)	
Mother's education				0.06			0.001*
Less than college	35.7 (32.5, 39.0)	31.9 (27.8, 36.0)	38.7 (34.6, 42.9)		29.9 (26.0, 33.9)	38.8 (35.3, 42.4)	
College or more	64.3 (61.0, 67.5)	68.1 (64.0, 72.2)	61.3 (57.1, 65.4)		70.1 (66.1, 74.0)	61.2 (57.6, 64.7)	
Felt sad/depressed				0.54			0.10
No	45.9 (43.7, 48.1)	51.5 (47.7, 55.3)	48.6 (44.1, 53.1)		48.2 (45.4, 50.9)	44.1 (40.9, 47.2)	
Yes	54.1 (51.9, 56.3)	48.5 (44.7, 52.3)	51.4 (46.9, 55.9)		51.8 (49.1, 54.6)	55.9 (52.8, 59.1)	
Current tobacco use				0.03*			0.006*
No	30.4 (28.3, 32.5)	35.4 (32.2, 38.7)	42.2 (38.1, 46.3)		26.9 (24.5, 29.4)	32.8 (30.0, 35.5)	
Yes	69.6 (67.5, 71.7)	64.6 (61.3, 67.8)	57.8 (53.7, 61.9)		73.1 (70.6, 75.5)	67.2 (64.5, 70.0)	
Current alcohol use				0.26			0.14
No	26.8 (25.0, 28.7)	29.7 (25.3, 34.0)	34.8 (30.3, 39.4)		23.9 (21.1, 26.7)	28.6 (25.4, 31.7)	
Yes	73.2 (71.3, 75.0)	70.3 (66.0, 74.7)	65.2 (60.6, 69.7)		76.1 (73.3, 78.9)	71.4 (68.3, 74.6)	
Number of times using cannabis, past 30 days				0.81			0.67
1 to 9 times	57.5 (55.6, 59.3)	75.3 (71.9, 78.7)	73.4 (70.1, 76.6)		60.4 (57.3, 63.4)	58.1 (55.7, 60.6)	
10 to 19 times	12.7 (11.6, 13.8)	8.3 (6.5, 10.2)	9.3 (7.4, 11.3)		12.4 (10.4, 14.4)	12.6 (11.1, 14.2)	
20 times or more	29.8 (28.0, 31.6)	16.4 (13.1, 19.7)	17.3 (14.6, 20.0)		27.2 (24.4, 30.1)	29.2 (26.8, 31.7)	

* $p < .05$. Note. Current substance use is any use in the past 30 days. The first comparison is exclusive novel use to exclusive flower smoking, excluding 2,328 students who used novel, other, and flower products, and 247 students who did not report using either flower or novel products. The second comparison is usual novel product use to smoking flower, inclusive of all students who currently use cannabis. Current tobacco use is inclusive of cigarette and/or e-cigarette use. Felt sad/depressed is reporting feeling sad for two weeks or more in the past 12 months. Rao-Scott chi-square tests were used to determined significant differences between novel mode of use vs. smoking within each demographic factor of individual level characteristic.

The second set of analysis focused on the second question in which students choose only one method of use as their “usual” use. Table 1 details the number of students endorsing each method of use for each of the questions (check all that apply and select only one).

Student responses were weighted to represent Colorado public high school enrollment for grade, sex, and race/ethnicity. Weighted prevalence estimates were calculated for any mode and usual mode of cannabis use. The Rao-Scott chi-square tests were used for comparing any and usual mode of novel method of cannabis use between different levels of each of the demographic, substance use, and mental health indicators (Rao & Scott, 2007). We used multivariable logistic regression, adjusted for sex, grade, race/ethnicity, mother’s education, current substance use (tobacco, alcohol), frequency of use, and feeling sad/depressed, to assess the relationship between novel methods of cannabis use and sleep duration (statistical significance, $p < .05$). Analyses were completed using SAS v9.4.

RESULTS

Weighted prevalence rates for usual mode of cannabis use were 56.5% for smoking, 20.6% for dabbing, 10.7% for vaping, 10.0% for edibles, and 2.2% for some other way (not reported), while weighted prevalence rates for any mode of use were 77.9% smoking, 52.0% dabbing, 35.6% edibles, 34.3% vaping, and 8.4% some other way (not reported). Among students who reported past-month cannabis use, there were significant differences in individual characteristics for using any form of edible, dab, or vaporizer products in the past 30 days, and for these novel methods being the usual mode of cannabis use (Table 2). Among those using any novel methods products, there was a significantly higher proportion of males and current tobacco use. Among those who reported these methods as their usual mode of use, there was a significantly higher proportion with current tobacco use and higher mothers’ education (college or more).

There was no significant difference between novel method of administration and mean hours of sleep in the unadjusted analysis (data not shown). In adjusted analysis including covariates, among students who used any novel method of administration in the past 30 days, they were 1.46

(95% CI: 1.05-2.02) times as likely to sleep 7 hours or fewer a night compared with those smoking cannabis flower (Table 3). Similarly, students who reported that these products were the usual mode of cannabis use were 1.41 (95% CI: 1.14-1.75) times as likely to report sleeping 7 hours or fewer a night compared to smoking flower.

DISCUSSION

Colorado high school students who reported using either edibles, dabs, or vaporizing or using any of these methods as their most common method of use in the past 30 days, were more likely to be categorized as not getting enough sleep (7 or less hours) on average in comparison to those who smoked flower. These are the first known findings of a relationship between these novel cannabis use methods and low sleep duration among adolescents, implying that potential sleep issues, above and beyond traditional flower, are associated with the growing use of novel cannabis methods with adolescents. A possible biological explanation is that using exogenous cannabinoids (such as THC) activates the endocannabinoid system, which can cause disruptions in the sleep-wake cycle and circadian rhythms (Prospéro-García et al., 2016). Use of cannabis products, especially ones potentially high in THC such as concentrates, might alter adolescent’s sleep-wake cycle leading to lower sleep duration. The association found could also be spurious and reflect the co-occurrence of other substance use, peer substance use, and risk factors that are associated with newer forms of cannabis use (Meier et al., 2019). Provided the role of confounders in our results, additional risk factors or behaviors could have a strong influence on this association. Future research is needed to understand the exact mechanisms responsible for this relationship.

We found several demographic associations that support prior research as well as one association that is novel and elicits future investigation. Prior findings of adolescent vaporizer use being significantly associated with the male sex (Morean et al., 2021; Peters et al., 2018) and tobacco use (Kowitt et al., 2019; Meier et al., 2019; Morean et al., 2021) complement our results, yet research regarding these relationships for both edibles and dabs has yet to be established. Studies regarding novel methods

Table 3. *Adjusted Association Between Sleep and Any or Usual Novel Method of Cannabis Use in the Past 30 Days Among Current Cannabis Users: Public High School Students In Colorado, 2019*

	Adjusted OR (95% CI) of having insufficient sleep (7 hours or fewer) [Ref: sufficient sleep (8 hours or more)]	
Cannabis use		
Smoked flower	ref	ref
Any novel method	1.46 (1.05, 2.02)*	-
Novel method as usual method	-	1.41 (1.14, 1.75)*
Estimate of other covariates		
Gender		
Female	ref	ref
Male	0.85 (0.65, 1.12)	0.72 (0.59, 0.87)
Grade		
9th	ref	ref
10 th	1.47 (0.84, 2.55)	1.35 (0.96, 1.90)
11 th	1.74 (1.01, 3.02)	1.46 (1.07, 2.01)
12 th	1.59 (0.99, 2.58)	1.54 (1.14, 2.08)
Race and ethnicity		
Non-Hispanic White	ref	ref
Non-Hispanic Black	2.04 (1.12, 3.69)	1.22 (0.80, 1.85)
Hispanic	1.70 (1.24, 2.33)	1.35 (1.07, 1.71)
Other and multi-racial	1.85 (0.97, 3.55)	1.68 (1.13, 2.52)
Mother's education		
College or above	ref	ref
Less than college	1.26 (0.90, 1.77)	1.25 (1.01, 1.54)
Current tobacco use		
No	ref	ref
Yes	1.34 (1.00, 1.79)	1.27 (1.02, 1.59)
Current alcohol use		
No	ref	ref
Yes	0.95 (0.63, 1.44)	0.95 (0.74, 1.23)
Felt sad/depressed		
No	ref	ref
Yes	1.57 (1.21, 2.03)	1.91 (1.52, 2.41)
Number of times using cannabis, past 30 days		
1 to 9 times	ref	ref
10 to 19 times	1.06 (0.66, 1.68)	1.49 (1.13, 1.96)
20 times+	0.75 (0.50, 1.14)	1.03 (0.79, 1.35)

Note. Novel method of cannabis use including edibles, dabs, and vaping with flower being the reference group. Models control for sex, grade, race/ethnicity, mother's education, current tobacco use, current alcohol use, frequency of use, and feeling sad/depressed. * $p < .05$.

of cannabis use and socio-economic status (SES) are mixed. There is evidence of lower SES factors being associated with lifetime edible (Peters et al., 2018) and concentrate use (smoked or vaped marijuana concentrates such as hash oil, wax, crumble, shatter) (Meier et al., 2019). However, other studies have failed to find significant relationships between cannabis vaporizing and SES (Kowitt et al., 2019; Meier et al., 2019; Morean et al., 2021).

Interestingly, there are studies that show higher SES in adolescence is associated with general cannabis use in early adulthood (Humensky, 2010), and that increased cannabis vaping frequency in young adults is associated with being from a higher SES family (Jones et al., 2016). In relation to our finding of a significant relationship between novel methods of cannabis use being the most common method of use in the past 30 days and increased mothers education (a proxy for higher SES), we can speculate (as have others (Peters et al., 2018)) that the high cost of these novel cannabis products in relation to flower is a financial barrier that could limit adolescents in lower SES from access or use, thus those in a higher-SES might have greater financial resource to use these types of novel methods. This finding warrants future research to better understand the relationship of SES and novel methods of cannabis use.

Limitations

Limitations of the study include the cross-sectional design, utilizing self-report measures, the single-item report of sleep duration, lack of detail regarding the specific methods of cannabis administration used (such as a lack of differentiation between vaporizing concentrates or flower), and a lack of detail regarding quantity and THC concentration of cannabis use. Additionally, the unadjusted analysis failed to find an effect, demonstrating the influential role of confounders in this complicated relationship. Despite these limitations, Colorado is unique in that it is a recreationally legal state with a robust legal cannabis market, and there are population-based data on alternative modes of marijuana consumption among adolescents. Future studies should focus on specific type of high concentrate products (edibles, dabbing, vaping, etc.) on sleep outcomes and should also include longitudinal

designs to better understand the influence of novel cannabis use on sleep during adolescence and into adulthood, and other possible health outcomes.

REFERENCES

- Altman, B. R., Mian, M. N., Slavin, M., & Earleywine, M. (2019). Cannabis expectancies for sleep. *Journal of Psychoactive Drugs, 51*(5), 405-412.
- Bidwell, L. C., Martin-Willett, R., & Karoly, H. C. (2021). Advancing the science on cannabis concentrates and behavioural health. *Drug and Alcohol Review, 40*(6), 900-913.
- Bidwell, L. C., YorkWilliams, S. L., Mueller, R. L., Bryan, A. D., & Hutchison, K. E. (2018). Exploring cannabis concentrates on the legal market: User profiles, product strength, and health-related outcomes. *Addictive Behaviors Reports, 8*, 102-106.
- Cohen-Zion, M., Drummond, S. P., Padula, C. B., Winward, J., Kanady, J., Medina, K. L., & Tapert, S. F. (2009). Sleep architecture in adolescent marijuana and alcohol users during acute and extended abstinence. *Addictive Behaviors, 34*(11), 976-979.
- Colorado Department of Public Health and Environment. (2021). Healthy Kids Colorado Survey. <https://cdphe.colorado.gov/hkcs>
- Edwards, D., & Filbey, F. M. (2021). Are sweet dreams made of these? Understanding the relationship between sleep and cannabis use. *Cannabis and Cannabinoid Research, 6*(6), 462-473.
- Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., ... & Hillard, P. J. A. (2015). National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health, 1*(1), 40-43.
- Humensky, J. L. (2010). Are adolescents with high socioeconomic status more likely to engage in alcohol and illicit drug use in early adulthood?. *Substance Abuse Treatment, Prevention, and Policy, 5*(1), 1-10.
- Hysing, M., Pallesen, S., Stormark, K. M., Lundervold, A. J., & Sivertsen, B. (2013). Sleep patterns and insomnia among adolescents: a population-based study. *Journal of Sleep Research, 22*(5), 549-556.

- Jones, C. B., Hill, M. L., Pardini, D. A., & Meier, M. H. (2016). Prevalence and correlates of vaping cannabis in a sample of young adults. *Psychology of Addictive Behaviors, 30*(8), 915.
- Knapp, A. A., Lee, D. C., Borodovsky, J. T., Auty, S. G., Gabrielli, J., & Budney, A. J. (2019). Emerging trends in cannabis administration among adolescent cannabis users. *Journal of Adolescent Health, 64*(4), 487-493.
- Kolla, B. P., He, J. P., Mansukhani, M. P., Kotagal, S., Frye, M. A., & Merikangas, K. R. (2019). Prevalence and correlates of hypersomnolence symptoms in US teens. *Journal of the American Academy of Child & Adolescent Psychiatry, 58*(7), 712-720.
- Kowitz, S. D., Osman, A., Meernik, C., Zarkin, G. A., Ranney, L. M., Martin, J., ... & Goldstein, A. O. (2019). Vaping cannabis among adolescents: prevalence and associations with tobacco use from a cross-sectional study in the USA. *BMJ Open, 9*(6), e028535.
- Kwon, M., Seo, Y. S., Park, E., & Chang, Y. P. (2021). Association between substance use and insufficient sleep in US high school students. *The Journal of School Nursing, 37*(6), 470-479.
- Lim, C. C., Sun, T., Leung, J., Chung, J. Y., Gartner, C., Connor, J., ... & Chan, G. C. (2021). Prevalence of adolescent cannabis vaping: a systematic review and meta-analysis of US and Canadian studies. *JAMA Pediatrics, 176*(1), 42-51.
- McKnight-Eily, L. R., Eaton, D. K., Lowry, R., Croft, J. B., Presley-Cantrell, L., & Perry, G. S. (2011). Relationships between hours of sleep and health-risk behaviors in US adolescent students. *Preventive Medicine, 53*(4-5), 271-273.
- Meier, M. H., Docherty, M., Leischow, S. J., Grimm, K. J., & Pardini, D. (2019). Cannabis concentrate use in adolescents. *Pediatrics, 144*(3).
- Morean, M. E., Davis, D. R., Kong, G., Bold, K. W., Camenga, D. R., Suttiratana, S., ... & Krishnan-Sarin, S. (2021). Demographic and substance use-related differences among high school adolescents who vape cannabis versus use other cannabis modalities. *Drug and Alcohol Dependence, 228*, 109104.
- Paruthi, S., Brooks, L. J., D'Ambrosio, C., Hall, W. A., Kotagal, S., Lloyd, R. M., ... & Wise, M. S. (2016). Consensus statement of the American Academy of Sleep Medicine on the recommended amount of sleep for healthy children: methodology and discussion. *Journal of Clinical Sleep Medicine, 12*(11), 1549-1561.
- Peters, E. N., Bae, D., Barrington-Trimis, J. L., Jarvis, B. P., & Leventhal, A. M. (2018). Prevalence and sociodemographic correlates of adolescent use and polyuse of combustible, vaporized, and edible cannabis products. *JAMA Network Open, 1*(5), e182765-e182765.
- Prospéro-García, O., Amancio-Belmont, O., Meléndez, A. L. B., Ruiz-Contreras, A. E., & Méndez-Díaz, M. (2016). Endocannabinoids and sleep. *Neuroscience & Biobehavioral Reviews, 71*, 671-679.
- Rao, J. N. K., & Scott, A. J. (1987). On simple adjustments to chi-square tests with sample survey data. *The Annals of Statistics, 15*(1), 385-397.
- Roane, B. M., & Taylor, D. J. (2008). Adolescent insomnia as a risk factor for early adult depression and substance abuse. *Sleep, 31*(10), 1351-1356.
- Schierenbeck, T., Riemann, D., Berger, M., & Hornyak, M. (2008). Effect of illicit recreational drugs upon sleep: cocaine, ecstasy and marijuana. *Sleep Medicine Reviews, 12*(5), 381-389.
- Spindle, T. R., Cone, E. J., Schlienz, N. J., Mitchell, J. M., Bigelow, G. E., Flegel, R., ... & Vandrey, R. (2018). Acute effects of smoked and vaporized cannabis in healthy adults who infrequently use cannabis: a crossover trial. *JAMA Network Open, 1*(7), e184841-e184841.
- Tarokh, L., Saletin, J. M., & Carskadon, M. A. (2016). Sleep in adolescence: Physiology, cognition and mental health. *Neuroscience and Biobehavioral Reviews, 70*, 182.
- Telzer, E. H., Goldenberg, D., Fuligni, A. J., Lieberman, M. D., & Gálvan, A. (2015). Sleep variability in adolescence is associated with altered brain development. *Developmental Cognitive Neuroscience, 14*, 16-22.
- Troxel, W. M., Ewing, B., & D'Amico, E. J. (2015). Examining racial/ethnic disparities in the association between adolescent sleep and alcohol or marijuana use. *Sleep Health, 1*(2), 104-108.
- Winiger, E. A., Hitchcock, L. N., Bryan, A. D., & Bidwell, L. C. (2021). Cannabis use and sleep: expectations, outcomes, and the role of age. *Addictive Behaviors, 112*, 106642.

Zhabenko, O., Austic, E., Conroy, D. A., Ehrlich, P., Singh, V., Epstein-Ngo, Q., ... & Walton, M. A. (2016). Substance use as a risk factor for sleep problems among adolescents presenting to the emergency department. *Journal of Addiction Medicine, 10*(5), 331.

Funding and Acknowledgements: The data used for this study were collected under a contract with the Colorado Department of Public Health and Environment (Brooks-Russell, principal investigator). This work was supported by National Institute on Mental Health grant T32 MH015442 (Winiger).

The National Institute on Drug Abuse and Colorado Department of Public Health and Environment had no role in determining study design, data collection, analysis, or interpretation, writing the report, or the decision to submit the report for publication. The authors have no conflicts of interest to disclose.

Dr.'s Winiger, Ma, and Brooks-Russell conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Copyright: © 2022 Authors et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by-nc-nd/4.0/), which permits unrestricted use, distribution, and reproduction, provided the original author and source are credited, the original sources is not modified, and the source is not used for commercial purposes.

