

Recent cannabis use and nightly sleep duration in adults: a population analysis of the NHANES from 2005 to 2018

Calvin Diep ¹, Chenchen Tian,¹ Kathak Vachhani,² Christine Won,³ Duminda N Wijeyesundera ^{1,4}, Hance Clarke ^{1,5}, Mandeep Singh ^{1,5}, Karim S Ladha^{1,4}

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/rapm-2021-103161>).

¹Department of Anesthesiology and Pain Medicine, University of Toronto, Toronto, Ontario, Canada

²Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada

³Department of Internal Medicine, Yale University School of Medicine, New Haven, Connecticut, USA

⁴Department of Anesthesia, St Michael's Hospital, Toronto, Ontario, Canada

⁵Department of Anesthesia and Pain Management, University Health Network, Toronto, Ontario, Canada

Correspondence to

Dr Karim S Ladha, Department of Anesthesiology and Pain Medicine, University of Toronto, Toronto, ON M5S 1A1, Canada; karim.ladha@mail.utoronto.ca

MS and KSL contributed equally.

Received 10 September 2021
Accepted 22 October 2021



► <https://doi.org/10.1136/rapm-2021-103294>



© American Society of Regional Anesthesia & Pain Medicine 2021. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Diep C, Tian C, Vachhani K, et al. *Reg Anesth Pain Med* Epub ahead of print: [please include Day Month Year]. doi:10.1136/rapm-2021-103161

ABSTRACT

Background While popularly consumed for its perceived benefits as a sleeping aid, the impact of cannabis on sleep-wake regulation in clinical studies is inconclusive. The purpose of this study was to determine the relationship between cannabis use and nightly sleep duration in a nationally representative dataset.

Methods A cross-sectional analysis of adults was undertaken using the National Health and Nutrition Examination Survey data from 2005 to 2018.

Respondents were dichotomized as recent users or non-users if they had used or not used cannabis in the past 30 days, respectively. The primary outcome was nightly sleep duration, categorized as short (<6 hours), optimal (6–9 hours), and long (>9 hours). Multinomial logistic regression was used to adjust for sociodemographic and health-related covariates, and survey sample weights were used in modeling.

Results From a sample representing approximately 146 million adults in the USA, 14.5% reported recent cannabis use. In an adjusted analysis, recent users were more likely than non-users to report both short sleep (OR 1.34, 95% CI 1.12 to 1.59, $p < 0.001$) and long sleep (OR 1.56, 95% CI 1.25 to 1.96, $p < 0.001$). Heavy users (≥ 20 of the past 30 days) were even more likely to be at the extremes of nightly sleep duration.

Discussion Recent cannabis use was associated with the extremes of nightly sleep duration in a nationally representative sample of adults, with suggestions of a dose–response relationship. Our findings highlight the need to further characterize the sleep health of regular cannabis users in the population.

INTRODUCTION

Cannabis use in North America continues to rise in prevalence. Approximately 45 million adults in the USA reported cannabis use in 2019, double the prevalence from the early 2000s.¹ This is, at least in part, related to widespread decriminalization in many states over the past decade, as well as scientific or clinical research that have encouraged a reduction in the perceived risk of cannabis use.² Ongoing research suggests that cannabinoids may have therapeutic value as well, having shown promise for pain relief³ with ongoing efforts to determine their role in anxiety and sleep disorders.

Despite popular use as sleeping aids,⁴ there are mixed findings about the effects of cannabis and

cannabinoids on various sleep metrics such as duration, architecture, and quality.⁵ Both sleep-wake regulation and human endocannabinoid physiology are immensely complex, and their interaction is not yet fully understood. While animal and in vitro studies have begun to elucidate these pathways, clinical studies with humans have typically been small and heterogeneous in design, leading to mixed results overall.^{6–8}

At the same time, sleep deprivation and insufficiency in the population has become a major public health concern.⁹ Experts recommend 7–9 hours of sleep per night, yet only two-thirds meet this guideline and almost half of all American adults report daytime sleepiness nearly every day.¹⁰ Chronic sleep disturbances increase overall morbidity and mortality related to traumatic accidents, cardiovascular comorbidities, psychiatric disorders, and chronic pain.^{11–13} Identifying or developing safe interventions to improve sleep health is thus a priority.

Characterizing relationships between current cannabis use trends and sleep patterns may help guide targeted clinical intervention and policy development to improve health outcomes at the patient and population levels. The purpose of this study was to determine the relationship between recent cannabis use and nightly sleep duration in a nationally representative data set.

METHODS

Study population

Data for this study were obtained from the National Health and Nutrition Examination Survey (NHANES), which is a cross-sectional survey designed by the National Center for Health Statistics (NCHS) and Centers for Disease Control and Prevention. The NHANES is designed to yield nationally representative data for the non-institutionalized civilian population in the continental USA. This is achieved using a multistage area probability sample selection (1): selection of primary sampling units (PSUs), (2) segments within PSUs (one or more blocks containing a cluster of households), (3) households within segments, and (4) at least one participant within each household. Sample weights and adjustments are then made to account for oversampling and control for non-response.¹⁴ For this present study, a data set was

Original research

constructed using publicly available files from seven 2-year cycles of NHANES responses (2005–2006, 2007–2008, 2009–2010, 2011–2012, 2013–2014, 2015–2016, and 2017–2018). The study population consisted of all respondents to the NHANES cannabis questionnaires, which were only administered to adults aged 20–59 years.

Exposure

Cannabis use was the primary exposure variable for this study. While there is no single definition for regular cannabis use across the scientific literature,¹⁵ we dichotomized participants as: (1) non-users if they reported no cannabis use in the past 30 days or; (2) recent users if they had reported any cannabis use in the past 30 days. This definition has been consistently used with previous studies examining cannabis use in the NHANES data set.¹⁶

Outcomes

The primary outcome for this study was nightly sleep duration categorized as short, optimal, or long. Based on previous studies examining sleep metrics and outcomes, we defined short sleep as <6 hours and long sleep as >9 hours on average weeknights or worknights.¹⁷ Secondary outcomes included: (1) whether participants reported having any trouble falling asleep, staying asleep, or sleeping too much in the past 2 weeks; (2) whether patients had ever told any physician about having any trouble with sleep (eg, duration, patterns, or habits), which was determined by any score greater than 0 for Item #3 of the Patient Health Questionnaire-9; and (3) whether participants experienced daytime sleepiness often, which was defined as feeling overly sleepy on at least 5 of the last 30 days (only captured in 2005–2006, 2007–2008, 2015–2016, and 2017–2018 cycles).

Covariates

Covariates were selected a priori based on biological plausibility of being a confounder in the relationship between the exposure and primary outcome. Demographic characteristics included age (categorical: 20–29, 30–39, 40–49, or 50–59 years old), sex, and race (categorical: Hispanic, white, black, or other) were included. Education beyond high school and number of hours worked per week (categorical: <20, 20–40, or >40 hours) were considered as socioeconomic factors. Health-related variables such as history of hypertension, diabetes, coronary artery disease, body mass index (categorical: <25 kg/m², 25–30 kg/m², or ≥30 kg/m²), smoking, heavy alcohol use (≥4 drinks per day, on average), and prescriptions within the past 30 days for the following classes of medications were all considered binary variables: opioids, benzodiazepines, ‘Z drugs’, barbiturates, other sedatives, and stimulants (see online Supplementary Table A for the full list of agents included in these classes).^{18 19} Finally, the 2-year survey cycle in which participants were interviewed or examined was included in statistical modeling. For any covariate for which >5% of survey participants were missing data, a separate level was coded for the missing values to retain these large samples in analyses. Respondents with missing values for exposure variables, outcome variables, or any other covariates were removed from analyses.

Data analysis

Weighted differences in baseline covariates and outcome variables between exposure groups were analyzed using χ^2 tests. Multinomial logistic regression was used to determine the association between recent cannabis use and sleep duration categories in the primary analysis while accounting for covariates.

A multinomial model was used to allow comparison of the outcomes of interest (‘short’ and ‘long’ sleep) to a reference level of ‘optimal’ sleep. The relationship between recent cannabis use and the binary secondary outcomes was then assessed with adjusted multiple logistic regression models. All regression models took into consideration NHANES sample weights which were adjusted by the number of years of survey data to represent a single year and population. All covariates were included in the model without further selection. To account for potential differences over time related to evolving attitudes towards cannabis use, an interaction term between cannabis use and the year of survey administration was added to the regression model. The regression term was found to be not statistically significant and thus was not included in the primary analysis. No other interaction terms were considered.

Further analyses were subsequently performed to test the robustness of our primary model. First, to test for a dose effect, recent cannabis users were further categorized as moderate or heavy users if they had, respectively, used <20 or ≥20 days of the past 30 days. Second, recent users were compared with former users, who were defined as having a history of use but none in the past 30 days.

Significance was tested through two-tailed tests at a significance level of $p < 0.05$ for all described analyses. All data analyses were performed using R V.3.5.2 (R Core Team, Vienna, Austria). Regression models that accounted for adjusted sample weights and maintained the complex survey design of the NHANES were built using the open source ‘survey’ and ‘svrepmisc’ packages, with guidance from published statistical methods.^{14 20} The sample size was based on the available data, no further observations were removed, and no a priori power calculations were performed.

RESULTS

From 2005 to 2018, surveys about cannabis use were administered to a total of 25,348 participants through the NHANES. After excluding participants with missing outcome, exposure, or covariate data (other than the exceptions described above), 21,729 were included in analyses (figure 1), representing an estimated 146,417,873 adults from the USA. A total of 3132 (14.5%) reported

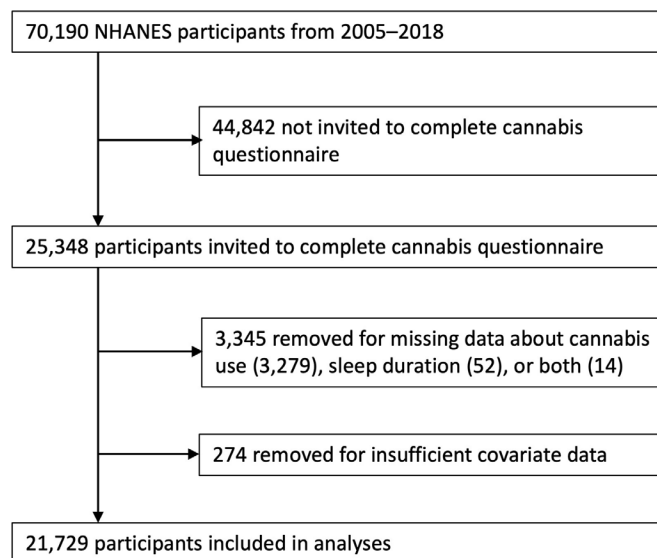


Figure 1 Participant inclusion flow chart from the National Health and Nutrition Examination Survey (NHANES) 2005–2018.

Table 1 Characteristics of included participants from the National Health and Nutrition Examination Survey, 2005–2018

Represented no of adults in the USA	Cannabis use in past 30 days?		P value
	No (n=18,597)	Yes (n=3132)	
Age in years, n (%)			
20–29	4375 (23.1)	1311 (41.2)	<0.001
30–39	4675 (23.9)	784 (23.2)	
40–49	4848 (26.5)	579 (19.1)	
50–59	4699 (26.5)	458 (16.5)	
Sex, n (%)			
Female	9962 (52.2)	1194 (37.9)	<0.001
Male	8635 (47.8)	1938 (62.1)	
Ethnicity, n (%)			
Hispanic	5320 (16.7)	498 (11.5)	<0.001
White	7251 (64.5)	1407 (65.5)	
Black	3731 (10.9)	953 (16.9)	
Other	2295 (8.0)	274 (6.1)	
Education beyond high school, n (%)	10 788 (65.0)	1590 (55.4)	<0.001
Hours worked per week, n (%)			
≤20	1113 (6.1)	244 (7.3)	<0.001
21–40	6899 (36.7)	1115 (37.2)	
41–80	5030 (31.6)	642 (24.9)	
>80	100 (0.5)	19 (0.7)	
Missing data	5455 (25.1)	1112 (29.8)	
Hypertension, n (%)	4363 (22.9)	669 (20.3)	<0.01
Diabetes, n (%)	1385 (6.1)	130 (3.4)	<0.001
Coronary artery disease, n (%)	206 (1.0)	27 (1.1)	0.76
BMI in kg/m ² , n (%)			
<25	5287 (29.5)	1251 (40.6)	<0.001
25–30	5921 (32.1)	921 (30.1)	
≥30	7389 (38.4)	960 (29.3)	
Smoker, n (%)	3615 (18.6)	1668 (50.2)	<0.001
Heavy alcohol use, n (%)	3271 (17.3)	1165 (38.3)	<0.001
Missing data	5280 (23.7)	261 (8.1)	
Prescription drug use, n (%)			
Opioids	814 (4.6)	200 (5.8)	<0.001
Benzodiazepines	395 (2.5)	98 (3.6)	<0.001
Z drugs	208 (1.5)	40 (1.5)	0.98
Barbiturates	63 (0.3)	9 (0.3)	0.44
Other sedatives	552 (3.0)	114 (3.0)	0.90
Stimulants	164 (1.2)	51 (2.4)	<0.001
Survey year, n (%)			
2005–2006	2508 (14.3)	325 (12.0)	<0.001
2007–2008	2747 (14.3)	394 (11.4)	
2009–2010	2961 (14.0)	466 (12.4)	
2011–2012	2570 (14.1)	422 (13.1)	
2013–2014	2835 (14.8)	492 (14.4)	
2015–2016	2637 (14.1)	477 (16.8)	
2017–2018	2339 (14.3)	556 (19.8)	

All proportions displayed are weighted to represent the non-institutionalized population in the continental USA. Survey weights are adjusted by the number of years of data included in analysis.

P values reflect χ^2 -analysis used to test significance between groups for categorical variables.

BMI, body mass index.;

Table 2 Self-reported sleep outcomes of included participants from the National Health and Nutrition Examination Survey, 2005–2018

Represented no of adults in the USA	Cannabis use in past 30 days?		P value
	No (n=18,597)	Yes (n=3132)	
Nightly sleep duration, n (%)			
<6 hours	2537 (11.6)	554 (15.7)	<0.001
6–9 hours	15,358 (85.3)	2376 (77.8)	
>9 hours	702 (3.1)	202 (6.5)	
Told doctor about trouble with sleep, n (%)	4309 (25.6)	877 (29.7)	<0.001
Trouble with sleep in past 2 weeks, n (%)*	7024 (38.0)	1470 (47.0)	<0.001
	No (n=10,226)	Yes (n=1752)	
Daytime sleepiness (≥5 of past 30 days), n (%)†	2288 (23.7)	467 (26.7)	<0.01

All proportions displayed are weighted to represent the non-institutionalized population in the continental USA. Survey weights are adjusted by the number of years of data included in analysis.

P values reflect χ^2 analysis used to test significance between groups for categorical variables.

*Defined as any score greater than 0 on Item #3 of the Patient Health Questionnaire: 'Have you had trouble falling asleep, staying asleep, or sleeping too much over the past 2 weeks?'

†Only respondents from the 2 year survey cycles (2005–2006, 2007–2008, 2015–2016, 2017–2018) with this variable were included in the regression model for this outcome.

cannabis use in the past 30 days. Sample characteristics grouped by cannabis exposure are presented in [table 1](#).

The mean self-reported sleep duration of all included survey respondents was 6.97 ± 1.47 hours; there was no difference between those with recent cannabis use and those without. Among all survey respondents, 12.2% reported <6 hours, and 3.6% reported >9 hours per night ([table 2](#)). Compared with those with no cannabis use in the past 30 days, recent users were more likely to report sleeping <6 hours per night (15.7% vs 11.6%; unadjusted OR 1.47, 95% CI 1.26 to 1.71, $p < 0.001$), or >9 hours per night (6.5% vs 3.1%; unadjusted OR 2.26, 95% CI 1.88 to 2.73, $p < 0.001$). After adjusting for covariates, the association persisted with cannabis users more likely to endorse either short sleep (adjusted OR (aOR) 1.34, 95% CI 1.12 to 1.59, $p < 0.001$) or long sleep (aOR 1.56, 95% CI 1.25 to 1.96, $p < 0.001$) ([table 3](#); full regression model displayed in online supplementary table [Bonline Supplementary Table B](#)).

Recent cannabis users were also more likely to report difficulty falling asleep, staying asleep, or sleeping too much in the past 2 weeks (aOR 1.31, 95% CI 1.18 to 1.45, $p < 0.001$), and having ever told a physician about having trouble with sleep (aOR 1.29, 95% CI 1.13 to 1.47, $p < 0.001$) ([table 2](#)). Recent cannabis exposure was not associated with frequent daytime sleepiness (aOR 1.00, 95% CI 0.88 to 1.14, $p = 0.94$).

When recent users were further categorized by frequency of use, moderate users (<20 of the past 30 days) were more likely to have long sleep (aOR 1.47, 95% CI 1.13 to 1.91, $p < 0.01$) but not short sleep (aOR 1.19, 95% CI 0.98 to 1.44, $p = 0.07$) compared with non-users. Heavy users (≥20 of the past 30 days) were more likely to have both short sleep (aOR 1.64, 95% CI 1.28 to 2.09, $p < 0.001$) and long sleep (aOR 1.76, 95% CI 1.19 to 2.60, $p < 0.01$) compared with non-users ([table 3](#)). Compared with former cannabis users (no

Table 3 Weighted and adjusted ORs for cannabis use and nightly sleep duration

Cannabis use	Short sleep (<6 hours per night)		Long sleep (>9 hours per night)	
	OR (95% CI)	P value	OR (95% CI)	P value
Primary analysis:				
No use in past 30 days	1 (reference)		1 (reference)	
Use in past 30 days				
Unadjusted	1.47 (1.26 to 1.71)	<0.001	2.26 (1.88 to 2.73)	<0.001
Adjusted*	1.34 (1.12 to 1.59)	<0.001	1.56 (1.25 to 1.96)	<0.001
Dose-response analysis:				
No use in past 30 days	1 (reference)		1 (reference)	
Moderate (<20 days/months)*	1.19 (0.98 to 1.44)	0.07	1.47 (1.13 to 1.91)	<0.01
Heavy (≥20 days/months)*	1.64 (1.28 to 2.09)	<0.001	1.76 (1.19 to 2.60)	<0.01

Bold values denote statistical significance at the $p < 0.05$ level.

*Reported ORs were adjusted for the following covariates: age, sex, ethnicity, education beyond high school, weekly work hours, hypertension, diabetes, coronary artery disease, body mass index, smoking, heavy alcohol use, prescription medication use (opioids, benzodiazepines, 'Z' sleep drugs, barbiturates, other sedatives, stimulants), year of survey cycle.

use in past 30 days), recent users were more likely to report both short sleep (aOR 1.34 95% CI 1.12 to 1.62, $p < 0.01$) and long sleep (aOR 1.65, 95% CI 1.29 to 2.11, $p < 0.001$).

DISCUSSION

In this study, we demonstrate a significant association between recent cannabis use and the extremes of nightly sleep duration in a nationally representative sample of adults aged 20–59. There was also an exposure–response between cannabis use frequency and the prevalence of both short sleep (<6 hours per night) and long sleep (>9 hours per night). These results were not different between survey years.

The literature examining the effects of cannabis on sleep duration, architecture, or quality in people with no sleep disturbances at baseline demonstrate overall mixed results.^{5–8} Early polysomnographic studies suggest that even a single cannabis exposure can cause reduced sleep-onset latency, increased total sleep time, and less disruptions once asleep.²¹ Repeated use can quickly demonstrate habituation and likely opposite effects: increased sleep-onset latency, decreased total sleep time, and greater sleep disruption.²² While there is no clear temporal or frequency definition for acute versus chronic exposure, participants in our study who endorsed regular use were thought to represent chronic users. We determined there to be a possible exposure–response relationship between frequency of use and sleep duration; heavy users (cannabis use on 20 or more of the past 30 days) were at the greatest risk of both extremes of nightly sleep duration compared with non-users. This bimodal risk distribution has not previously been reported, particularly the association between cannabis use and long sleep. With our cross-sectional analyses, we can only speculate that these findings may be related to an unknown consequence of repeated cannabis exposure alone or may be a reflection of other underlying sociodemographic or health factors. While the doses used by NHANES participants were not reported, our results imply that frequency of use alone may impact sleep architecture. Further clinical study is needed to characterize the dose–response relationships between cannabis use and sleep outcomes.

There has been a surge of interest in cannabinoids such as cannabidiol (CBD) in recent years as potential sleep aids for primary sleep-wake disorders such as insomnia, restless leg syndrome, central sleep apnea, obstructive sleep apnea (OSA), as well as for sleep disturbances secondary to other conditions such as chronic pain or post-traumatic stress disorder (PTSD).^{7,8} In contrast to CBD, current evidence suggests that delta-9 tetrahydrocannabinol (THC), the other major cannabinoid present in most strains of cannabis, has stimulant and hallucinogenic

properties contributing to sleep disruption.⁸ With an evolving market of new cannabis strains and cannabinoid formulations, each with varying proportions of CBD and THC, the generalizability of the current literature about sleep impact is limited. Despite insomnia being one of the most cited reasons for self-medication with cannabis or cannabinoids, the evidence base is overall inconsistent and of poor quality, as described in a recent systematic review.²³ Currently, the only indications with some robust evidence for therapeutic cannabis use to improve sleep duration or quality are OSA, PTSD, and chronic pain syndromes.^{24–26}

Increasing prevalence of both cannabis use and sleep deprivation in the population is a potential cause for concern. While our cross-sectional analysis did not demonstrate an association between recent cannabis use and daytime sleepiness, insufficient sleep in the modern world is a growing public health issue⁹ and sleep disturbances can be a major risk factor for initiating cannabis use.²⁷ This can perpetuate cycles of increased cannabis use, progressive sleep disturbances, and acute cessation leading to withdrawal which may add further negative effects to sleep architecture and quality.²⁸ The importance of adequate sleep is underscored by the known health consequences of chronic sleep deprivation and chronic oversleeping. Both states can predispose to traumatic injuries, cardiovascular comorbidities, depression, cognitive deficits, and pain.^{11–13} The extremes of sleep thus exhibit a 'U-shaped' relationship with morbidity and mortality at the individual and population levels.^{17,29} This is thought to be related to pathological states of generalized systemic inflammation with chronic short sleep, long sleep, or other disturbances.³⁰ The role of the endocannabinoid system in exacerbating or alleviating these inflammatory pathways in the long term is not fully understood and an important area of ongoing study as cannabis use continues to grow in prevalence.

This study has several limitations inherent in its design that should be considered when interpreting the results. First, data collected from survey questionnaires are self-reported and therefore subject to selection bias; only persons willing and able to participate in the survey and examination process are included. In addition, the historical (and still present) stigma associated with cannabis may impact participant responses to questions about cannabis use. However, in our analyses, there was no significant interaction between survey year and cannabis use variables, suggesting that the effects of this response bias did not differ over the study period. Second, given the cross-sectional nature of our study there may be residual unmeasured confounding we are unable to account for, including confounding by indications for cannabis use. Furthermore, these cross-sectional data are unable to provide insight on causality (or

reverse causality) between sleep outcomes and cannabis use. Third, granular data related to cannabis exposure (formulations, dosing, intended purpose of use) and sleep-related metrics (timing, quality, efficiency, alertness, or prior sleep disorders) were not available but would have allowed for further analysis. Fourth, the NHANES cannabis survey did not include the adolescent demographic, which represent the group at highest risk of both cannabis-related harms and sleep disturbances.³¹ Thus, the generalizability of our findings is limited.

CONCLUSIONS

Recent cannabis use was associated with the extremes of self-reported nightly sleep duration in this nationally representative sample of adults, with suggestions of a dose–response relationship. Despite the current literature demonstrating mixed effects of cannabis and various cannabinoid formulations on sleep architecture and quality, these agents are being increasingly used as both prescribed and unprescribed experimental therapies for sleep disturbances. Sleep-wake physiology and regulation is complex and research about related endocannabinoid pathways is in its early stages. Given the growing prevalence of cannabis use, future studies should continue exploring the relationship to human sleep using polysomnographic or actigraphic analysis. A better understanding of the endocannabinoid-mediated effects on sleep can inform development of clinical guidelines to target improved long term health outcomes at the patient and population levels, particularly for demographic groups that may be at increased risk of consequent sleep disturbances.

Twitter Calvin Diep @calvdiep, Chenchen Tian @chenchentian, Kathak Vachhani @kathak_v, Christine Won @wonchristine, Hance Clarke @drhaclarke, Mandeep Singh @mndpsingh7 and Karim S Ladha @drladha

Contributors CD, MS, and KSL conceived the study. CD conducted data retrieval, coding, and analysis. CD, CT, KV, CW, DNW, HC, MS, and KSL all contributed to drafting and preparation of the manuscript. KSL acts as a guarantor for all activities of this study.

Funding DNW, HC, MS, and KSL are supported in part by Merit Awards from the Department of Anesthesiology and Pain Medicine at the University of Toronto (Toronto, Canada). DNW is supported in part by an Endowed Chair in Translational Anesthesiology Research at St. Michael's Hospital (Toronto, Canada) and the University of Toronto (Toronto, Canada). MS is supported by a Career Scientist Award from the Canadian Anesthesiologists' Society (Toronto, Canada).

Competing interests HC and KSL are co-principal investigators for an observational study of medical cannabis use funded by Shoppers Drug Mart.

Patient consent for publication Not applicable.

Ethics approval The data collection protocols are approved by the NCHS Ethics Review Board and all survey participants provide informed consent prior to being interviewed and examined.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Data are available on reasonable request. All data for this study and tutorials to access the data are publicly available at <https://www.cdc.gov/nchs/nhanes/>.

ORCID iDs

Calvin Diep <http://orcid.org/0000-0001-9596-5101>
 Duminda N Wijeyesundera <http://orcid.org/0000-0002-5897-8605>
 Hance Clarke <http://orcid.org/0000-0003-4975-3823>
 Mandeep Singh <http://orcid.org/0000-0002-3393-8586>

REFERENCES

- 1 SAMHSA. *Key substance use and mental health indicators in the United States: Results from the 2019 National Survey on Drug Use and Health [Internet]*. Rockville, MD, 2020. <https://www.samhsa.gov/data/>

- 2 Martins SS, Mauro CM, Santaella-Tenorio J, *et al*. State-level medical marijuana laws, marijuana use and perceived availability of marijuana among the general U.S. population. *Drug Alcohol Depend* 2016;169:26–32.
- 3 Deshpande A, Mailis-Gagnon A, Zoheiry N, *et al*. Efficacy and adverse effects of medical marijuana for chronic noncancer pain: systematic review of randomized controlled trials. *Can Fam Physician* 2015;61:e372–81.
- 4 Bonn-Miller MO, Boden MT, Bucossi MM, *et al*. Self-reported cannabis use characteristics, patterns and helpfulness among medical cannabis users. *Am J Drug Alcohol Abuse* 2014;40:23–30.
- 5 Edwards D, Filbey FM. Are sweet dreams made of these? understanding the relationship between sleep and cannabis use. *Cannabis Cannabinoid Res* 2021. doi:10.1089/can.2020.0174. [Epub ahead of print: 18 Jun 2021].
- 6 Babson KA, Sottile J, Morabito D. Cannabis, cannabinoids, and sleep: a review of the literature. *Curr Psychiatry Rep* 2017;19:23.
- 7 Choi S, Huang BC, Gamaldo CE. Therapeutic uses of cannabis on sleep disorders and related conditions. *J Clin Neurophysiol* 2020;37:39–49.
- 8 Kaul M, Zee PC, Sahni AS. Effects of cannabinoids on sleep and their therapeutic potential for sleep disorders. *Neurotherapeutics* 2021;18:217–27.
- 9 Colten HR, Altevogt BM. *Sleep disorders and sleep deprivation: an unmet public health problem*. Institute of Medicine (US) Committee on Sleep Medicine and Research, 2006.
- 10 Consensus Conference Panel, Watson NF, Badr MS, *et al*. Joint consensus statement of the American Academy of sleep medicine and sleep research Society on the recommended amount of sleep for a healthy adult: methodology and discussion. *Sleep* 2015;38:1161–83.
- 11 Léger D, Guilleminault C, Bader G, *et al*. Medical and socio-professional impact of insomnia. *Sleep* 2002;25:621–5.
- 12 St-Onge M-P, Grandner MA, Brown D, *et al*. Sleep duration and quality: impact on lifestyle behaviors and cardiometabolic health: a scientific statement from the American heart association. *Circulation* 2016;134:e367–86.
- 13 Dashti HS, Cade BE, Stutaite G, *et al*. Sleep health, diseases, and pain syndromes: findings from an electronic health record Biobank. *Sleep* 2021;44:zsaa189.
- 14 Chen T-C, Clark J, Riddles MK, *et al*. National health and nutrition examination survey, 2015–2018: sample design and estimation procedures. *Vital Health Stat 2* 2020:1–35.
- 15 Gabrys R, Porath A. *Clearing the smoke on cannabis series: regular use and cognitive functioning*. Canadian Centre on Substance Abuse, 2019.
- 16 Caulkins JP, Pardo B, Kilmer B. Intensity of cannabis use: findings from three online surveys. *Int J Drug Policy* 2020;79:102740.
- 17 Yin J, Jin X, Shan Z, *et al*. Relationship of sleep duration with all-cause mortality and cardiovascular events: a systematic review and dose-response meta-analysis of prospective cohort studies. *J Am Heart Assoc* 2017;6:e005947.
- 18 Atkin T, Comai S, Gobbi G. Drugs for insomnia beyond benzodiazepines: pharmacology, clinical applications, and discovery. *Pharmacol Rev* 2018;70:197–245.
- 19 Thorpy MJ. Recently Approved and upcoming treatments for narcolepsy. *CNS Drugs* 2020;34:9–27.
- 20 Diep C, Bhat V, Wijeyesundera DN. The association between recent cannabis use and suicidal ideation in adults: a population-based analysis of the NHANES from 2005 to 2018. *Can J Psych* 2021;706743721996112.
- 21 Cousens K, DiMascio A. (-) delta 9 THC as an hypnotic. An experimental study of three dose levels. *Psychopharmacologia* 1973;33:355–64.
- 22 Gorelick DA, Goodwin RS, Schwilke E, *et al*. Around-the-clock oral THC effects on sleep in male chronic daily cannabis smokers. *Am J Addict* 2013;22:510–4.
- 23 Bhagavan C, Kung S, Doppen M, *et al*. Cannabinoids in the treatment of insomnia disorder: a systematic review and meta-analysis. *CNS Drugs* 2020;34:1217–28.
- 24 Carley DW, Prasad B, Reid KJ, *et al*. Pharmacotherapy of apnea by cannabinimetic enhancement, the PACE clinical trial: effects of dronabinol in obstructive sleep apnea. *Sleep* 2018;41:zsx184.
- 25 Orsolini L, Chiappini S, Volpe U, *et al*. Use of medicinal cannabis and synthetic cannabinoids in post-traumatic stress disorder (PTSD): a systematic review. *Medicina* 2019;55:525.
- 26 Ware MA, Fitzcharles M-A, Joseph L, *et al*. The effects of nabilone on sleep in fibromyalgia: results of a randomized controlled trial. *Anesth Analg* 2010;110:604–10.
- 27 Roane BM, Taylor DJ. Adolescent insomnia as a risk factor for early adult depression and substance abuse. *Sleep* 2008;31:1351–6.
- 28 Bolla KI, Lesage SR, Gamaldo CE, *et al*. Polysomnogram changes in marijuana users who report sleep disturbances during prior abstinence. *Sleep Med* 2010;11:882–9.
- 29 Dashti HS, Redline S, Saxena R. Polygenic risk score identifies associations between sleep duration and diseases determined from an electronic medical record Biobank. *Sleep* 2019;42:zsy247.
- 30 Irwin MR, Olmstead R, Carroll JE. Sleep disturbance, sleep duration, and inflammation: a systematic review and meta-analysis of cohort studies and experimental sleep deprivation. *Biol Psychiatry* 2016;80:40–52.
- 31 Mednick SC, Christakis NA, Fowler JH. The spread of sleep loss influences drug use in adolescent social networks. *PLoS One* 2010;5:e9775.

Supplementary Table A. Categories of prescription medications considered as covariates in regression modeling.

Opioids	Benzodiazepines	“Z” Drugs	Barbiturates	Other Sedatives	Stimulants
Buprenorphine	Alprazolam	Eszopiclone	Amobarbital	Agomelatine	Amphetamine
Codeine	Chlordiazepoxide	Zaleplon	Butobarbital	Amitriptyline	Armodafinil
Fentanyl	Clobazam	Zolpidem	Butalbital	Diphenhydramine	Caffeine
Hydrocodone	Clonazepam	Zopiclone	Phenobarbital	Dimenhydrinate	Dexmethylphenidate
Hydromorphone	Clorazepate		Secobarbital	Doxepin	Dextroamphetamine
Meperidine	Diazepam			Doxylamine	Methylphenidate
Methadone	Estazolam			Gabapentin	Modafinil
Morphine	Flurazepam			Melatonin	Pitolisant
Oxycodone	Lorazepam			Mirtazapine	Sodium oxybate
Oxymorphone	Oxazepam			Olanzapine	Solriamfetol
Tapentadol	Quazepam			Pregabalin	
	Temazepam			Quetiapine	
	Triazolam			Ramelteon	
				Suvorexant	
				Tasimelteon	
				Trazodone	

Agents and categories were selected for inclusion in regression model based on biologic plausibility and evidence of effect on sleep duration and use for sleeping disorders.

Supplementary Table B. Multinomial regression model for the association between cannabis use in the past 30 days and the extremes of nightly sleep duration.

	Short sleep (<6 h per night)				Long sleep (>9 h per night)				
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Recent cannabis use	1.34	1.12	1.59	<0.001	1.56	1.25	1.96	<0.001	
Age in years									
20–29	1 (reference)				1 (reference)				
30–39	1.22	1.06	1.41	<0.01	0.63	0.46	0.84	<0.01	
40–49	1.23	1.05	1.44	<0.01	0.39	0.30	0.51	<0.001	
50–59	1.12	0.94	1.34	0.18	0.40	0.31	0.52	<0.001	
Sex									
Male	1 (reference)				1 (reference)				
Female	0.96	0.86	1.07	0.42	1.36	1.11	1.68	<0.01	
Ethnicity									
Hispanic	1 (reference)				1 (reference)				
White	0.82	0.71	0.94	<0.01	0.85	0.66	1.09	0.178	
Black	2.09	1.82	2.41	<0.001	1.25	1.03	1.52	0.02	
Other	1.03	0.83	1.28	0.78	0.96	0.72	1.28	0.78	
Education beyond high school	0.76	0.66	0.87	<0.001	0.54	0.43	0.67	<0.001	
Hours worked per week									
≤ 20	1 (reference)				1 (reference)				
21–40	1.01	0.80	1.28	0.93	0.57	0.40	0.82	<0.01	
41–80	1.43	1.10	1.85	<0.01	0.29	0.19	0.44	<0.001	
>80	4.71	2.91	7.63	<0.001	0.29	0.01	5.58	0.39	
Missing data	1.28	0.97	1.68	0.07	1.69	1.23	2.33	<0.001	
Hypertension	1.29	1.15	1.44	<0.001	1.15	0.90	1.46	0.26	
Diabetes	1.05	0.87	1.27	0.61	1.20	0.89	1.61	0.22	
Coronary artery disease	1.27	0.82	1.97	0.26	0.99	0.52	1.90	0.98	
BMI (kg/m²)									
<25	1 (reference)				1 (reference)				
25–30	1.13	0.96	1.32	0.12	0.97	0.77	1.22	0.78	
≥ 30	1.28	1.10	1.48	<0.001	0.91	0.74	1.12	0.35	
Smoker	1.73	1.51	1.97	<0.001	1.40	1.11	1.76	<0.01	
Heavy alcohol use	1.05	0.91	1.22	0.48	1.26	0.98	1.61	0.06	
Missing data	1.42	1.25	1.61	<0.001	1.65	1.36	1.99	<0.001	
Prescriptions									
Opioids	1.56	1.32	1.84	<0.001	1.31	0.86	2.00	0.19	
Benzodiazepines	1.50	1.06	2.14	0.02	1.33	0.90	1.97	0.14	
Z drugs	1.75	1.09	2.80	0.02	0.85	0.30	2.35	0.74	

Barbiturates	1.03	0.38	2.78	0.96	1.41	0.35	5.57	0.62
Other sedatives	1.28	0.96	1.70	0.08	2.50	1.64	3.83	<0.001
Stimulants	1.61	0.90	2.89	0.10	1.36	0.58	3.16	0.46
Survey year								
2005-06	1 (reference)				1 (reference)			
2007-08	1.08	0.85	1.37	0.51	0.72	0.48	1.09	0.11
2009-10	0.86	0.72	1.03	0.09	0.69	0.44	1.08	0.09
2011-12	1.07	0.86	1.35	0.53	0.77	0.48	1.24	0.27
2013-14	0.95	0.79	1.14	0.54	0.82	0.54	1.25	0.34
2015-16	0.46	0.38	0.57	<0.001	4.68	3.49	6.28	<0.001
2017-18	0.68	0.51	0.91	<0.01	3.56	2.51	5.04	<0.001