Sleep Medicine Reviews 70 (2023) 101792

Contents lists available at ScienceDirect

Sleep Medicine Reviews

journal homepage: www.elsevier.com/locate/smrv

A systematic review and meta-analysis of the association between young adults' sleep habits and substance use, with a focus on self-medication behaviours

Debora Meneo [a, *], Valeria Bacaro [b], Sara Curati [a], Paolo Maria Russo [c], Monica Martoni [c], Francesca Gelfo [a, d], Chiara Baglioni [a, e]

[a] Department of Human Sciences, Guglielmo Marconi University, Rome, Italy
[b] Department of Psychology, University of Bologna, Bologna, Italy
[c] Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy
[d] IRCCS Fondazione Santa Lucia, Rome, Italy
[e] Department of Clinical Psychology and Psychophysiology/Sleep, Medicine, Centre for Mental Disorders, University Medical Centre, Freiburg, Germany

ARTICLE INFO

Article history:
Received 2 May 2022
Received in revised form
5 May 2023
Accepted 10 May 2023
Available online 22 May 2023

Handling Editor: M Vitello

Keywords:
Meta-analysis
Insomnia
Sleep health
Substance use
Self-medication
Young adults

ABSTRACT

Young adults (18–30 years) are vulnerable to sleep-wake disturbances and substance use, which are bidirectionally associated. The present work aims to organise the literature that deals with the association between sleep and substance use in young adults, also considering self-medication behaviours.

We adopted a framework that accounts for the multidimensionality of sleep and the effect of different substances. We considered sleep disturbances (insomnia symptoms, sleep quality), sleep health dimensions (duration, satisfaction, efficiency, timing, daytime alertness), circadian characteristics (chronotype). Substances were alcohol, caffeine, nicotine, cannabis, others. We included 46 studies. The use of caffeine and nicotine was associated with higher odds of sleep disturbances. No significant effect was detected for sleep duration. In narrative findings, daytime dysfunction was associated with alcohol and caffeine use, and poor sleep satisfaction with nicotine use. Few evidence were available for the other sleep health dimensions. Evening chronotype was associated with alcohol, caffeine, and nicotine use. Few studies focused on cannabis or self-medication. Longitudinal results were inconclusive.

We found a distinct pattern of associations between different substances and different sleep outcomes. Further investigation considering the multidimensionality of sleep would create a better understanding of the complex relationship between substance use and sleep health in young adults.

1. Introduction

Insufficient sleep and insomnia symptoms are common complaints in adults worldwide, with high individual and societal costs [1]. Around 30% of healthy adults are frequently unsatisfied with their sleep, one third sleeps less than the recommended 7 h [2], and one in ten suffers from insomnia disorder [3]. Young adults (18–30 years) are particularly vulnerable to sleep problems: throughout this developmental period, sleep duration decreases and insomnia incidence increases [4,5]. College students appear at risk for sleep disturbances, with up to 60% complaining of poor sleep quality [6]. On the other hand, there are reports of higher odds of insufficient sleep among non-college and working young adults [7,8]. Overall, 10–30% of young adults meet the criteria for chronic insomnia [9,10]. Parallel to the increase in sleep difficulties, there is an increase in substance use throughout young adulthood [11,12]. Illicit drug use is often initiated between 18 and 25 years of age [13]. During this time period, there is also an increase in the use of alcohol and caffeinated products [13]. Neurobiological findings indicate that psychoactive substances disrupt sleep-wake regulation systems [14]. On the other hand, sleep-wake disturbances affect the course of substance use disorder [15]. Longitudinal data indicates that the pattern of substance use is predicted by sleep and circadian characteristics, such as late chronotype (eveningness) and sleep timing [16,17], sleep duration [17–19], daytime sleepiness [19], and insomnia symptoms [20]. On the other hand, sleep health

* Corresponding author. Department of Human Sciences, Guglielmo Marconi University, Via Plinio, 44 - 00193, Rome, Italy.
E-mail address: d.meneo@unimarconi.it (D. Meneo).

https://doi.org/10.1016/j.smrv.2023.101792
1087-0792/

is predicted by substance use, including alcohol [20], nicotine [17,21], and cannabis [17]. One proposed underlying mechanism for this bi-directional association is self-medication: the experience of sleep-wake difficulties may prompt the use of sleep promoting substances [22]. Similarly, the experience of non-restorative sleep can encourage the use of wake-enhancing substances to overcome daytime sleepiness [23]. Among young adults, 10–15% use alcohol or cannabis as sleep aids [6,24] and 15–25% report using stimulant beverages to counter insufficient sleep or to relieve fatigue [23]. Both sleep-inducing and wake-enhancing substances are associated with sleep impairment [25]. A further deterioration of sleep may then increase the need to self-medicate, creating a vicious circle [6]. This may further increase the risk of incurring the negative effects of sleep and substance use problems on mental health [26–28].

It is important to understand how sleep-wake disturbances and substance use influence each other during young adulthood. The literature poses difficulties in disentangling sleep and circadian characteristics associated with substance use. Self-reported poor sleep quality and insomnia symptoms have been associated with a pattern of substance use [29]. Other aspects of sleep, most notably sleep duration and daytime alertness, are also associated with substance use [14]. The multidimensionality of sleep needs to be considered in order to better understand the impact of substance use. Buysse [30] proposed a definition of sleep health that entails a) subjective sleep satisfaction; b) the ability to maintain alert wakefulness during the day; c) appropriate timing of sleep in the 24-h cycle; d) the ability to fall asleep or return to sleep easily (efficiency); e) age-appropriate sleep duration. To our knowledge, no systematic review and meta-analysis has appraised the association between the use of different substances and sleep health dimensions, sleep-wake disturbances, and circadian characteristics in young adulthood. The present systematic review and meta-analysis aims to organise and synthesize the evidence on the relationship between sleep-wake dimensions and substance use in a restricted age group (18–30 years). The synthesis is guided by a framework that accounts for the specificity of both sleep dimensions and substances. The framework includes sleep difficulties, sleep health as a multidimensional construct, and circadian characteristics, as well as the effects of different substances (see Fig. 1 for a graphic display). Furthermore, the contribution of self-medication in the association between substance use and sleep is also considered.

Following the framework adopted, we will comprehensively assess evidence regarding the following aspects:

1) the association between substance use and a) sleep-wake disturbances, b) sleep health dimensions, c) circadian characteristics
2) the bi-directional longitudinal association between substance use and sleep
3) the association between substance use with the purpose of promoting sleep or enhancing wakefulness and sleep.

2. Methods

The study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [31] and pre-registered in the PROSPERO database (ID: CRD42022359727). The PRISMA checklist is available as Supplementary File S1.

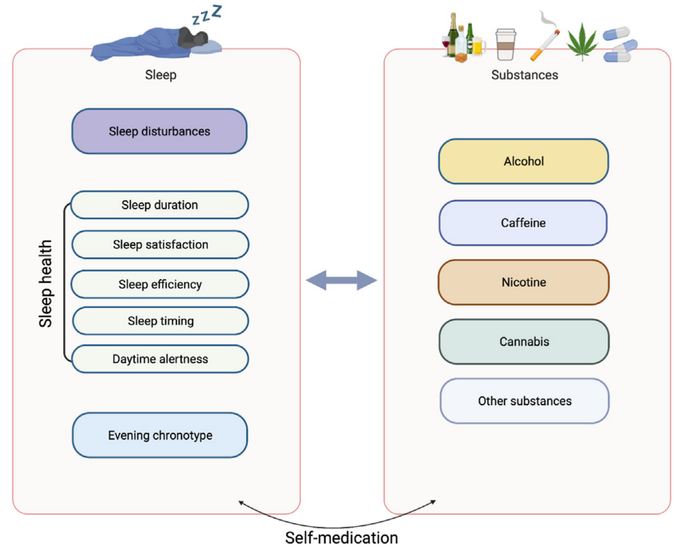

Fig. 1. A multidimensional framework. The association between different sleep dimensions and different substances is investigated. In the framework, we considered sleep disturbances, Buysse's sleep health dimensions, and circadian characteristics (left side) in their association with the use of alcohol, caffeine, nicotine, cannabis, and other substances (right side). The group “other substances” includes illicit substances (such as cocaine, amphetamines, heroine) and controlled drugs (such as tranquillizers, stimulants, opioids) (see Supplementary Table S1 for a complete list). Figure created with BioRender.com.

2.1. Study selection

Study eligibility was assessed using the Population, Intervention, Comparison, Outcomes and Study design (PICOS) approach [32]. PICOS is a structured approach for framing questions using five components: the patient population or the disease being addressed (P), the interventions or exposure (I), the comparison group (C), the outcome or endpoint (O), and the study design chosen (S).

We adopted the following inclusion criteria:

Population: studies in which participants were between the age of 18 and 30 years (including baseline age in prospective studies), free from mental or medical diagnoses, drawn from the college or non-college population, either unselected or selected for being habitual substance consumers or having sleep impairments. Studies in which participants were drawn from special populations (e.g., army personnel or veterans, pregnant women) were excluded.

Intervention/exposure and outcome: We included studies in which at least one of the following is an outcome and the other an exposure:

a) Recent use of any of the following substances: alcohol, caffeine, nicotine, cannabis, illicit substances, or misuse of prescription medications.
b) Any of the following sleep-wake dimensions subjectively reported: sleep-wake disturbances, sleep health dimensions (duration, satisfaction, efficiency, timing, daytime alertness), circadian characteristics. Objective assessments of sleep variables (e.g., polysomnography, actigraphy) were excluded.

We included studies in which differences in mean, odds ratio, rate ratio, risk ratio, or incidence ratio were reported or were computable from available data.

Comparator: we included studies in which comparisons were made based on substance use or on sleep. Based on substance use, we included the following criteria for comparison: a) various levels of substance consumption, including no consumption compared to any consumption; b) use to self-medicate sleep-wake disturbances compared to other use. Based on sleep, we included the following comparisons: a) above and below a cut-off for sleep impairment; b) various levels of sleep duration, satisfaction, timing, efficiency, or daytime alertness; c) evening chronotype compared to morning and/or intermediate chronotype.

Study design: longitudinal, cross-sectional, case-control, cohort studies
Languages: English, Italian, German, Spanish, French.

When data were not available in the study report, corresponding authors were contacted twice with a direct request; in the case of no response, the study was excluded.

2.2. Search procedure

A keyword-based search was performed in July 2022. The searches were run in the electronic databases of PubMed, PsycINFO, and Scopus. We used a combination of terms related to sleep, to each different substance (see *Definition of variables of interest* below), and their association (prevalence OR incidence OR frequency OR rate OR epidemiology OR correlation OR determinants OR risk OR association OR relationship). The full search strategy is available in the PRISMA checklist in Supplementary File S1. Reference lists of the retrieved original articles, relevant reviews, and meta-analyses were screened to identify any missing reports. The first author conducted the literature search. The results were uploaded to CITAVI 6 software (https://www.citavi.com). The review team developed test screening questions for an assessment based on inclusion and exclusion criteria. Together, the first and second authors (D.M., V.B.) screened the titles and abstracts yielded by the search against the inclusion criteria, with a weekly appointment to discuss selection process. Decisions were reached by consensus between reviewers. Disagreement and uncertainty were resolved by contacting a third author (C.B.). Final selection of the articles was discussed by the review team.

2.3. Data extraction

Data were extracted using a format developed by the review authors under the supervision of a professional statistician (S.C.). Data extraction was discussed with all authors and performed by the first and second reviewers (D.M., V.B.). Any uncertainty about data coding was discussed with a third author (C.B.) until reaching a consensus. We extracted the following: country, demographics of the sample (target population, mean age and standard deviation, age range, gender composition), information on sleep (sleep-wake dimension and relative assessment), information on substance use (type of substance and relative assessment), main findings.

2.4. Definitions of the variables of interest

Substance use. Substances included in the keyword-based search of electronic databases were derived from the literature and from two international reports on substance use, the National Survey on Drug Use and Health (NSDUHD), 2020 [13] and the European Drug Report 2021 [33]. From the literature, we extracted four groups of substances based on their potential sleep-disrupting effect: alcohol, caffeine, nicotine, and cannabis [34–36]. From international reports [13,33], we extracted a group labelled *other substances*, which included both illicit substances (e.g., cocaine, amphetamines) and controlled drugs (e.g., sedatives, stimulants) (see Supplementary Table S1 for a detailed list). We included assessments of substance use that referred to a specific time frame (from the past year to last week or month) or to current or regular use. We excluded measures of lifetime use because our main purpose was the association between current substance use and sleep. Self-medication was defined as the motivation to use a substance (e.g., “as a sleep aid”). For our purpose, the use of non-prescribed sleep medications alone was not considered as self-medication. While the term “sleep aid” is often used to indicate self-medication [37], we did not include this definition in absence of a clear elicitation of motivation for use. A similar approach was used for wake-enhancing substances, for which we considered the motivation (e.g., “to promote wakefulness” or “to compensate for lack of sleep”) and not the substance itself (e.g., “stimulants”). Indeed, sleep medications and stimulant substances can be used for a variety of reasons, including experimentation [38,39].

Sleep-wake dimensions. Coding of the sleep variables included is reported in Supplementary Table S2. We included the following assessments:

Sleep disturbances: Insomnia symptoms and overall sleep quality assessed using validated multidimensional questionnaires.
Sleep health dimensions:

- Sleep duration: average hours of sleep at night
- Sleep satisfaction: subjective rating of sleep quality, perception of sleep as being refreshing
- Sleep efficiency: ratio between sleep time and time spent in bed
- Sleep timing: bedtime and midpoint of sleep
- Daytime alertness: sleepiness during the day

Circadian characteristics:

- Circadian preference as measured by a validated questionnaire
- Social jet lag as the differences in midpoint of sleep between work/school days and free days

2.5. Quality assessment (risk of bias)

The risk of bias assessment was performed independently by the first and second reviewer, with a weekly appointment for discussion. Any doubt was managed through author consensus and disagreements were resolved by contacting a third author (C.B.). For cross-sectional studies, the Appraisal tool for Cross-Sectional Studies (AXIS) was used [40]. This tool is composed of 20 items, with higher scores indicating a lower risk of bias. We considered a score of at least 15 as an overall low risk of bias (high quality). For prospective and case-control studies we used the appropriate version of the Newcastle-Ottawa Scale (NOS) [41]. A higher score indicates a lower risk of bias, with a score of at least 5 indicating low risk (fair quality) [42]. Details can be found in Supplementary File S3.

2.6. Meta-analytic calculations and synthesis

Analyses were performed by a professional statistician (S.C.) using SAS Software 9.4 version with SAS/STAT version 14.1 (SAS Institute Inc., Cary, NC, USA) and MetaXL Software program for Meta-analysis in Microsoft Excel. We calculated the odds ratios (ORs) and 95% confidence intervals (CIs) to estimate the effect size of the association between sleep dimensions and the use of substances. After variable coding, studies were divided by substance investigated and by sleep dimension, following the adopted framework (Fig. 1). We further coded the assessment of the two groups of variables (sleep dimensions and substance use). We could then extract the 7 sleep dimensions (sleep disturbances, the five sleep health dimensions, circadian characteristics) and the 5 groups of substances (alcohol, caffeine, nicotine, cannabis, other substances). Data were entered in meta-analyses based on comparability of the variables considered and of their assessments. Effect sizes were entered into meta-analysis for each sleep dimension and substance. Therefore, one study could enter in multiple meta-analyses based on the number of substances and sleep dimensions reported. Firstly, meta-analyses were conducted by pooling the ORs of the substances presented in each study. For studies reporting data regarding more than one substance, we averaged the log odds ratios (logOR) for each substance (logOR of substance X + logOR of substance Y/No. of non-users) and averaged the standard errors (SE) for each substance (SE of substance X + SE of substance Y/No. of non-users); in the case of different reference numbers for ORs, a weighted average was made. We used these metrics to calculate the OR and 95% CI for the 'use of at least one substance' category for each study. This method reduced the likelihood of artificially narrowing the CIs. Then, separate meta-analyses for each substance and sleep outcome were performed for cases in which at least 3 studies could be included in the model. We used random effect models since we expected heterogeneity in the distribution of ORs. An OR greater than 1 indicated that the sleep outcome was more likely in those reporting substance use. Heterogeneity was tested for each model, using Chi-square tests and I^2 metrics. Indications of heterogeneity were noted when the test showed a p-value <0.20 and an $I^2 \geq 50\%$. Asymmetry was evaluated using a funnel plot and tested with the LFK index, which provides a quantitative measure to assess the degree of asymmetry [43]. LFK scores within ±1 indicate 'no asymmetry', those exceeding ±1 but within ±2 suggest minor asymmetry, and a score of > ± 2 indicates major asymmetry. All report probabilities (*p* value) were two-sided, with a significance level of 0.05 except where otherwise specified.

We did not transform among effect sizes when results were presented as means, to reduce bias due to imprecise estimations. We reported a narrative synthesis of the studies not included in the analyses, describing study characteristics, sample composition, and results of individual studies.

3. Results

3.1. Study selection

We identified a total of 20755 titles from our database search; prior to screening, 10018 duplicates were removed. Title and abstract screening led to 622 eligible studies. After screening full texts against the inclusion criteria, 44 studies were included. Screening of references yielded 33 additional studies, of which 2 were included. The results of our selection process yielded 46 studies. See Fig. 2 for detailed search flow.

3.2. Risk of bias

The judgement of risk of bias (quality scores) according to the appropriate tools for each study design is reported in the last column of Table 1. For details of risk of bias assessment of the studies included see Supplementary File S3. Judgment of low risk of bias was carried out for 26 cross-sectional studies (AXIS>14), 3 prospective studies (NOS>4), and 3 case-control studies (NOS>4).

3.3. Study characteristics

Table 1 reports the descriptive characteristics of the included studies divided by study design and sampling. The selection process yielded 36 cross-sectional [44–79], 4 case-control [80–83], and 6 prospective studies [84–89]. In total, 7 studies recruited participants who had been selected due to their use of substances and 39 had samples drawn from the general population. We refer to them as selected and unselected samples, respectively. Prior to data analysis and synthesis, we organised the literature based on study design and sampling (Fig. 3). For the rest of the review, we will follow this classification. Sample composition was heterogeneous. Most studies were carried out among college students (n = 43) and had a sample in the age range of 18–25 years (n = 26). Gender ratio was mostly balanced, with females representing at least half the sample. The sleep dimensions and substances investigated are reported in Table 1. Some studies reported more than one sleep dimension in association with more than one substance. In most cases, the Pittsburgh Sleep Quality Index (PSQI) [90] was used. In accordance with our data coding, we extracted the following PSQI components: subjective sleep quality (sleep satisfaction), sleep duration, sleep efficiency, daytime dysfunction. The most often-reported sleep assessment was sleep disturbances (n = 25), followed by sleep duration (n = 17). Circadian characteristics regarded only chronotype (n = 7), while none of the included studies assessed social jetlag or circadian rhythm disorders. Meta-analysis could only be performed on sleep disturbances assessed using the PSQI and on sleep duration, due to a high variability in the assessment of other sleep outcomes among a smaller number of studies.

3.4. Cross-sectional association between substance use and sleep

3.4.1. Sleep disturbances

Table 2 reports the characteristics and main findings from each of the included studies, divided by study design and samples. A total of 19 cross-sectional studies on unselected samples assessed sleep disturbances in association with alcohol (n = 8), caffeine (n = 10), nicotine (n = 11), cannabis (n = 1), and other substances (n = 1).

Because sleep disturbances were mostly assessed using the PSQI (n = 14), we performed meta-analytic computations on 10 [46,47,51,52,55,57,62,68,71,74] studies reporting odds based on the total score. The forest plot of the random-effect model for use of at least one substance (alcohol, caffeine, and/or nicotine) is available in Supplementary File S4. Results showed that the use of any substance was associated with 1.38 higher odds of reporting a sleep disturbance (95% CI: 1.20–1.59). No asymmetry (publication bias) was detected (LFK-index: 0.26; See Supplementary File S4). As expected, there was heterogeneity (Q = 15.97, df(Q) = 9, p = 0.07; $I^2 = 44$).

The forest plots of the random effect models for alcohol (a), caffeine (b), and nicotine (c) are reported in Fig. 4.

Alcohol. The pooled OR for alcohol use was 1.24 (95% CI: 1.01–1.53). Heterogeneity was high (Q = 9.93; df(Q) = 4; p = 0.04; $I^2 = 60$). Studies were homogenous in terms of population (college students) and PSQI cut-off (>5). Differences in the assessment of alcohol use did not contribute to heterogeneity. One study with a high risk of bias was removed [51]. Pooled OR of studies with low risk of bias yielded a non-significant association (OR = 1.16; 95% CI: 0.97–1.38) among non-heterogenous studies (Q = 5.1; df(Q) = 3; p = 0.2; $I^2 = 41$). It is worth noting that two studies found that the odds of suffering from a sleep disturbance were higher with higher levels of alcohol consumption, while the odds were non-significant for moderate consumption [51,57].

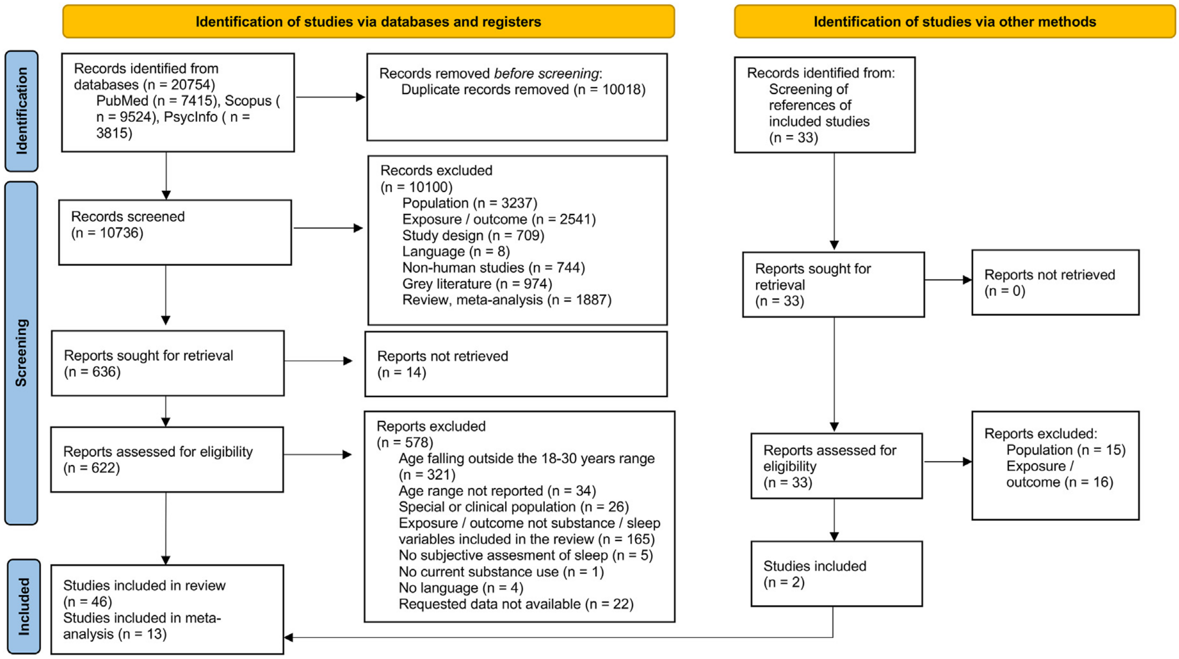

Fig. 2. Flow chart of the study selection process. PRISMA 2020 flow diagram including searches of databases, registers, and other sources.

Caffeine. The random-effect model for caffeine use was performed after removal of two studies that were outliers [49,51]. Pooled OR showed an effect size of 1.69 (95% CI: 1.40–2.03) with no indication of heterogeneity ($Q = 3.73$; $df(Q) = 3$; $p = 0.29$; $I^2 = 19$). In one study, higher consumption of caffeine was associated with higher odds of sleep disturbances [51].

Nicotine. Pooled OR for the 7 studies on current nicotine use was 1.35 (95% CI: 1.14–1.61) with moderate heterogeneity ($Q = 13.62$; $df(Q) = 6$; $p = 0.03$; $I^2 = 56$). Sample composition did not contribute to heterogeneity, as removing one study on the general population [55] did not affect statistics. Sensitivity analysis showed that, after removing one study at a time, results were robust. The major contributor to heterogeneity was one study with a high risk of bias [62]. The remaining studies yielded a pooled OR of 1.22 (95% CI:1.23–1.63) and were not heterogenous ($Q = 7.12$; $df(Q) = 5$; $p = 0.2$).

Major asymmetry (publication bias) was detected only for nicotine (LFK-index: 2.31).

Narrative findings. Among the cross-sectional studies on unselected samples that were not included in the meta-analyses, three compared mean substance use between those above and below the PSQI cut-off for sleep disturbances [56,63,73] and four used different sleep assessments [58,64,67,70]. Three studies were on selected samples [77–79] and three were case-control studies [80–82].

Alcohol use and heavy episodic drinking were found to be more frequent in college students with sleep disturbances [56,63]. One study found that students who consumed more alcohol also had a higher rate of sleep disturbances [64]. Studies on selected samples of alcohol consumers did not find a significant association between sleep disturbances and pattern of alcohol consumption, either measured with retrospective questionnaires [78] or via daily diaries [79]. A significant association was found between sleep disturbances and excessive drinking, defined as a frequency of at least 12 drinks in a single sitting [78].

The association between caffeine use and sleep disturbances was generally confirmed in studies that were not included in the meta-analysis. Caffeine use from any source was associated with a higher occurrence of sleep disturbances in 6 studies, both in college [46,58,63,64] and non-college samples [70,74]. The total PSQI score was found to be associated with lower coffee consumption in one study [73]. This result should be considered in light of the low number of college students scoring above cut-off for sleep disturbances ($n = 35$). Individual studies considering the source of caffeine revealed mixed findings. In one study, the consumption of both coffee and energy drinks was associated with sleep disturbances [64]. One study found that sleep disturbances were associated with a higher consumption of coffee but not of energy drinks during the evening [63]. On the contrary, Mendoza et al. [58] found that higher insomnia symptoms were associated with energy drink use but not with coffee consumption in college students. Results from Young et al. [74] on a non-college sample confirmed that a greater use of energy drinks is associated with a higher PSQI score. Another study on young adults who were not college students found insomnia symptoms to be associated with the consumption of energy drinks in females but not in males [70].

Studies that were not included in the meta-analysis were nonconcordant regarding the association between nicotine use and sleep disturbances. One study found that smokers had higher odds of presenting clinical insomnia symptoms [67], while in another study sleep disturbances were not associated with smoking status [64]. Two case-control studies comparing college students who were current smokers to those who were non-smokers found no significant difference in the PSQI total [80,81]. In a study on smokers, the odds of experiencing a sleep disturbance increased with the number of cigarettes smoked [77].

Cannabis use was not cross-sectionally associated with sleep disturbances in one study [64]. In a case-control study, Conroy et al. [82] found that daily use was associated with increased sleep disturbances compared to non-daily use and non-use. Sleep disturbance occurrence was associated with higher odds of consuming illicit substances both in unselected college students [56] and among students selected for excessive drinking [78].

Table 1
Descriptive characteristics of included studies by study design and sampling.

Study	Country	Population	Age range	Mean age (SD)	Sample size	Female (%)	Substance	Sleep dimension	Sleep assessment	Risk of bias
Cross-sectional studies (n = 36)										
Unselected samples										
Adan 1994 [44]	Spain	G (31.8% C)	21−30	25.3 (2.87)	537	52.1	Alcohol, caffeine (coffee) nicotine	Chronotype	rMEQ	High
Al Otaibi & Kamel 2017 [45]	Saudi Arabia	C	18−26	F: 21.1 (2.2) M: 22.8 (6.1)	414	52.9	Caffeine (energy drinks)	Sleep duration	Single item	Low
Al Sharif et al., 2018 [46]	Saudi Arabia	C	18−25	nr	476	82.8	Caffeine (coffee, energy drinks)	Sleep disturbances	PSQI	High
Arbinaga et al., 2019 [47]	Spain	C	19−26	22.38 (2.13)	444	56.1	Nicotine	Sleep disturbances, sleep duration, sleep efficiency, sleep satisfaction, daytime dysfunction	PSQI	Low
Barbosa et al., 2020 [48]	Brazil	G	18−19	nr	2514	52.4	Caffeine (energy drinks)	Daytime dysfunction	ESS	Low
Bin Ismayatim et al., 2021 [49]	Malaysia	C	18−29	nr	256	59.8	Nicotine	Sleep disturbances	PSQI, ISI	High
Bodur et al., 2021 [50]	Turkey	C	19−24	21.4 (1.38)	661	27.8	Caffeine (coffee, energy drinks)	Chronotype	MEQ	Low
Bogati et al., 2020 [51]	Nepal	C	19−27	21.97 (1.37)	350	42.6	Alcohol, caffeine (coffee, energy drinks), nicotine	Sleep disturbances, sleep duration, sleep efficiency, daytime dysfunction	PSQI	High
Elwasify et al., 2016 [52]	Egypt	C	18−24	21.4	1182	67.7	Caffeine, nicotine	Sleep disturbances	PSQI	Low
Hug et al., 2019 [53]	Switzerland	G	18−25	21.7 (1.7)	146	100	Alcohol, caffeine (coffee, energy drinks)	Sleep timing	MCTQ	Low
Kianersi et al., 2021 [54]	USA	G (30.5% C)	18−24	nr	19701	45.3	Alcohol, nicotine	Sleep duration	Single item	Low
Liao et al., 2019* [55]	China	G	18−29	nr	6124	nr	Nicotine	Sleep disturbances	PSQI	Low
Liu et al., 2021 [56]	USA	C	18−24	20.05 (1.75)	820	62.7	Alcohol, other substances	Sleep disturbances	PSQI	Low
Lohsoonthorn et al., 2013 [57]	Thailand	C	18−28	20.3 (1.3)	2854	67.4	Alcohol, caffeine (coffee, energy drinks), nicotine	Sleep disturbances, sleep duration, sleep efficiency, daytime dysfunction	PSQI	Low
Mendoza et al., 2021 [58]	Peru	C	19−22	nr	289	66.1	Caffeine (coffee, energy drinks)	Sleep disturbances	ISI	High
Naito et al., 2021 [59]	Malaysia	C	18−25	20.71 (1.47)	1017	51	Alcohol, nicotine	Sleep duration	Single item	Low
Nakade et al., 2009 [60]	Japan	C	18−29	19.26 (1.33)	800	100	Alcohol, nicotine	Chronotype	rMEQ	High
Ogilvie et al., 2018 [61]	USA	G	20−30	nr	1854	55.6	Caffeine (coffee, energy drinks)	Sleep duration, sleep timing	Author-constructed questionnaire	Low
Orsal et al., 2012 [62]	Turkey	C	18−27	21.3 (1.91)	803	55.2	Alcohol, nicotine	Sleep disturbances	PSQI	High
Pham et al., 2021 [63]	Vietnam	C	18−25	20.3 (2.5)	369	65.6	Alcohol, caffeine (coffee, energy drinks), nicotine	Sleep disturbances	PSQI	High
Riera-Sampol et al., 2022** [64]	Spain	C	18−25	20.6 (2.1)	886	68.6	Alcohol, caffeine (coffee, energy drinks), cannabis, nicotine	Sleep disturbances	MOS-SS	Low
Rosso et al., 2020** [65]	USA	C	18−25	20.9 (1.5)	4376	59.3	Alcohol, nicotine	Sleep satisfaction	Single item	Low
Sato-Mito et al., 2011 [66]	Japan	C	18−20	18.1 (0.3)	3304	100	Nicotine	Sleep timing	MTCQ	High
Średniawa et al., 2019 [67]	Poland	C	18−26	22.22 (1.5)	264	56.8	Nicotine	Sleep disturbances	AIS	High
Štefan et al., 2018 [68]	Croatia	C	18−24	20.87 (2.11)	2100	50.4	Alcohol, nicotine	Sleep disturbances	PSQI	Low
Tran et al., 2014 [69]	Thailand	C	18−28	20.3 (1.3)	3000	66.9	Alcohol, caffeine (coffee, energy drinks), nicotine	Chronotype, daytime dysfunction	MEQ, ESS	Low
Trapp et al., 2021 [70]	Australia	G	22	nr	1115	53.7	Caffeine (energy drinks)	Sleep disturbances, daytime dysfunction	PSSQ-I, ESS	Low
Vik et al., 2020[a] [71]	USA	(C)	18−20	nr	144	58.7	Alcohol	Sleep disturbances	PSQI	Low
Vo et al., 2015 [72]	USA	C	18−24	20	1976	70.4	Prescription drugs	Sleep duration	Single item	Low
	Australia	C	20−27	21.8 (1.05)	151	60.3	Caffeine	Sleep disturbances	PSQI	Low

Table 1 (*continued*)

Cross-sectional studies (n = 36)

Unselected samples

Study	Country	Population	Age range	Mean age (SD)	Sample size	Female (%)	Substance	Sleep dimension	Sleep assessment	Risk of bias
Vollmer-Conna et al., 2020[a] [73]										
Young et al., 2020 [74]	USA	G	22–23	22.9 (0.45)	462	100	Caffeine (energy drinks)	Sleep disturbances, sleep duration, sleep efficiency, sleep satisfaction, daytime dysfunction	PSQI	Low

Selected samples reporting substance use

Study	Country	Substance use reported	Age range	Mean age (SD)	Sample size	Female (%)	Substances	Sleep dimension	Sleep assessment	Risk of bias
Caviness et al., 2019 [75]	USA	Cannabis or alcohol (60.4% C)	18–25	21.3 (2.07)	498	52.2	Alcohol, caffeine (coffee, energy drinks), cannabis, nicotine, prescription medications	Sleep duration, sleep efficiency, sleep satisfaction	PSQI	Low
DeMartini & Fucito 2014 [76]	USA	Alcohol (C)	18–25	18.90 (0.97)	312	43.3	Alcohol	Sleep timing	SWPS	Low
Dugas et al., 2017 [77]	USA	Nicotine	22–26	24 (0.6)	405	55.1	Nicotine	Sleep disturbances	PSQI	Low
Miller et al., 2022 [78]	USA	Alcohol (C)	18–30	19.0 (1.4)	461	68.8	Alcohol, other substances	Insomnia	ISI	Low
Miller, Van Reen et al., 2017 [79]	USA	Alcohol (C)	18–30	18.6 (0.4)	385	51.7	Alcohol	Sleep disturbances	PSQI	Low

Case-Control studies (n = 4)

Study	Country	Case definition	Age range	Mean age (SD)	Sample size	Female (%)	Substance	Sleep dimension	Sleep assessment	Risk of bias
Cohen et al., 2019 [80]	Israel	Current smokers (C)	19–30	Case; 23.92 (2.94); Control: 23.05 (1.82)	77	74	Nicotine	Sleep disturbances	PSQI	Low
Cohen et al., 2020 [81]	Israel	Current smokers (C)	19–28	Case: 24.03 (2.84); Control: 22.44 (2.23)	86	69.8	Nicotine	Sleep disturbances, sleep duration, sleep efficiency, sleep satisfaction, daytime dysfunction	PSQI	Low
Conroy et al., 2016 [82]	USA	Habitual and occasional cannabis users (G)	18–29	22.3 (3.0)	98	54.1	Cannabis	Sleep disturbances, daytime dysfunction chronotype	PSQI, ISI, ESS, MEQ	Low
Rusnac et al., 2018 [83]	USA	Sleep deprivation and insomnia (C)	19–25	nr	536	47	Alcohol	Sleep disturbances, sleep duration	ISI, single item	High

Prospective studies (n = 6)

Unselected samples

Study	Country	Population	Baseline age range and time points	Baseline mean age (SD)	Baseline sample size	Female (%)	Substance and time point of assessment	Sleep dimension and time point of assessment	Sleep assessment	Risk of bias
Hasler et al., 2022[b] [84]	USA	G	18–21	19.6 (1.1)	637	53.8	Alcohol, cannabis	Sleep duration, sleep satisfaction, sleep timing, daytime dysfunction, chronotype	CASQ, PSQI, STQ, CSM	Low
Liu et al., 2022 [85]	USA	C	19–25	21.36 (0.81)	1363	61	Alcohol	Sleep satisfaction	Single item	High
Samek & Akua 2022[a] [86]	USA	C	18–20	19.1 (0.41)	209	61.7	Alcohol, cannabis	Sleep duration	Two items	Low
Van Reen et al., 2016 [87]	USA	C	18–22	nr	878	50.1	Alcohol	Sleep duration, sleep timing, sleep variability	Sleep diary	High

Selected samples reporting substance use

Study	Country	Substance use reported	Baseline age range	Baseline mean age (SD)	Sample size	Female (%)	Substance	Sleep dimension	Sleep assessment	Risk of bias
	USA		18–25	19.33 (1.11)	217	76				Low

(*continued on next page*)

Table 1 (*continued*)

Selected samples reporting substance use										
Study	Country	Substance use reported	Baseline age range	Baseline mean age (SD)	Sample size	Female (%)	Substance	Sleep dimension	Sleep assessment	Risk of bias
Goodhines, Gellis, Ansell, & Park 2019 [88]		Alcohol, cannabis (C)					Alcohol, cannabis (sleep aid)	Sleep disturbances, sleep duration, sleep satisfaction, daytime dysfunction	PSQI, sleep diary (CSD)	
Goodhines, Gellis, Kim et al., 2019 [89]	USA	Alcohol, cannabis (C)	18–28	19 (1.32)	171	67.8	Alcohol, cannabis, OTC	Sleep disturbances, sleep duration, chronotype	ISI, single item, MEQ	Low

Notes
Abbreviations: C: College students only; G: College and non-college students recruited (percentage in parenthesis represents number of college students in the sample, when reported); nr: Not reported; F: Females; M: Males.
Questionnaires: AIS: Athens Insomnia Scale; ESS: Epworth Sleepiness Scale; CASQ: Cleveland Adolescent Sleepiness Questionnaire; CSD: Consensus Sleep Diary; CSM: Composite Scale of Morningness; ISI: Insomnia Severity Index; MCTQ: Munich Chronotype Questionnaire; MEQ: Morningness-Eveningness Questionnaire; MOS-SS: Medical Outcome Study-Sleep Scale; PSQI: Pittsburgh Sleep Quality Index; PSSQ-I: Pittsburgh Sleep Symptoms Questionnaire– Insomnia; rMEQ: Morningness-Eveningness Questionnaire-reduced; STQ: Sleep Timing Questionnaire; SWPS: Sleep/Wake Behavior Problems Scale.
All caffeine refers to caffeinated drinks; in parentheses the drinks included in this category are indicated for each study; when only caffeine is reported, it indicates that the specific substance was not reported.
Cut-off for risk of bias judgment is 15 on the AXIS for cross-sectional studies and 5 on the NOS for case-control and prospective studies.
*Age subgroup of a larger sample (n = 26035) aged 12 to 60+ years
[a] Studies included after the corresponding authors had provided requested data via personal communication
[b] Age subgroup of a larger accelerated longitudinal design (age range 12–27)

3.4.2. Sleep duration

9 cross-sectional studies on unselected samples assessed sleep duration in association with alcohol (n = 4), caffeine (n = 5), nicotine (n = 5), and other substances (n = 1). Characteristics and main findings are reported in Table 3. Meta-analyses were performed on 7 studies [45,47,51,54,57,59,61] reporting the odds ratio for short sleep duration classified as <7 h, uniformly with the National Sleep Foundation recommendations.

The random effect meta-analytic models for use of alcohol, caffeine, and/or nicotine revealed a high level of heterogeneity ($Q = 30.54$; $df(Q) = 6$; $p < 0.001$; $I^2 = 80$) and minor asymmetry (LFK-index: 1.05). The forest plot is available in Supplementary Fig. S4. The pooled estimate was 1.44 (95% CI: 1.08–1.91). Forest plots for models considering each substance are reported in Fig. 5. High heterogeneity was detected for alcohol ($Q = 30.08$; $df(Q) = 3$;

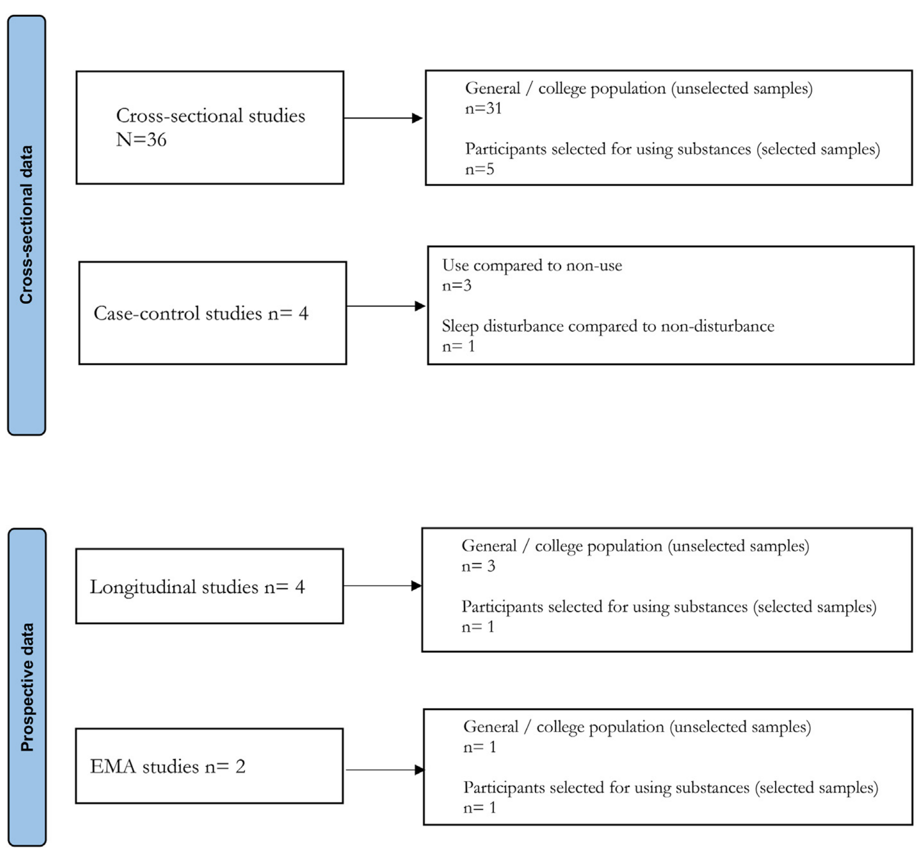

Fig. 3. Literature organisation. Included studies (n = 46) are organised based on study design and samples.

Table 2
Characteristics and main findings of studies on sleep disturbances, divided by study design and sample.

Reference	Type of sample (n)	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep disturbances
Sleep disturbances (n = 24)					
Cross-sectional studies on unselected samples (n = 18)					
Al Sharif et al., 2018 [46]	C (n = 476)	PSQI	Coffee (92%)	Level of consumption in cups per day: tolerable (1–3 cups), excessive (at least 4 cups)	Sleep disturbances: higher prevalence of excessive use
Arbinaga et al., 2019 [47]	C (n = 444)	PSQI	Nicotine (41.2%)	Current use	Use vs non-use: higher odds of sleep disturbances; higher PSQI scores
Bin Ismayatim et al., 2021 [49]	C (n = 256)	PSQI; ISI	Nicotine (10.2%)	Current use	Use vs non-use: higher prevalence of sleep disturbances
Bogati et al., 2020 [51]	C (n = 350)	PSQI	Alcohol (38%)	Level of consumption in units per month: low (0–4 units), moderate (4–15 units), high (>16 units)	Use vs non-use: higher odds of sleep disturbances
			Coffee (96%)	Level of consumption in mg per day: low (<100 mg), moderate (100–250 mg), high (>250 mg)	Use vs non-use: higher odds of sleep disturbances
			Nicotine (14.3%)	Level of consumption in cigarettes per week: low (<10 cigarettes), moderate-high (≥10 cigarettes)	Use vs non-use: higher odds of sleep disturbances
Elwasify et al., 2016 [52]	C (n = 1182)	PSQI	Caffeine (85.5%)	Daily use	Use vs non-use: higher odds of sleep disturbances
			Nicotine (3.4%)	Current use	Use vs non-use: higher odds of sleep disturbances
Liao et al., 2019 [55]	G (n = 7590)	PSQI	Nicotine (21.9%)	Current use	Use vs non-use: higher prevalence of sleep disturbances
Liu et al., 2021[a] [56]	C (n = 746)	PSQI	Alcohol (nr)	Frequency of use, frequency of heavy episodic drinking	Sleep disturbances: higher frequency of use
			Other substances (nr)	Current use	Sleep disturbances: higher number of substances used
Lohsoonthorn et al., 2013 [57]	C (n = 2854)	PSQI	Alcohol (34.2%)	Level of consumption in drinks per week: low (<1 drink), moderate (1–19 drinks), high (≥20 drinks)	Use vs non-use: higher odds of sleep disturbances
			Caffeine (58%)	Use defined as at least one stimulant drink per week	Use vs non-use: higher odds of sleep disturbances
			Nicotine (6.8%)	Current use	No association
Mendoza et al., 2021 [58]	C (n = 289)	ISI	Coffee (81.3%)	Current use	No association
			Energy drinks (39.4%)	Number of drinks/month; number of days of use/month; number of drinks per sitting	Higher frequency and greater quantity of use: higher prevalence of sleep disturbances
Orsal et al., 2012 [62]	C (n = 803)	PSQI	Alcohol (30.5%)	Current use	Use vs non-use: higher odds of sleep disturbances
			Nicotine (35%)	Current use	No association
Pham et al., 2021 [63]	C (n = 369)	PSQI	Alcohol (36%)	Use after 4 p.m.	Use vs non-use: higher PSQI scores
			Coffee (15.4%)	Use after 4 p.m.	Use vs non-use: higher PSQI scores
			Energy drinks (10.3%)	Use after 4 p.m.	No association
			Nicotine (4.3%)	Current use	No association
Riera-Sampol et al., 2022[a] [64]	C (n = 886)	MOS-SS	Alcohol (78.5%)	Frequency of use	Use vs non-use: higher MOS-SS scores
			Caffeine (93.2%)	Mg/day caffeinated drinks; use of coffee, use of energy drinks	Use vs non-use: higher MOS-SS scores
			Cannabis (4.5%)	Current use	No association
			Nicotine (18.5%)	Current use	No association
Średniawa et al., 2019 [67]	C (n = 264)	AIS	Nicotine (17%)	Current use	Use vs non-use: higher prevalence of sleep disturbances
Štefan et al., 2018 [68]	C (n = 2100)	PSQI	Alcohol (27.1%)	At least one heavy episodic drinking	No association
				Current use	Use vs non-use: higher odds of sleep disturbances

(continued on next page)

Table 2 (*continued*)

Reference	Type of sample (n)	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep disturbances
Sleep disturbances (n = 24)					
Cross-sectional studies on unselected samples (n = 18)					
Trapp et al., 2021 [70]	G (n = 934)	PSSQ-I	Nicotine (24.1%) Energy drinks (35.3%)	Use at least once/week	Use vs non-use: higher odds of sleep disturbances; higher PSSQ-I scores (in F)
Vik et al., 2020[a] [71]	C (n = 144)	PSQI	Alcohol (49.3%)	Use at least once/past 3 months	No association
Vollmer-Conna et al., 2020[a] [73]	C (n = 148)	PSQI	Coffee (nr)	Cups/day	Sleep disturbances: lower consumption
Young et al., 2020 [74]	G (n = 462)	PSQI	Energy drinks (12.1%)	Number of drinks/day	Use vs non-use: higher prevalence of sleep disturbances; higher PSQI scores
Cross-sectional studies on selected samples (n = 3)					
Dugas et al., 2017 [77]	Nicotine use in past year (G) (n = 405)	PSQI	Nicotine	Frequency/past year, number of cigarettes smoked/past month	Higher number of cigarettes smoked in past month: higher odds of reporting a sleep disturbance
Miller et al., 2022 [78]	Heavy drinking in the past 30 days (C) (n = 461)	ISI	Alcohol	Drinking days/week, drinks/drinking day, days of binge drinking/week, days 12+ drinks/sitting, maximum drinking quantity	Sleep disturbances: higher frequency of 12+ drinks/sitting
			Other substances	Any use in past month	Sleep disturbance: higher prevalence of consumption
Miller, Van Reen et al., 2017 [79]	Violation of campus alcohol policy (C) (n = 385)	PSQI	Alcohol	Number of heavy drinking days (diary)	No association
Case-control studies (n = 3)					
Cohen et al., 2019 [80]	Current smokers vs. non-smokers (C) (n = 38 cases; n = 39 controls)	PSQI	Nicotine	Case definition: at least 10 cigarettes a day for at least 2 years in the smokers' group	No significant difference between smokers and non-smokers
Cohen et al., 2020 [81]	Current smokers vs. non-smokers (C) (n = 40 cases; n = 46 controls)	PSQI	Nicotine	Case definition: at least 10 cigarettes a day for at least 2 years in the smokers' group	No significant difference between smokers and non-smokers
Conroy et al., 2016 [82]	Habitual and occasional cannabis users vs. non-users (G) (n = 78 cases; n = 20 controls)	PSQI, ISI	Cannabis	Case definition: use in past month (daily and non-daily)	Higher prevalence of sleep disturbances in daily consumers compared to non-daily consumers and to non-consumers (both PSQI and ISI)

Notes.
Abbreviations: C: College students only; G: College and non-college students recruited (percentage in parenthesis represents number of college students in the sample, when reported); nr: Not reported; F: Females.
Questionnaires: AIS: Athens Insomnia Scale; ESS: Epworth Sleepiness Scale; ISI: Insomnia Severity Index; MOS-SS: Medical Outcome Study-Sleep Scale; PSQI: Pittsburgh Sleep Quality Index; PSSQ-I: Pittsburgh Sleep Symptoms Questionnaire— Insomnia; STQ: Sleep Timing Questionnaire.
[a] Unpublished data from personal communication with authors.

$p = 0.00$; $I^2 = 90$), caffeine ($Q = 16.57$ (df(Q) = 2; $p = 0.00$; $I^2 = 88$), and nicotine use ($Q = 43.28$ (df(Q) = 4; $p = 0.00$; $I^2 = 91$).

Alcohol. The pooled effect size was 0.95 (95% CI: 0.69–1.31) for alcohol use. Sample composition and risk of bias did not affect heterogeneity. Two studies also reported the odds for level of use. High but not moderate alcohol consumption was significantly associated with shorter sleep duration compared to non-use in one study (OR = 1.74; 95% CI: 1.07–2.81) [51]. In Lohsoonthorn et al. [57], moderate but not high consumption was associated with lower odds of reporting short sleep compared to non-use (OR = 0.75; 95% CI: 0.62–0.90).

Caffeine. In terms of caffeine, one study was removed at the beginning for being an outlier [51]; the pooled effect size was 1.55 (95% CI: 0.94–2.54). One study provided odds based on quantity of use: a higher daily consumption was associated with higher odds of short sleep duration [51].

Nicotine. The model for nicotine use showed a pooled OR of 1.47 (95% CI: 0.85–2.54). One study was identified as a major contributor to heterogeneity [57]. After its removal, the pooled OR was 2.10 (95% CI: 1.92–2.28), with a Q-value of 1.75 (df(Q) = 3; $p = 0.63$). Only one study assessed range of consumption [51]: the number of cigarettes per day was not associated with sleep duration. Nonetheless, a low number of high consumers (>10 cigarettes per day; n = 29) limits the interpretation of this result.

Major asymmetry was observed for alcohol (LFK: 4.68), caffeine (LFK: 4.53), and nicotine (LFK: 4.44).

Narrative findings. Three studies not included in the meta-analyses compared average hours of sleep duration in those consuming a substance and those who were not consumers [45,47,74]. One study was on a sample selected for using either alcohol or cannabis [75] and two were case-control studies [81,83]. In a case-control study, Rusnac et al. [83]. Compared college students reporting only sleep deprivation (<7 average sleep hours) to those reporting chronic insomnia and to a group with sufficient sleep. Students with sleep deprivation alone consumed significantly more drinks per week than those with sufficient sleep and those with insomnia.

Regarding caffeine use, two studies on unselected samples, that were not included in the meta-analysis, found that consumers of energy drinks slept significantly less than non-consumers [45,74].

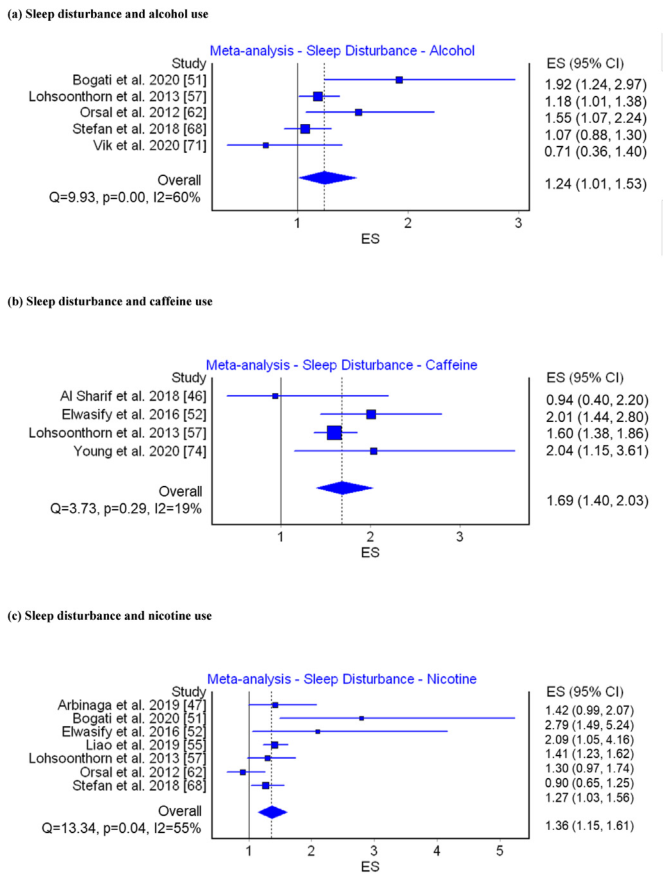

Fig. 4. Forest plots. Random effect meta-analytic models: pooled odds ratios (ORs) of sleep disturbances for those consuming alcohol (a), caffeine (b), and nicotine (c), compared to non-consumers. The right arm of the forest plot favours those reporting consumption of the substance compared to those reporting no consumption.

Those sleeping less than 7 h consumed significantly more coffee than those with at least 7 h of sleep [74]. Among alcohol consumers, caffeine consumption or smoking status were not associated with sleep duration [75].

No observational study analysed cannabis use in association with sleep duration, while two studies assessed stimulant medication misuse. Short sleep duration was not associated with the use of either prescribed or non-prescribed stimulant medications, in a sample of college students [72]. A significant association was found in a sample of college students selected for consuming alcohol [75].

3.4.3. Narrative findings for other sleep-wake dimensions

Results regarding other dimensions of sleep health besides sleep duration, as defined by Buysse [30], are presented in Table 3. Overall, 4 studies investigated sleep satisfaction [47,65,74,75], 5 examined sleep efficiency [47,51,57,74,75], 4 looked at sleep timing [53,61,66,76], and 8 focused on daytime alertness [47,48,51,57,69,70,74,82].

Sleep satisfaction. Sleep satisfaction was defined as the rate of overall sleep quality through the PSQI component (n = 3) and as the number of restful nights (n = 1). Results did not indicate a robust association with substance use, with the exception of nicotine use. One study assessed alcohol use in association with frequency of restful sleep, finding no association [65]. Results regarding caffeine and nicotine indicate that stimulant use affects sleep satisfaction: smokers were more likely to have frequent nights of unrestful sleep [65] and low sleep quality rating [47]. Lower PSQI-derived sleep satisfaction was associated with energy drink use in a sample of young adults [74]. Among alcohol consumers, smoking status was associated with lower sleep satisfaction [75]. In the same sample, the misuse of stimulant medication was not associated with sleep satisfaction [75].

Sleep efficiency. Five studies analysed the association between sleep efficiency as assessed through PSQI and the use of alcohol (n = 2), caffeine (n = 4), nicotine (n = 4), and other substances (n = 1). Sleep efficiency was not found to be associated with alcohol use in college students [51,57]; nor was with caffeine use in young adults who attended college and those who did not [51,57,74,75]. Nicotine use was not associated with sleep efficiency either [47,57], although one study found that current smokers had double the odds of reporting low sleep efficiency [51]. In a sample of alcohol consumers, both the number of cigarettes per day and use of other substances were associated with low sleep efficiency [75].

Sleep timing. The four studies reporting sleep timing were heterogenous in terms of sample composition, assessment of sleep timing and substances investigated (see Table 2). They all found significant associations between substance use and sleep timing, although in one study no association was detected for coffee use [53]. Hug et al. [53] found that diary-reported alcohol use was higher in young adults not attending college who had a later midpoint of sleep [53]. DeMartini & Fucito [76] reported that among college students selected for excessive alcohol use those with a late bedtime also showed a higher alcohol consumption than those with an earlier bedtime. One study assessed bedtime in association with the use of coffee and energy drinks [61], finding that those who had the latest bedtimes (>12:30 a.m.) were more likely to be energy drink consumers (PR = 1.83; 95% CI: 1.10–2.55) and to consume more caffeinated beverages ($p < 0.05$). Nicotine use in college students [66] was found to be associated with a later midpoint of sleep. The latter result is limited by the small number of smokers (1.3% of the sample). Cannabis and other substance use was not investigated in relation to sleep timing.

Daytime alertness. A total of 8 observational studies investigated the effect of substance use on daytime dysfunction (low levels of alertness), 4 of which were performed on college students. Three studies assessed the outcome using the ESS and four using the PSQI (see Table 2 for details). Across three studies, alcohol use was associated with higher prevalence of daytime dysfunction [51,57,69]. Results on caffeine were robust, with the exception of one study that found no association with energy drink consumption in a non-college sample [74]. The use of caffeinated drinks was associated with daytime dysfunction, measured with the PSQI component in college students [51,57] and with the ESS in non-college samples [48,69,70]. Tran et al. (2014) found that the use of energy drinks, but not coffee, was associated with ESS scores. One report indicates a gender effect: the frequent use of energy drinks was associated with a higher level of sleepiness in females but not in males [70]. The four studies assessing nicotine use found no association with daytime dysfunction [47,51,57,69]. Lohsoonthorn et al. [57], found an effect of demographics: after adjusting for age and sex, current smokers had higher odds of experiencing daytime dysfunction (AOR: 1.43; 95% CI: 1.02–1.98).

3.4.4. Narrative findings for chronotype

Table 4 reports characteristics and main findings of the 5 observational studies investigating chronotype in connection to alcohol (n = 3), caffeine (n = 3), nicotine (n = 3), and cannabis (n = 1). All studies used either the full or reduced version of the MEQ. Eveningness was found to be consistently associated with substance use across studies. Evening-types consumed on average more alcoholic drinks than morning- and intermediate-types [44], and those consuming alcohol were more likely to be evening-types

Table 3
Characteristics and main findings of studies on each sleep health dimension, divided by study design and sample.

Study	Type of sample (n)	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep duration
Sleep health dimensions					
Sleep duration (n = 11)					
Cross-sectional studies on unselected samples (n = 9)					
Al Otaibi & Kamel 2017 [45]	C (n = 414)	Single item	Energy drinks (39.9%)	Use defined as at least one drink/week	Use vs non-use: higher odds of short sleep duration; shorter average sleep duration
Arbinaga et al., 2019 [47]	C (n = 444)	PSQI	Nicotine (41.2%)	Current use	Use vs non-use: not higher odds of short sleep duration; shorter average sleep duration
Bogati et al., 2020 [51]	C (n = 350)	PSQI	Alcohol (38.3%)	Level of consumption in units per month: low (0–4 units), moderate (4–15 units), high (>16 units)	Use vs non-use: higher odds of short sleep duration
			Caffeine (96%)	Level of consumption in mg per day: low (<100 mg), moderate (100–250 mg), high (>250 mg)	Use vs non-use: higher odds of short sleep duration; higher level of use: higher odds of short sleep duration
			Nicotine (14.3%)	Level of consumption in cigarettes per week: low (<10 cigarettes), moderate-high (≥10 cigarettes)	Use vs non-use: higher odds of short sleep duration
Kianersi et al., 2021 [54]	G (n = 18766)	Single item	Alcohol (53.3%)	Use in last 30 days	Use vs non-use: higher prevalence of short sleep duration
			Nicotine (12.3%)	Occasional and frequent use	Use vs non-use: higher prevalence of short sleep duration
Lohsoonthorn et al., 2013 [57]	C (n = 284)	PSQI	Alcohol (23%)	Level of consumption in drinks per week: low (<1 drink), moderate (1–19 drinks), high (≥20 drinks)	Moderate Use vs non-use: higher odds of long sleep duration
			Caffeine (58%)	Use defined as at least one stimulant drink per week	Use vs non-use: higher odds of short sleep duration
			Nicotine (6.9%)	Current use	Use vs non-use: higher odds of short sleep duration
Naito et al., 2021 [59]	C (n = 1017)	Single item	Alcohol (19.5%)	Current use	Use vs non-use: higher prevalence of long sleep duration
			Nicotine (2.9%)	Current use	No association
Ogilvie et al., 2018 [61]	G (n = 1773)	Author-constructed questionnaire	Coffee (nr)	Drinks per day	No association
			Energy drinks (17.9%)	Current use	No association
Vo et al., 2015 [72]	C (n = 1976)	Single item	Stimulant medications (4%)	Current use	No association
Young et al., 2020 [74]	G (n = 462)	PSQI	Energy drinks (12.1%)	Use at least once a day	No association
Cross-sectional studies on selected samples (n = 1)					
Caviness et al., 2019 [75]	Cannabis or alcohol use in past month (60.4% C) (n = 498)	PSQI	Prescription stimulant medications used non-medically (NPS), nicotine, caffeine, cocaine	Days of use in last 90 days for NPS, cigarettes per day in last 30 days for nicotine	Higher number of days of NPS use: higher odds of short sleep duration
					No other association
Case-control studies (n = 1)					
Rusnac et al., 2018 [83]	Sleep deprivation vs. sufficient sleep (C) (n = 134 cases; n = 299 controls)	author-constructed questionnaire	Alcohol	Frequency of consumption, number of drinks per week	Sleep loss sleep loss compared to sufficient sleep: higher quantity of alcohol consumed

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep satisfaction
Sleep satisfaction (n = 4)					
Cross-sectional studies on unselected samples (n = 3)					
Arbinaga et al., 2019 [47]	C (n = 444)	PSQI	Nicotine (41.2%)	Current use	Use vs non-use: lower sleep satisfaction
Rosso et al., 2020* [65]	C (n = 4371)	Single item	Alcohol (81.7%)	Current use	No association
			Nicotine: cigarettes (24%)	Current use (cigarettes)	Use vs non-use: higher odds of lower sleep satisfaction
			Nicotine: tobacco (19.6%)	Current use (tobacco)	No association
Young et al., 2020 [74]	G (n = 462)	PSQI	Energy drinks (12%)	Use defined as at least one drink a day	Use vs non-use: lower sleep satisfaction
Cross-sectional studies on selected samples (n = 1)					

Table 3 (*continued*)

Sleep satisfaction (n = 4)

Cross-sectional studies on unselected samples (n = 3)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep satisfaction
Caviness et al., 2019 [75]	Cannabis or alcohol use in past month (60.4% C) (n = 498)	PSQI	Prescription stimulant medications used non-medically (NPS), nicotine, caffeine, cocaine	Days of use in past 90 days for NPS, cigarettes/day in past 30 days for nicotine	Higher number of cigarettes/day: higher odds of low sleep satisfaction No other association

Sleep efficiency (n = 5)

Cross-sectional studies on unselected samples (n = 4)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep efficiency
Arbinaga et al., 2019 [47]	C (n = 444)	PSQI	Nicotine (nd)	Current use	No association
Bogati et al., 2020 [51]	C (n = 350)	PSQI	Alcohol (38.3%)	Level of consumption in units per month: low (0–4 units), moderate (4–15 units), high (>16 units)	No association
			Coffee (96%)	Level of consumption in mg per day: low (<100 mg), moderate (100–250 mg), high (>250 mg)	No association
			Nicotine (14.3%)	Level of consumption in cigarettes per week: low (<10 cigarettes), moderate-high (≥10 cigarettes)	Use vs non-use: higher odds of low sleep efficiency
Lohsoonthorn et al., 2013 [57]	C (n = 2854)	PSQI	Alcohol (23%)	Level of consumption in drinks per week: low (<1 drink), moderate (1–19 drinks), high (≥20 drinks)	No association
			Caffeine (58%)	Use defined as at least one stimulant drink per week	Use vs non-use: higher odds of low sleep efficiency
			Nicotine (6.9%)	Current use	No association
Young et al., 2020 [74]	G (n = 462)	PSQI	Energy drinks (12%)	Use defined as at least one drink a day	No association

Cross-sectional studies on selected samples (n = 1)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep efficiency
Caviness et al., 2019 [75]	Cannabis or alcohol use in past month (60.4% C) (n = 498)	PSQI	Prescription stimulant medications used non-medically (NPS), nicotine, caffeine, cocaine	Days of use in past 90 days for NPS, cigarettes/day in past 30 days for nicotine	Higher number of cigarettes/day: higher odds of low sleep efficiency No other association

Sleep timing (n = 4)

Cross-sectional studies on unselected samples (n = 3)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep timing
Hug et al., 2019 [53]	G (n = 146)	MCTQ (midpoint of sleep)	Alcohol (nr)	Quantity in mL with diary	Latest midpoint: higher frequency of consumption
			Coffee (nr)	Quantity in cups with diary	No association
Ogilvie et al., 2018 [61]	G (n = 1854)	Author-constructed questionnaire (bedtime)	Caffeine (nr)	Quantity in drinks per day	Latest bedtime: higher frequency of consumption (adjusted means)
Sato-Mito et al., 2011 [66]	C (n = 3304)	MCTQ (midpoint of sleep)	Nicotine (1.3%)	Current use	Latest midpoint: higher prevalence of consumption

Cross-sectional studies on selected samples (n = 1)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on sleep timing
DeMartini & Fucito 2014 [76]	Excessive alcohol use defined by AUDIT-C scores (C) (n = 312)	SWPS (bedtime)	Alcohol	Quantity in drinks in a typical week; frequency of heavy episodic drinking	Those reporting sleepiness and late bedtime compared to sleepiness alone: higher level of alcohol consumption

Daytime dysfunction (n = 8)

Cross-sectional studies on unselected samples (n = 7)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on daytime dysfunction
Arbinaga et al., 2019 [47]	C (n = 444)	PSQI	Nicotine (41.2%)	Current use	No association
Barbosa et al., 2020 [48]	G (n = 2514)	ESS	Energy drinks (24%)	Current use	Use vs non-use: higher risk of excessive daytime sleepiness
Bogati et al., 2020 [51]	C (n = 350)	PSQI	Alcohol (38.3%)	Level of consumption in units per month: low (0–4 units), moderate (4–15 units), high (>16 units)	Use vs non-use: higher odds of daytime dysfunction

(*continued on next page*)

Table 3 (*continued*)

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on daytime dysfunction
Daytime dysfunction (n = 8)					
Cross-sectional studies on unselected samples (n = 7)					
			Coffee (96%)	Level of consumption in mg per day: low (<100 mg), moderate (100–250 mg), high (>250 mg)	Use vs non-use: higher odds of daytime dysfunction
			Nicotine (14.3%)	Level of consumption in cigarettes per week: low (<10 cigarettes), moderate-high (≥10 cigarettes)	No association
Lohsoonthorn et al., 2013 [57]	C (n = 2854)	PSQI	Alcohol (23%)	Level of consumption in drinks per week: low (<1 drink), moderate (1–19 drinks), high (≥20 drinks)	Use vs non-use: higher odds of daytime dysfunction
			Caffeine (58%)	Use defined as at least one stimulant drink per week	Use vs non-use: higher odds of daytime dysfunction
			Nicotine (6.9%)	Current use	Use vs non-use: higher odds of daytime dysfunction (adjusting for covariates)
Tran et al., 2014 [69]	C (n = 2983)	ESS	Alcohol (35.2%)	Level of consumption in drinks per week: low (<1 drink), moderate (1–19 drinks), high (≥20 drinks)	Use vs non-use: higher ESS scores
			Caffeine (57.4%)	Use defined as at least one stimulant drink per week	Use vs non-use: higher odds of excessive daytime sleepiness; no association with coffee
			Nicotine (7%)	Current use	No association
Trapp et al., 2021 [70]	G (n = 937)	ESS	Energy drinks (35.4%)	Use defined as at least once a week	Use vs non-use: higher odds of excessive daytime sleepiness; higher ESS scores (in F)
Young et al., 2020 [74]	G (n = 462)	PSQI	Energy drinks (12%)	Number of days of use	No association
Case-control studies (n = 1)					
Conroy et al., 2016 [82]	Habitual and occasional cannabis users vs. non-users (G) (n = 78 cases; n = 20 controls)	PSQI, ISI	Cannabis	Use in past month: daily and non-daily	No significant difference between consumers and non-consumers

Notes.
Abbreviations: C: College students only; G: College and non-college students recruited; nr: Not reported; F: Females.
Questionnaires: AIS: Athens Insomnia Scale; ESS: Epworth Sleepiness Scale; CASQ: Cleveland Adolescent Sleepiness Questionnaire; CSD: Consensus Sleep Diary; CSM: Composite Scale of Morningness; ISI: Insomnia Severity Index; MCTQ: Munich Chronotype Questionnaire; MEQ: Morningness-Eveningness Questionnaire; MOS-SS: Medical Outcome Study-Sleep Scale; PSQI: Pittsburgh Sleep Quality Index; PSSQ-I: Pittsburgh Sleep Symptoms Questionnaire– Insomnia; STQ: Sleep Timing Questionnaire; SWPS: Sleep/Wake Behavior Problems Scale.

[60,69]. Evening-types also consumed significantly more caffeine than morning-types [44,50] and those consuming caffeine, either as coffee or energy drinks, were more likely to be evening-types [69]. Nicotine use was also associated with eveningness, both in terms of cigarettes smoked [44] and of smoking status [60,69]. Only one study assessed cannabis use: in a case-control design, no differences in MEQ score were observed between daily users, non-daily users, and non-users [82].

3.5. Longitudinal association between substance use and sleep

Table 5 reports characteristics and main findings of prospective studies, divided in terms of unselected (n = 4) and selected (n = 2) samples of college students. Sleep was longitudinally assessed in relation to alcohol (n = 5) and cannabis (n = 3) use. Two studies assessed the use of alcohol and/or cannabis as sleep aids.

Prospective data indicates that alcohol use plays a role in subsequent sleep health outcomes [85,87] and sleep timing has an effect on subsequent alcohol use [84]. In a study by Liu et al. [85], college students were monitored from their last semester throughout the period of their first full-time employment. The authors found that the stability of their drinking profile was associated with sleep satisfaction at 12-month follow-up. That is, those who remained in the high-risk drinking profile had lower sleep satisfaction compared to those who had transitioned to a moderate-risk profile. The authors concluded that the reduction of alcohol consumption was associated with better sleep outcomes [85]. Samek & Akua [86] observed 167 college students for 4 years from their first year of enrolment, assessing the frequency of their alcohol and cannabis use and average sleep duration during the previous month. Results based on unpublished data indicated that substance use did not predict sleep duration at follow-up. Van Reen et al. [87] monitored sleep and alcohol consumption of college students through their first 9 weeks of admission through the medium of daily diaries. Data showed that in this period, students consuming alcohol had later bedtimes across the week compared to non-consumers. In an accelerated longitudinal design, Hasler et al. [84] observed a significant effect of sleep timing and circadian characteristics on alcohol use: greater eveningness (OR = 1.30; 96% CI: 1.08–1.54) and a later midpoint of sleep (OR = 1.32; 96% CI: 1.12–1.56) were associated with higher odds of showing a more severe heavy drinking pattern the following year. Sleep duration, sleep satisfaction, and daytime dysfunction were not significantly associated with pattern of alcohol consumption [84]. Goodhines et al. [88] adopted 14-day daily diaries to perform an EMA study on college students selected for using either alcohol or cannabis. Results showed that days of greater alcohol consumption were associated with a poorer sleep quality that night and a shorter sleep duration [88]. Across three studies, non-significant longitudinal and daily associations were found for cannabis use [84,86,88].

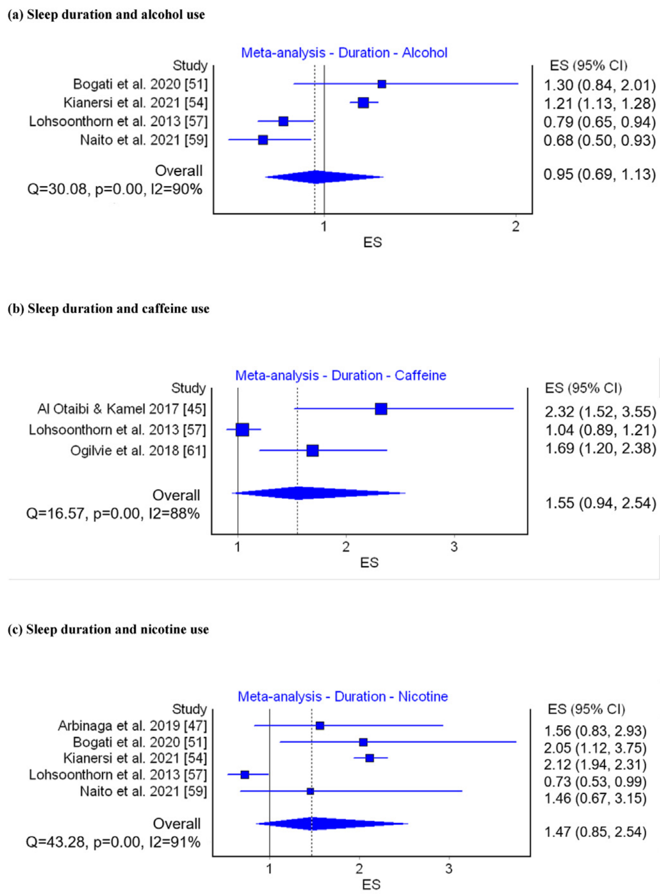

Fig. 5. Forest plots. Random effect meta-analytic models: pooled odds ratios (ORs) of short sleep duration for those consuming alcohol (a), caffeine (b), and nicotine (c), compared to non-consumers. The right arm of the forest plot favours those reporting consumption of the substance compared to those reporting no consumption.

3.6. Use of alcohol and cannabis as sleep aids

One longitudinal [89] and one EMA [88] study found significant concurrent associations between cannabis and/or alcohol use as a sleep aid and sleep outcomes in selected samples of college students. At baseline, 25% [89] to 38% [88] reported using cannabis and/or alcohol as a sleep aid. 14% [89] to 29% [88] reported that they took over-the-counter medications as sleep aids. In both samples, sleep aid users had a higher occurrence of sleep disturbances (ISI) compared to non-sleep aid users. Regarding sleep health dimensions, one study found that sleep-aid users had lower sleep satisfaction and a shorter sleep duration compared to non-sleep aid users [88]. The results were not replicated in the study by Goodhines et al. [89] and no association with chronotype emerged.

EMA data indicates a daily association between sleep aid use and lower sleep satisfaction, but no effect on sleep duration or daytime fatigue as assessed through sleep diaries [88]. In within-person analysis, days of cannabis use as a sleep aid, but not alcohol, were associated with a shorter sleep duration and daytime fatigue. The reverse effect was non-significant: sleep-wake variables were not associated with subsequent sleep aid use or substance use. Longitudinal data from Goodhines et al. [89] showed a persistence of sleep aid use at the 68-day follow-up: 63% of T1 sleep aid users and 19% of T1 non-sleep aid users reported using alcohol and/or cannabis to aid sleep at T2. The initiation was not associated with any sleep variables at baseline or at follow-up. Longitudinal data did not show a significant predictive role of sleep aid use on sleep disturbances, sleep health dimensions or chronotype.

Discussion

In our synthesis, we considered the association between different substances and different sleep dimensions. We adopted a framework accounting for sleep disturbances, Buysse's [30] sleep health dimensions (sleep duration, efficiency, satisfaction, timing, daytime alertness), and chronotype. Sleep dimensions were assessed in association with the most used substances among young adults: alcohol, caffeine, nicotine, cannabis, other substances. This multidimensional view on sleep revealed a distinctive pattern of associations.

Meta-analytic results were robust and showed that young adults consuming caffeine and nicotine have higher odds of reporting a sleep disturbance. Evidence on sleep duration suggest an association with alcohol consumption, but meta-analytic findings were inconclusive. Sleep satisfaction appears to be associated only with nicotine use, although there were few studies concerning this point. Sleep efficiency was not consistently associated with substance use. The few studies on sleep timing suggest that this dimension is associated with substance use both cross-sectionally and prospectively. Daytime dysfunction (low levels of alertness) was consistently associated with alcohol and caffeine consumption. Eveningness was associated with alcohol, caffeine, and nicotine use. Few studies investigated cannabis use, and only one found association between daily use and sleep disturbances. Both alcohol and cannabis used as a sleep aid were cross-sectionally associated with sleep disturbances and poorer sleep health. Prospective data were scarce and suggested that sleep timing and chronotype may be longitudinally associated with alcohol use, but further investigations are needed.

The association found between sleep-wake dimensions and the use of alcohol, caffeine, and nicotine are in line with polysomnographic findings that attest to their sleep-disrupting effect [34]. Our narrative findings indicate that young adults who experience sleep problems also report higher alcohol consumption. Meta-analytic results did not robustly indicate higher odds of sleep disturbances in alcohol consumers. Together, these mixed results may be accounted for by a dose-dependent effect of alcohol on sleep [91]. Indeed, the consumption of alcohol at high doses suppresses slow-wave sleep and REM sleep and leads to complaints of unsatisfactory sleep [91]. It is possible that a dichotomous classification (alcohol use vs. non-use) is not sensitive enough to detect associations in a population in which alcohol use is common. In the pool of included studies, from 30 to 80% of samples were habitual alcohol consumers. Furthermore, sleep disturbances are prevalent in heavy-drinking college students [78,79]. The effect of alcohol consumption on sleep health is not clear. In our synthesis, significant associations were found with both short and long sleep durations. This may be partially due to the sedating effect of alcohol at low doses, which leads to greater sleepiness and a longer sleep duration [14]. The timing of sleep is an important factor to consider. When a later bedtime is associated with an early academic or work schedule, it is difficult to obtain the recommended 7 h of sleep. The studies included suggest that alcohol use is associated with sleep timing, daytime dysfunction, and eveningness. It is possible that a later sleep timing and/or circadian preference are associated with higher levels of psychophysiological activation in the evening, which may lead to a greater consumption of alcohol as a sedating agent [44]. A higher level of activation may also encourage participation in evening social events in which alcohol is mostly consumed, thus postponing sleep timing.

Table 4
Characteristics and main findings of studies regarding chronotype, divided by study design.

Study	Population	Sleep assessment	Substance (Use%)	Substance assessment	Main findings on chronotype
Chronotype (n = 5)					
Cross-sectional studies on unselected samples (n = 4)					
Adan 1994 [44]	G (n = 573)	rMEQ	Alcohol (nr)	Quantity in mL/day	Eveningness: higher daily consumption
			Coffee (nr)	Quantity in mg/day	Eveningness: higher daily consumption
			Nicotine (nr)	Quantity in cigarettes/day	Eveningness: higher daily consumption
Bodur et al., 2021 [50]	C (n = 661)	MEQ	Caffeine (nr)	Quantity in mg/day	Eveningness: higher levels of consumption
Nakade et al., 2009 [60]	C (n = 800)	rMEQ	Alcohol (21.5%)	Current use	Use vs non-use: lower MEQ scores[a]
			Nicotine (8.3%)	Current use	Use vs non-use: lower MEQ scores[a]
Tran et al., 2014 [69]	C (n = 2906)	MEQ	Alcohol (35.2%)	Level of consumption in drinks per week: low (<1 drink), moderate (1−19 drinks), high (≥20 drinks)	Use vs non-use: lower MEQ scores[a]
			Caffeine (57.4%)	Use defined as at least one stimulant drink per week	Use vs non-use: higher odds of being an evening chronotype
			Nicotine (7%)	Current use	Use vs non-use: lower MEQ scores[a]
Case-control studies (n = 1)					
Conroy et al., 2016 [82]	Cannabis users vs. non-users (G) (n = 78 cases; n = 20 controls)	MEQ	Cannabis	Use in past month: daily and non-daily	No significant difference between consumers and non-consumers

Notes.
Abbreviations: C: College students only; G: College and non-college students recruited; nr: Not reported.
Questionnaires: MEQ: Morningness-Eveningness Questionnaire; rMEQ: Morningness-Eveningness Questionnaire-reduced.
[a] MEQ scores are reverse-coded: higher scores indicate a greater morning preference.

In our synthesis, we showed that higher caffeine use was associated with sleep disturbances, high daytime dysfunction, and eveningness. Caffeine is a wake-promoting agent that, in high doses or with chronic use, may disrupt the sleep-wake regulation system and lead to subjective complaints of poor sleep quality, reduced sleep duration, and high daytime sleepiness [34]. Meta-analytic results for sleep disturbances were robust, and no heterogeneity was detected. This result was also generally supported by studies not included in the meta-analysis. Differences emerged in two individual studies that investigated the use of coffee and energy drinks separately. Investigations into sources of caffeine are warranted, as brands of energy drinks highly differ in terms of other possible sleep-disturbing additives, such as sugar [92]. Furthermore, in accordance with sleep hygiene practices, the time of consumption could also enhance the negative effect of caffeine on sleep [63]. Contrary to the literature [35], caffeine use was not consistently associated with short sleep duration (<7 h). This may suggest that a cut-off of sleep duration is not sensitive enough to detect significant differences among young adults. In fact, sleep duration was generally short (<7 h) in the included studies. Nevertheless, the few studies comparing mean hours suggest that caffeine consumers may sleep fewer hours than non-consumers. The association between daytime dysfunction and caffeine use was expected, based on the literature [35]. A higher level of sleepiness during the day is often associated with an attempt to overcome the drowsiness by consuming more caffeine. On the other hand, a high caffeine intake leads to sleep disturbances, which in turn lead to high daytime dysfunction. Across studies, the association between chronotype and caffeine consumption was robust. Caffeine products, in particular coffee, are most often consumed in the first half of the day, when levels of alertness in evening-types are lower than in morning-types [44]. It is plausible that a greater need for energy in the morning is partially responsible for the association between eveningness and caffeine.

Our findings showed that young adults who were smokers were more likely to report sleep disturbances, low sleep satisfaction, and an evening preference. The stimulating effect of nicotine, together with the sleep-disrupting effect of cravings at night, are among the mechanisms involved in the association between sleep disturbances and both chronic smoking and acute nicotine administration [34]. Nonetheless, two case-control studies suggested that among smokers self-reported sleep disturbances are non-concordant with physiological indices [80,81]. The absence of significant differences in subjective assessment may be due to the instrument employed. While the PSQI is a validated assessment of sleep disturbances with sound psychometric properties, the external validity of each component is more problematic [93]. This may be of relevance for subjectively-reported sleep efficiency, which was not found to be associated with any substance use.

In our systematic review and meta-analysis, the few studies included that investigated cannabis use found no consistent association with sleep. One case-control study showed that the frequency of use is an important factor to consider [82]. After an initial sleep-promoting effect of cannabis, frequent use rapidly leads to tolerance and, with chronic use, the negative impact on sleep architecture increases [36]. The long-term effect of cannabis use in young adults is not clear. Prospective data does not support a predictive effect of cannabis use on sleep [86,88] or of sleep dimension on cannabis use [84]. A longitudinal association has been found in studies performed from adolescence to young adulthood [11]. How the relationship between cannabis use and sleep problems evolves during young adulthood needs further investigation.

A functional perspective should also be considered: the experience of sleep-wake disturbances may prompt self-medication with sedating and stimulating substances. Self-medication has been found to be bi-directionally associated with sleep disturbances [94]. Although we had planned to carry out a focused

Table 5
Details and main findings of prospective studies on unselected (a) and selected (b) samples.

Study	Population	Follow-up	Substance	Substance assessment	Sleep assessment	Sleep variables	Main findings on sleep disturbance, sleep health, chronotype
Prospective studies							
(a) Unselected samples (n = 4)							
Hasler et al., 2022 [84]	G (n = 637)	6 years	Alcohol, cannabis	Frequency, quantity, heavy episodic drinking	CSM, CASQ, PSQI, STQ	Sleep duration, sleep satisfaction, sleep timing, daytime dysfunction, chronotype	Eveningness and late timing > more severe binge category the subsequent year; no association for cannabis use
Liu et al., 2022 [85]	C (n = 1363)	3: last semester of college, first full-time employment (M = 8.34 months, SD: 2.80), 12 months after employment	Alcohol	Drinks in a typical week/ past month	Single item	Sleep satisfaction	Staying in the high-risk drinking profile > more sleep problems compared to those reducing to moderate drinking profile
Samek & Akua 2022[a] [86]	C (n = 167)	3: first year of college, 1 year later, 4 year later	Alcohol, cannabis	Frequency/ past month	Single item	Sleep duration	No association
Van Reen et al., 2016 [87]	C (n = 878)	9 weeks	Alcohol	Daily use and heavy episodic drinking (diary)	Sleep diary	Sleep duration, sleep timing, sleep variability	Use vs non-use: later bedtime and rise time; no association with sleep duration
***(a) Selected* samples (*n* = 2)**							
Goodhines, Gellis, Ansell, & Park 2019 [88]	Alcohol and/or cannabis consumers (C) (n = 217)	14 days	Alcohol, cannabis	Sleep aid use, frequency	PSQI, sleep diary	Sleep disturbance, sleep duration, sleep satisfaction, daytime dysfunction	Sleep aid users (past month): lower sleep satisfaction Daily cannabis sleep aid use: longer sleep duration Daily alcohol sleep aid use: no association Days of greater cannabis frequency: no association Days of greater alcohol quantity: lower sleep satisfaction, shorter sleep duration
Goodhines, Gellis, Kim et al., 2019 [89]	Alcohol and/or cannabis consumers (C) (n = 171)	68 days	Alcohol, cannabis, OTC	Sleep aid use, frequency	ISI, MEQ, sleep diary	Sleep disturbance, sleep duration, sleep satisfaction, daytime dysfunction, chronotype	At baseline, sleep aid users: higher prevalence of sleep disturbances No longitudinal association

Notes
Abbreviations: C: College students only; G: College and non-college students recruited.
Questionnaires: CASQ: Cleveland Adolescent Sleepiness Questionnaire; CSM: Composite Scale of Morningness; ISI: Insomnia Severity Index; MEQ: Morningness-Eveningness Questionnaire; PSQI: Pittsburgh Sleep Quality Index; STQ: Sleep Timing Questionnaire.
[a] Unpublished data from personal communication with authors.

synthesis on self-medication, data could be derived from only two of the included studies [88,89]. Self-medication was found to be prevalent and persistent among college students who consume alcohol and/or cannabis. A concurrent association between sleep aid use and sleep disturbances was reported. Nonetheless, longitudinal data did not support a prospective association at two-month follow-up. A longer follow-up period may be needed to detect the possible long-term effects of sleep aid use on sleep. This is of particular concern among college students, as recent evidence indicates that the phenomenon is becoming embedded in the college culture [95]. No included study assessed the specific motivation for use of stimulants in association with sleep-wake outcomes. Wake-enhancement is among the most common of motivations for caffeine use [23]. This may also explain the higher consumption of stimulants among evening-types. It has been suggested that sedative use and stimulant use have different functional roles in evening-types: alcohol allows for relaxation in the evening when energy levels of evening-types are still high; stimulants, on the other hand, help counteract sleepiness early in the day [44]. Taking these initial findings together, the motivation for using a substance as sleep- or wake-enhancer needs to be further considered.

Another explanation for the associations found could be that poor sleep health and consumption of substances are concurrently associated in the context of unhealthy lifestyles. Alcohol, caffeine, and nicotine consumption in the evening is a poor sleep hygiene practice that is common among young adults [96]. Younger adults have a worse awareness of sleep hygiene compared to older adults, and seldom implement good habits [97]. While the association between sleep disturbances and sleep hygiene has been widely investigated in young people, especially college students [98], less is known about the association with substance use at bedtime. No study in our synthesis considered the association between sleep hygiene and substance use and their effect on sleep. In an ongoing unpublished study (Meneo et al.), the authors found that the frequency of use of alcohol, nicotine, cannabis, coffee, and other substances in the hour preceding bedtime correlated with sleep hygiene practices and insomnia symptoms. An unhealthy lifestyle and poor attention to sleep hygiene can interact and have negative consequences on sleep health.

Limitations

The present work is not free of limitations. High heterogeneity was detected, and sensitivity analyses were performed based on sampling and risk of bias. It cannot be excluded that other factors contributed to mixed findings. For instance, cultural factors are the main sources of heterogeneity when analysing substance use, for two main reasons. Firstly, availability and stances towards a substance are highly subject to cultural variability. Secondly, the degree of fidelity of self-reported substance use is tied to the cultural stance toward the specific substance; for example, alcohol use is more likely to be reported in countries without strong social disapproval. A second limitation concerns the generalizability of our results. Most studies were performed on college students, which are more vulnerable to sleep disorders and have sleep-wake habits that may be profoundly different from that of working young adults. Thirdly, our inclusion criteria may have excluded relevant work in the field of substance-sleep interaction. We adopted an aged-based criterion, including studies performed on young adults from age 18 to 30, following the definition of emerging adulthood proposed by Arnett and colleagues [99]. Nonetheless, young adulthood is defined in some context as extending throughout the 30s. As a consequence, our definition of young adulthood may have excluded other relevant studies, especially regarding the effect of cannabis use. While we considered a plethora of substances and different sleep-wake dimensions, we did not include lifetime use and objective assessment of sleep outcomes; nor did we take other sleep dimensions such as sleep onset latency and wake after sleep onset into consideration. Furthermore, the applied definition of sleep aid use included a clear reference to motivation for use, and other relevant work on the use of sleep aids may have been excluded. An extensive review on the topic is beyond the scope of the present work, but this area of research may benefit from future attempts to organise and synthetize the literature on the subject.

Conclusions

A multidimensional view on sleep is useful in order to understand its interaction with substance use in a young population. We noted a lack of literature on most sleep health dimensions, except for sleep duration and daytime sleepiness. Self-medication was also seldom investigated in association with sleep health. Our results showed that the use of alcohol, caffeine, nicotine, cannabis, and other substances was differentially associated with sleep disturbances, sleep health dimensions, and chronotype. We found some mixed results, especially on alcohol use. More investigations are needed to understand the effect of different substances on sleep health dimensions, and the role of motivation for use.

Practice points

1) The consumption of different substances shows a differential pattern of association with sleep disturbances, sleep health dimensions, and circadian preference in young adults aged 18–30 years
2) The most robust association was between caffeine use and sleep disturbances, while the impact of alcohol and nicotine use needs further investigations in this age group
3) More longitudinal investigations are needed to elucidate how the use of alcohol and/or cannabis as sleep aids may contribute to the effect of these substances on sleep health

Research agenda

Future research should further enhance our understanding of the relationship between substance use and sleep difficulties in young adults, focusing on the role of self-medication attempts. Prospective data are particularly needed to follow the parallel increase in substance use and sleep disturbances during young adulthood. A multidimensional view on sleep health appears to be useful to capture the effect of substance use on sleep in younger people, and further investigations in this direction are advisable. Psychological and contextual factors may also be explored, as they may be crucial in the process of coping with a sleep problem.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

Acknowledgements

We are grateful to the authors who kindly responded to requests for study information.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2023.101792.

References

[1] Garbarino S, Lanteri P, Durando P, Magnavita N, Sannita WG. Co-morbidity, mortality, quality of life and the healthcare/welfare/social costs of disordered sleep: a rapid review. Int J Environ Res Publ Health 2016;13(8):831. https://doi.org/10.3390/ijerph13080831. 2016 Aug 18.
[2] Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, Hazen N, Herman J, Katz ES, Kheirandish-Gozal L, Neubauer DN, O'Donnell AE, Ohayon M, Peever J, Rawding R, Sachdeva RC, Setters B, Vitiello MV, Ware JC, Adams Hillard PJ. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep health 2015;1(1):40–3. https://doi.org/10.1016/j.sleh.2014.12.010.
[3] Baglioni C, Altena E, Bjorvatn B, Blom K, Bothelius K, Devoto A, Espie CA, Frase L, Gavriloff D, Tuuliki H, Hoflehner A, Högl B, Holzinger B, Järnefelt H, Jernelöv S, Johann AF, Lombardo C, Nissen C, Palagini L, Peeters G, et al. The European academy for cognitive behavioural therapy for insomnia: an initiative of the European insomnia network to promote implementation and dissemination of treatment. J Sleep Res 2020;29(2):e12967. https://doi.org/10.1111/jsr.12967.
[4] Buysse DJ, Angst J, Gamma A, Ajdacic V, Eich D, Rössler W. Prevalence, course, and comorbidity of insomnia and depression in young adults. Sleep 2008;31(4):473–80. https://doi.org/10.1093/sleep/31.4.473.
[5] Maslowsky J, Ozer EJ. Developmental trends in sleep duration in adolescence and young adulthood: evidence from a national United States sample. J Adolesc Health : official publication of the Society for Adolescent Medicine 2014;54(6):691–7. https://doi.org/10.1016/j.jadohealth.2013.10.201.
[6] Lund HG, Reider BD, Whiting AB, Prichard JR. Sleep patterns and predictors of disturbed sleep in a large population of college students. J Adolesc Health 2010;46(2):124–32. https://doi.org/10.1016/j.jadohealth.2009.06.016.
[7] Morita Y, Sasai-Sakuma T, Asaoka S, Inoue Y. Prevalence and correlates of insufficient sleep syndrome in Japanese young adults: a web-based cross-sectional study. J Clin Sleep Med : JCSM : official publication of the American Academy of Sleep Medicine 2015;11(10):1163–9. https://doi.org/10.5664/jcsm.5092.
[8] Tzilos GK, Caviness CM, Anderson BJ, Stein MD. Stimulant use and associated health risks among student and non-student emerging adults. Emerg Adulthood 2016;4(4):298–302. https://doi.org/10.1177/2167696815617077.
[9] Sivertsen B, Vedaa Ø, Harvey AG, Glozier N, Pallesen S, Aarø LE, Lønning KJ, Hysing M. Sleep patterns and insomnia in young adults: a national survey of Norwegian university students. J Sleep Res 2019;28(2):e12790. https://doi.org/10.1111/jsr.12790.
[10] Taylor DJ, Bramoweth AD, Grieser EA, Tatum JI, Roane BM. Epidemiology of insomnia in college students: relationship with mental health, quality of life, and substance use difficulties. Behav Ther 2013;44(3):339–48. https://doi.org/10.1016/j.beth.2012.12.001.
[11] Troxel WM, Rodriguez A, Seelam R, et al. Longitudinal associations of sleep problems with alcohol and cannabis use from adolescence to emerging adulthood. Sleep 2021;44(10):zsab102. https://doi.org/10.1093/sleep/zsab102.
[12] Windle M. Maturing out of alcohol use in young adulthood: latent class growth trajectories and concurrent young adult correlates. Alcohol Clin Exp Res 2020;44(2):532–40. https://doi.org/10.1111/acer.14268.
[13] SAMHSA. The national Survey on drug use and health. 2019. https://www.samhsa.gov/data/report/2020-nsduh-detailed-tables. [Accessed 6 July 2022].

[14] Angarita GA, Emadi N, Hodges S, et al. Sleep abnormalities associated with alcohol, cannabis, cocaine, and opiate use: a comprehensive review. Addiction Sci Clin Pract 2016;11:9. https://doi.org/10.1186/s13722-016-0056-7.
[15] Roehrs T, Sibai M, Roth T. Sleep and alertness disturbance and substance use disorders: a bi-directional relation. Pharmacol Biochem Behav 2021;203: 173153. https://doi.org/10.1016/j.pbb.2021.173153.
[16] Hasler BP, Casement MD, Sitnick SL, Shaw DS, Forbes EE. Eveningness among late adolescent males predicts neural reactivity to reward and alcohol dependence 2 years later. Behav Brain Res 2017;327:112–20. https://doi.org/10.1016/j.bbr.2017.02.024.
[17] Pasch KE, Latimer LA, Cance JD, Moe SG, Lytle LA. Longitudinal bi-directional relationships between sleep and youth substance use. J Youth Adolesc 2012;41(9):1184–96. https://doi.org/10.1007/s10964-012-9784-5.
[18] Geoffroy PA, Tebeka S, Blanco C, Dubertret C, Le Strat Y. Shorter and longer durations of sleep are associated with an increased twelve-month prevalence of psychiatric and substance use disorders: findings from a nationally representative survey of US adults (NESARC-III). J Psychiatr Res 2020;124:34–41. https://doi.org/10.1016/j.jpsychires.2020.02.018.
[19] Miller MB, Janssen T, Jackson KM. The prospective association between sleep and initiation of substance use in young adolescents. J Adolesc Health 2017;60(2):154–60. https://doi.org/10.1016/j.jadohealth.2016.08.019.
[20] Hasler BP, Martin CS, Wood DS, Rosario B, Clark DB. A longitudinal study of insomnia and other sleep complaints in adolescents with and without alcohol use disorders. Alcohol Clin Exp Res 2014;38(8):2225–33. https://doi.org/10.1111/acer.12474.
[21] Bilsky SA, Luber MJ, Cloutier RM, Dietch JR, Taylor DJ, Friedman HP. Cigarette use, anxiety, and insomnia from adolescence to early adulthood: a longitudinal indirect effects test. Addict Behav 2021;120:106981. https://doi.org/10.1016/j.addbeh.2021.106981.
[22] Brower KJ. Insomnia, alcoholism and relapse. Sleep Med Rev 2003;7(6): 523–39. https://doi.org/10.1016/s1087-0792(03)90005-0.
[23] Malinauskas BM, Aeby VG, Overton RF, Carpenter-Aeby T, Barber-Heidal K. A survey of energy drink consumption patterns among college students. Nutr J 2007;6:35. https://doi.org/10.1186/1475-2891-6-35. 2007 Oct 31.
[24] Taylor DJ, Bramoweth AD. Patterns and consequences of inadequate sleep in college students: substance use and motor vehicle accidents. J Adolesc Health 2010;46(6):610–2. https://doi.org/10.1016/j.jadohealth.2009.12.010.
[25] Ogeil RP, Phillips JG, Savic M, Lubman DI. Sleep- and wake-promoting drugs: where are they being sourced, and what is their impact? Subst Use Misuse 2019;54(12):1916–28. https://doi.org/10.1080/10826084.2019.1609040.
[26] Baglioni C, Battagliese G, Feige B, Spiegelhalder K, Nissen C, Voderholzer U, et al. Insomnia as a predictor of depression: a meta-analytic evaluation of longitudinal epidemiological studies. J Affect Disord 2011;135(1–3):10–9. https://doi.org/10.1016/j.jad.2011.01.011.
[27] Hertenstein E, Feige B, Gmeiner T, Kienzler C, Spiegelhalder K, Johann A, et al. Insomnia as a predictor of mental disorders: a systematic review and meta-analysis. Sleep Med Rev 2019;43:96–105. https://doi.org/10.1016/j.smrv.2018.10.006.
[28] Esmaeelzadeh S, Moraros J, Thorpe L, Bird Y. Examining the association and directionality between mental health disorders and substance use among adolescents and young adults in the U.S. And Canada-A systematic review and meta-analysis. J Clin Med 2018;7(12):543. https://doi.org/10.3390/jcm7120543. 2018 Dec 13.
[29] Kenney SR, Lac A, Labrie JW, Hummer JF, Pham A. Mental health, sleep quality, drinking motives, and alcohol-related consequences: a path-analytic model. J Stud Alcohol Drugs 2013;74(6):841–51. https://doi.org/10.15288/jsad.2013.74.841.
[30] Buysse DJ. Sleep health: can we define it? Does it matter? Sleep 2014;37(1): 9–17. https://doi.org/10.5665/sleep.3298. 2014 Jan 1.
[31] Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ 2015;350:g7647. https://doi.org/10.1136/bmj.g7647. 2015 Jan 2.
[32] O'Connor DA, Green SE, Higgins JPT. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Defining the review question and developing criteria for including studies. *Cochrane Handbook for systematic Reviews of interventions*version 6.3; 2022 (updated February 2022). Cochrane, www.training.cochrane.org/handbook.
[33] EMCDDA. European. Drug report 2021: trends and developments. https://www.emcdda.europa.eu/publications/edr/trends-developments/2021_en. [Accessed 6 July 2022].
[34] Garcia AN, Salloum IM. Polysomnographic sleep disturbances in nicotine, caffeine, alcohol, cocaine, opioid, and cannabis use: a focused review. Am J Addict 2015;24(7):590–8. https://doi.org/10.1111/ajad.12291.
[35] Clark I, Landolt HP. Coffee, caffeine, and sleep: a systematic review of epidemiological studies and randomized controlled trials. Sleep Med Rev 2017;31:70–8. https://doi.org/10.1016/j.smrv.2016.01.006.
[36] Babson KA, Sottile J, Morabito D. Cannabis, cannabinoids, and sleep: a review of the literature. Curr Psychiatr Rep 2017;19(4):23. https://doi.org/10.1007/s11920-017-0775-9.
[37] Chong Y, Fryer CD, Gu Q. Prescription sleep aid use among adults: United States, 2005-2010. NCHS Data Brief 2013;(127):1–8.
[38] Ghandour LA, El Sayed DS, Martins SS. Prevalence and patterns of commonly abused psychoactive prescription drugs in a sample of university students from Lebanon: an opportunity for cross-cultural comparisons. Drug Alcohol Depend 2012;121(1–2):110–7. https://doi.org/10.1016/j.drugalcdep.2011.08.021.
[39] White BP, Becker-Blease KA, Grace-Bishop K. Stimulant medication use, misuse, and abuse in an undergraduate and graduate student sample. J Am Coll Health 2006;54(5):261–8. https://doi.org/10.3200/JACH.54.5.261-268.
[40] Downes MJ, Brennan ML, Williams HC, Dean RS. Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). BMJ Open 2016;6(12):e011458. https://doi.org/10.1136/bmjopen-2016-011458. 2016 Dec 8.
[41] Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality if nonrandomized studies in meta-analyses. https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
[42] McPheeters ML, Kripalani S, Peterson NB, et al. Closing the quality gap: revisiting the state of the science (vol. 3: quality improvement interventions to address health disparities). Evid Rep Technol Assess 2012;208.3:1–475.
[43] Furuya-Kanamori L, Barendregt JJ, Doi SAR. A new improved graphical and quantitative method for detecting bias in meta-analysis. Int J Evid Base Healthc 2018;16(4):195–203. https://doi.org/10.1097/XEB.0000000000000141.
[44] Adan A. Chronotype and personality factors in the daily consumption of alcohol and psychostimulants. Addiction 1994;89(4):455–62. https://doi.org/10.1111/j.1360-0443.1994.tb00926.x.
[45] Al Otaibi HH, Kamel SM. Health-risk behaviors associated with sugar-sweetened beverage consumption among saudi young adults. Biomed Res 2017;28(19):8484–91.
[46] AlSharif SM, Al-Qathmi MS, Baabdullah WM, Alhrkan TA, Fayoumi YA, Alhejaili FF, et al. The effect of caffeinated beverages on sleep quality in college students. Saudi Journal of Internal Medicine 2018;8(1):43–8. https://doi.org/10.32790/sjim.2018.8.1.6.
[47] Arbinaga F, Fernandez-Cuenca S, Joaquin-Mingorance M. The relationship between subjective sleep quality and smoking in university students. Sleep Hypn 2019;21(4):309–20.
[48] Barbosa SMML, Batista RFL, Rodrigues LDS, et al. Prevalence of excessive daytime sleepiness and associated factors in adolescents of the RPS cohort, in São Luís (MA), Brazil. Prevalência de sonolência diurna excessiva e fatores associados em adolescentes da coorte RPS, em São Luís (MA). Rev Bras Epidemiol 2020;23:e200071. https://doi.org/10.1590/1980-549720200071.
[49] Bin Ismayatim IA, Binti Azhar NH, Islam N, Lail SABMS, Ismail SB. A cross-sectional study on association of smoking habits and insomnia among university students in cyberjaya. Malaysian Journal of Medicine and Health Sciences 2021;17:13–8.
[50] Bodur M, Baspinar B, Özçelik AÖ. Do sleep quality and caffeine consumption mediate the relationship between late chronotype and body mass index? Food Funct 2021;12(13):5959–66. https://doi.org/10.1039/d0fo03435e.
[51] Bogati S, Singh T, Paudel S, Adhikari B, Baral D. Association of the pattern and quality of sleep with consumption of stimulant beverages, cigarette and alcohol among medical students. J Nepal Health Res Counc 2020;18(3): 379–85. https://doi.org/10.33314/jnhrc.v18i3.2633. Published 2020 Nov 13.
[52] Elwasify M, Barakat DH, Fawzy M, Rashed I, Radwan DN. Quality of sleep in a sample of Egyptian medical students. Middle East Current Psychiatry 2016;23(4):200–7. https://doi.org/10.1097/01.XME.0000490933.67457.d4.
[53] Hug E, Winzeler K, Pfaltz MC, Cajochen C, Bader K. Later chronotype is associated with higher alcohol consumption and more adverse childhood experiences in young healthy women. Clocks Sleep 2019;1(1):126–39. https://doi.org/10.3390/clockssleep1010012. 2019 Feb 12.
[54] Kianersi S, Zhang Y, Rosenberg M, Macy JT. Association between e-cigarette use and sleep deprivation in U.S. Young adults: results from the 2017 and 2018 behavioral risk factor surveillance system. Addict Behav 2021;112: 106646. https://doi.org/10.1016/j.addbeh.2020.106646.
[55] Liao Y, Xie L, Chen X, et al. Sleep quality in cigarette smokers and nonsmokers: findings from the general population in central China. BMC Publ Health 2019;19(1):808. https://doi.org/10.1186/s12889-019-6929-4. 2019 Jun 24.
[56] Liu D, Kahathuduwa C, Vazsonyi AT. The Pittsburgh Sleep Quality Index (PSQI): psychometric and clinical risk score applications among college students. Psychol Assess 2021;33(9):816–26. https://doi.org/10.1037/pas0001027.
[57] Lohsoonthorn V, Khidir H, Casillas G, et al. Sleep quality and sleep patterns in relation to consumption of energy drinks, caffeinated beverages, and other stimulants among Thai college students. Sleep Breath 2013;17(3):1017–28. https://doi.org/10.1007/s11325-012-0792-1.
[58] Mendoza L, Marco G, Gonzalo CV, Ali AKC, Rosales K, Álvaro A, Chávez R, Bruno S, Alvarado Germán F. Use of energy drinks and insomnia symptoms in medical students from a Peruvian university. Rev Chil Neuro Psiquiatr 2021;59(4):289–301. https://doi.org/10.4067/S0717-92272021000400289.
[59] Naito R, Yun Low W, Wan Yuen C. Sleep deprivation and its associated factors among undergraduate students in Malaysia. Asia Pac J Publ Health 2021;33(5):530–8. https://doi.org/10.1177/10105395211019930.
[60] Nakade M, Takeuchi H, Kurotani M, Harada T. Effects of meal habits and alcohol/cigarette consumption on morningness-eveningness preference and sleep habits by Japanese female students aged 18-29. J Physiol Anthropol 2009;28(2):83–90. https://doi.org/10.2114/jpa2.28.83.
[61] Ogilvie RP, Lutsey PL, Widome R, Laska MN, Larson N, Neumark-Sztainer D. Sleep indices and eating behaviours in young adults: findings from Project

EAT. Publ Health Nutr 2018;21(4):689–701. https://doi.org/10.1017/S1368980017003536.
[62] Orsal O, Orsal O, Alparslan GB, Unsal A. Evaluation of the relation between quality of sleep and anxiety among university students. HealthMED 2021;6(7):2244–55 [DOI: Cited].
[63] Pham HT, Chuang HL, Kuo CP, Yeh TP, Liao WC. Electronic device use before bedtime and sleep quality among university students. Health Care 2021;9(9):1091. https://doi.org/10.3390/healthcare9091091. 2021 Aug 24.
[64] Riera-Sampol A, Rodas L, Martínez S, Moir HJ, Tauler P. Caffeine intake among undergraduate students: sex differences, sources, motivations, and associations with smoking status and self-reported sleep quality. Nutrients 2022;14(8):1661. https://doi.org/10.3390/nu14081661. 2022 Apr 16.
[65] Rosso AC, Wilson OWA, Papalia Z, Duffey M, Kline CE, Bopp M. Frequent restful sleep is associated with the absence of depressive symptoms and higher grade point average among college students. Sleep Health 2020;6(5):618–22. https://doi.org/10.1016/j.sleh.2020.01.018.
[66] Sato-Mito N, Sasaki S, Murakami K, et al. The midpoint of sleep is associated with dietary intake and dietary behavior among young Japanese women. Sleep Med 2011;12(3):289–94. https://doi.org/10.1016/j.sleep.2010.09.012.
[67] Średniawa A, Drwiła D, Krotos A, Wojtaś D, Kostecka N, Tomasik T. Insomnia and the level of stress among students in Krakow, Poland. Trends Psychiatry Psychother 2019;41(1):60–8. https://doi.org/10.1590/2237-6089-2017-0154.
[68] Štefan L, Krističević T, Sporiš G. The associations of self-reported physical fitness and physical activity with sleep quality in young adults: a population-based study. Mental Health and Physical Activity 2018;14:131–5. https://doi.org/10.1016/j.mhpa.2018.04.002.
[69] Tran J, Lertmaharit S, Lohsoonthorn V, et al. Daytime sleepiness, circadian preference, caffeine consumption and use of other stimulants among Thai college students. J Publ Health Epidemiol 2014;8(6):202–10. https://doi.org/10.5897/JPHE2014.0620.
[70] Trapp GS, Hurworth M, Jacoby P, et al. Energy drink intake is associated with insomnia and decreased daytime functioning in young adult females. Publ Health Nutr 2021;24(6):1328–37. https://doi.org/10.1017/S1368980020001652.
[71] Vik P, Dorenkamp MA, Egusquiza JA, Miceli LB. Cannabis as a factor in the moderating relationship between alcohol, sleep, and adverse drinking consequences. J Subst Use 2019;12(1):76–81. https://doi.org/10.1080/14659891.2019.1664657. 25.
[72] Vo K, Neafsey PJ, Lin CA. Concurrent use of amphetamine stimulants and antidepressants by undergraduate students. Patient Prefer Adherence 2015;9:161–72. https://doi.org/10.2147/PPA.S74602. Published 2015 Jan 22.
[73] Vollmer-Conna U, Beilharz JE, Cvejic E, et al. The well-being of medical students: a biopsychosocial approach. Aust N Z J Psychiatr 2020;54(10):997–1006. https://doi.org/10.1177/0004867420924086.
[74] Young DR, Sidell MA, Grandner MA, Koebnick C, Troxel W. Dietary behaviors and poor sleep quality among young adult women: watch that sugary caffeine. Sleep Health 2020;6(2):214–9. https://doi.org/10.1016/j.sleh.2019.12.006.
[75] Caviness CM, Anderson BJ, Stein MD. Impact of nicotine and other stimulants on sleep in young adults. J Addiction Med 2019;13(3):209–14. https://doi.org/10.1097/ADM.0000000000000481.
[76] DeMartini KS, Fucito LM. Variations in sleep characteristics and sleep-related impairment in at-risk college drinkers: a latent profile analysis. Health Psychol 2014;33(10):1164–73. https://doi.org/10.1037/hea0000115.
[77] Dugas EN, Sylvestre MP, O'Loughlin EK, et al. Nicotine dependence and sleep quality in young adults. Addict Behav 2017;65:154–60. https://doi.org/10.1016/j.addbeh.2016.10.020.
[78] Miller MB, Boness CL, DiBello AM, Froeliger B. Insomnia as a moderator of alcohol use and blackout: potential role in acute physiological consequences [published online ahead of print, 2022 Jun 7]. Addict Behav 2022;134:107395. https://doi.org/10.1016/j.addbeh.2022.107395.
[79] Miller MB, Van Reen E, Barker DH, et al. The impact of sleep and psychiatric symptoms on alcohol consequences among young adults. Addict Behav 2017;66:138–44. https://doi.org/10.1016/j.addbeh.2016.11.023.
[80] Cohen A, Colodner R, Masalha R, Haimov I. The relationship between tobacco smoking, cortisol secretion, and sleep continuity. Subst Use Misuse 2019;54(10):1705–14. https://doi.org/10.1080/10826084.2019.1608250.
[81] Cohen A, Ben Abu N, Haimov I. The interplay between tobacco dependence and sleep quality among young adults. Behav Sleep Med 2020;18(2):163–76. https://doi.org/10.1080/15402002.2018.1546707.
[82] Conroy DA, Kurth ME, Strong DR, Brower KJ, Stein MD. Marijuana use patterns and sleep among community-based young adults. J Addict Dis 2016;35(2):135–43. https://doi.org/10.1080/10550887.2015.1132986.
[83] Rusnac N, Spitzenstetter F, Tassi P. Chronic sleep loss and risk-taking behavior: does the origin of sleep loss matter? Behav Sleep Med 2019;17(6):729–39. https://doi.org/10.1080/15402002.2018.1483368.
[84] Hasler BP, Graves JL, Wallace ML, et al. Self-reported sleep and circadian characteristics predict alcohol and cannabis use: a longitudinal analysis of the National Consortium on Alcohol and Neurodevelopment in Adolescence Study. Alcohol Clin Exp Res 2022;46(5):848–60. https://doi.org/10.1111/acer.14808.
[85] Liu S, Bamberger P, Wang M, Nahum-Shani I, Larimer M, Bacharach SB. Behavior change versus stability during the college-to-work transition: life course and the "stickiness" of alcohol misuse at career entry. Person Psychol 2022. https://doi.org/10.1111/peps.12519.
[86] Samek DR, Akua BA. Predictors of persistent alcohol use disorder and co-occurring depressive symptoms: insights from the longitudinal college experiences study. J Adolesc 2022;94(6):844–54. https://doi.org/10.1002/jad.12068.
[87] Van Reen E, Roane BM, Barker DH, McGeary JE, Borsari B, Carskadon MA. Current alcohol use is associated with sleep patterns in first-year college students. Sleep 2016;39(6):1321–6. https://doi.org/10.5665/sleep.5862. 2016 Jun 1.
[88] Goodhines PA, Gellis LA, Ansell EB, Park A. Cannabis and alcohol use for sleep aid: a daily diary investigation. Health Psychol 2019;38(11):1036–47. https://doi.org/10.1037/hea0000765.
[89] Goodhines PA, Gellis LA, Kim J, Fucito LM, Park A. Self-medication for sleep in college students: concurrent and prospective associations with sleep and alcohol behavior. Behav Sleep Med 2019;17(3):327–41. https://doi.org/10.1080/15402002.2017.1357119.
[90] Buysse DJ, Reynolds 3rd CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatr Res 1989;28(2):193–213. https://doi.org/10.1016/0165-1781(89)90047-4.
[91] Ebrahim IO, Shapiro CM, Williams AJ, Fenwick PB. Alcohol and sleep I: effects on normal sleep. Alcohol Clin Exp Res 2013;37(4):539–49. https://doi.org/10.1111/acer.12006.
[92] Heckman MA, Sherry K, De Mejia EG. Energy drinks: an assessment of their market size, consumer demographics, ingredient profile, functionality, and regulations in the United States. Compr Rev Food Sci Food Saf 2010;9(3):303–17. https://doi.org/10.1111/j.1541-4337.2010.00111.x.
[93] Fabbri M, Beracci A, Martoni M, Meneo D, Tonetti L, Natale V. Measuring subjective sleep quality: a review. Int J Environ Res Publ Health 2021;18(3):1082. https://doi.org/10.3390/ijerph18031082. Published 2021 Jan 26.
[94] Drazdowski TK, Kliewer WL, Marzell M. College students' using marijuana to sleep relates to frequency, problematic use, and sleep problems. J Am Coll Health 2021;69(1):103–12. https://doi.org/10.1080/07448481.2019.1656634.
[95] Graupensperger S, Hultgren BA, Fairlie AM, Lee CM, Larimer ME. Using alcohol and cannabis as sleep aids: associations with descriptive norms among college students. Behav Sleep Med 2023;21(1):84–96. https://doi.org/10.1080/15402002.2022.2040505.
[96] Humphries RK, Bath DM, Burton NW. Dysfunctional beliefs, sleep hygiene and sleep quality in university students. Health Promot J Aust 2022;33(1):162–9. https://doi.org/10.1002/hpja.471.
[97] Voinescu BI, Szentagotai-Tatar A. Sleep hygiene awareness: its relation to sleep quality and diurnal preference. J Mol Psychiatry 2015;3(1). https://doi.org/10.1186/s40303-015-0008-2. Published 2015 Jan 31.
[98] Gellis LA, Park A, Stotsky MT, Taylor DJ. Associations between sleep hygiene and insomnia severity in college students: cross-sectional and prospective analyses. Behav Ther 2014;45(6):806–16. https://doi.org/10.1016/j.beth.2014.05.002.
[99] Arnett JJ, Žukauskienė R, Sugimura K. The new life stage of emerging adulthood at ages 18-29 years: implications for mental health. The lancet. Psychiatry 2014;1(7):569–76. https://doi.org/10.1016/S2215-0366(14)00080-7.