Volume 7, No. 9 September, 2026
p ISSN 2723-6927-e ISSN 2723-4339

Problematic Smartphone Use and Sleep Disturbance in Adolescents and Young Adults: A Systematic Review of Longitudinal and Experimental Evidence

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Keywords:
Problematic Smartphone Use; Sleep Disturbance; Adolescents; Young Adults; Insomnia

ABSTRACT

Problematic smartphone use (PSU) refers to excessive or poorly regulated smartphone use associated with functional impairment. Adolescents and young adults are vulnerable to both PSU and sleep disturbances; however, existing evidence has been predominantly cross-sectional and limited in determining temporal relationships. This review aimed to synthesize longitudinal and experimental evidence regarding the association between PSU and sleep disturbances among adolescents and young adults. PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials were searched from inception to January 2026. Eligible studies included prospective cohort studies and randomized controlled trials involving adolescents or young adults that assessed PSU or related smartphone behaviors and reported at least one sleep-related outcome or a relevant mental health pathway associated with PSU and sleep disturbances. Nine studies were included, comprising six prospective cohort studies and three randomized controlled trials, with a total of 11,857 participants. The mean age of participants ranged from 12.5 to 22.7 years, and follow-up or intervention durations ranged from 4 weeks to 2 years. Longitudinal evidence showed that nocturnal mobile phone-related awakenings were associated with restless sleep (aOR 5.39, 95% CI: 2.13–13.65) and difficulty falling asleep (aOR 3.44, 95% CI: 1.03–11.54). High screen time was associated with difficulty falling asleep (aOR 2.41, 95% CI: 1.41–4.13). Cross-lagged analyses suggested bidirectional associations between PSU and sleep problems. Experimental studies indicated that mindfulness-based interventions, screen-time reduction, and bedtime phone restriction improved several sleep outcomes. Overall, longitudinal and experimental evidence suggests a bidirectional association between PSU and sleep disturbances among adolescents and young adults.

INTRODUCTION

Smartphone use has become increasingly widespread among adolescents and young adults worldwide. In the United States, 95% of teenagers aged 13–17 years reported having access to a smartphone in 2022. Globally, approximately 23% of children and young people are estimated to meet criteria for problematic smartphone use (PSU), which is characterized by excessive or poorly regulated smartphone use, compulsive behaviors, withdrawal-like symptoms, and impairment in daily functioning (Imelda, 2019; Sohn et al., 2019; Vogels et al., 2022) . PSU has been associated with poor sleep quality, depression, and anxiety; however,

much of the existing evidence remains cross-sectional and is therefore limited in establishing temporal relationships.

Adolescence is a developmental period characterized by increased vulnerability to sleep disturbances. The American Academy of Sleep Medicine recommends 8–10 hours of sleep per 24 hours for adolescents aged 13–18 years to support health and daytime functioning (Paruthi et al., 2016). However, insufficient sleep remains common in this population and has been associated with depression, anxiety, suicidal ideation, and poor academic performance (Johri et al., 2025). Pubertal maturation also contributes to delayed sleep timing through circadian phase delays and changes in homeostatic sleep regulation, which may shift bedtimes later and reduce weekday sleep duration (Crowley et al., 2007) .

Several mechanisms may explain how PSU and smartphone-related behaviors contribute to sleep disturbances. Evening exposure to short-wavelength light emitted from screens may suppress melatonin secretion and delay sleep onset, while interactive content, social feedback, and notifications may increase pre-sleep cognitive and emotional arousal (Hale & Guan, 2015) . Smartphone use may also reduce available sleep time, contribute to bedtime procrastination, and trigger nocturnal awakenings through calls, messages, or notifications.

Although previous reviews have summarized associations between digital media use and sleep outcomes, many included studies were cross-sectional or examined broad digital media exposure rather than PSU specifically (Mac Cárthaigh et al., 2020) . Therefore, a synthesis of causally informative study designs is needed to better understand the directionality of these associations and the potential responsiveness to interventions.

This systematic review aimed to synthesize evidence from prospective cohort studies and randomized controlled trials examining the association between PSU and sleep disturbances among adolescents and young adults. Specifically, this review aimed to characterize the directionality and effect sizes reported across studies and evaluate the methodological quality of the available evidence using contemporary risk-of-bias assessment tools.

METHOD

Protocol and reporting

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021) . A review protocol was developed before the review process began and was available from the corresponding author upon reasonable request. No formal registration was conducted.

Eligibility criteria

Studies were eligible if they met the following criteria: (i) enrolled adolescents or young adults with a mean age between from 10 to 25 years); (ii) used a prospective cohort design or randomized controlled trial; (iii) assessed problematic smartphone use (PSU), smartphone addiction, mobile phone addiction, online social networking addiction, or pathological internet use, or related smartphone behaviors as an exposure or intervention; and (iv) reported at least one sleep-related outcome or a related mental-health pathway relevant to problematic smartphone use and sleep disturbance.

Cross-sectional studies, case reports, conference abstracts, meta-analyses, reviews, protocols, studies outside the adolescent or young-adult age range, studies with non-smartphone-related exposures or interventions, and studies without eligible sleep-related outcomes or relevant mental-health pathways were excluded.

Information sources and search strategy

Four electronic databases were searched from inception to January 2026: PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials. Search terms combined three concepts using Boolean operators: (i) population terms, including adolescent*, teen*, youth, young adult*, college student*, university student*, and high school student*; (ii) exposure terms, including smartphone*, mobile phone*, cell phone*, screen time, problematic smartphone use, smartphone addiction, mobile phone addiction, and internet addiction; and (iii) outcome terms, including sleep*, insomnia, sleep quality, sleep duration, sleep disturbance, and daytime sleepiness. Reference lists of included studies and relevant reviews were also hand-searched. The full search strings are provided in the Supplementary Material.

Study selection and data extraction

All records were imported into a reference management system, and duplicates were removed. Two reviewers independently screened titles and abstracts, followed by full-text assessment against the eligibility criteria. Disagreements were resolved through discussion or consultation with a third reviewer.

Data were extracted using a standardized form, including author, year, country, study design, sample size, participant characteristics, exposure instrument, sleep outcome instrument, follow-up or intervention duration, statistical method, and effect estimates with 95% confidence intervals when available. The Smartphone Addiction Scale-Short Version (SAS-SV) and Pittsburgh Sleep Quality Index (PSQI) were among the most frequently used instruments (Buysse et al., 1989; Kwon et al., 2013) .

Risk of bias assessment

The Newcastle-Ottawa Scale (NOS) was used to assess risk of bias in prospective cohort studies across three domains: selection, comparability, and outcome. Scores of 7 to 9 were categorized as good quality, 5 to 6 as fair quality, and 4 or less as poor quality (Kim et al., 2003) . The revised Cochrane Risk of Bias tool (RoB 2) was used to assess randomized controlled trials across five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Overall judgments were categorized as low risk, some concerns, or high risk (Sterne et al., 2019) . Two reviewers independently completed the assessments, and disagreements were resolved by consensus.

Data synthesis

Because of substantial heterogeneity in exposure instruments, sleep outcome measures, follow-up or intervention duration, and effect-estimate formats, a quantitative meta-analysis was not performed. Findings were synthesized narratively and tabulated. Results were grouped by study design, namely prospective cohort studies and randomized controlled trials, and by direction of association: PSU or smartphone-related behaviors predicting subsequent sleep outcomes, sleep disturbance predicting subsequent PSU, and intervention effects on sleep outcomes (Foerster et al., 2019) .

RESULTS AND DISCUSSION

Study selection

A total of 7,727 records were identified through database searching and reference-list screening. These consisted of records from PubMed/MEDLINE (n = 1,600), Scopus (n = 2,046), Web of Science (n = 4,080), the Cochrane Central Register of Controlled Trials (n = 1), and reference-list screening (n = 1). After removal of 1,506 duplicate records, 6,221 records were screened by title and abstract, of which 6,149 were excluded.

Seventy-two reports were sought for retrieval, and four reports could not be retrieved. Therefore, 68 full-text reports were assessed for eligibility. Of these, 59 reports were excluded for the following reasons: review, meta-analysis, protocol, case report, or abstract-only publication (n = 20); outside the adolescent or young-adult age range (n = 16); non-PSU or non-smartphone-related exposure/intervention (n = 18); and no eligible sleep-related outcome reported (n = 5). Nine studies were included in the final synthesis. The study selection process is presented in Figure 1.

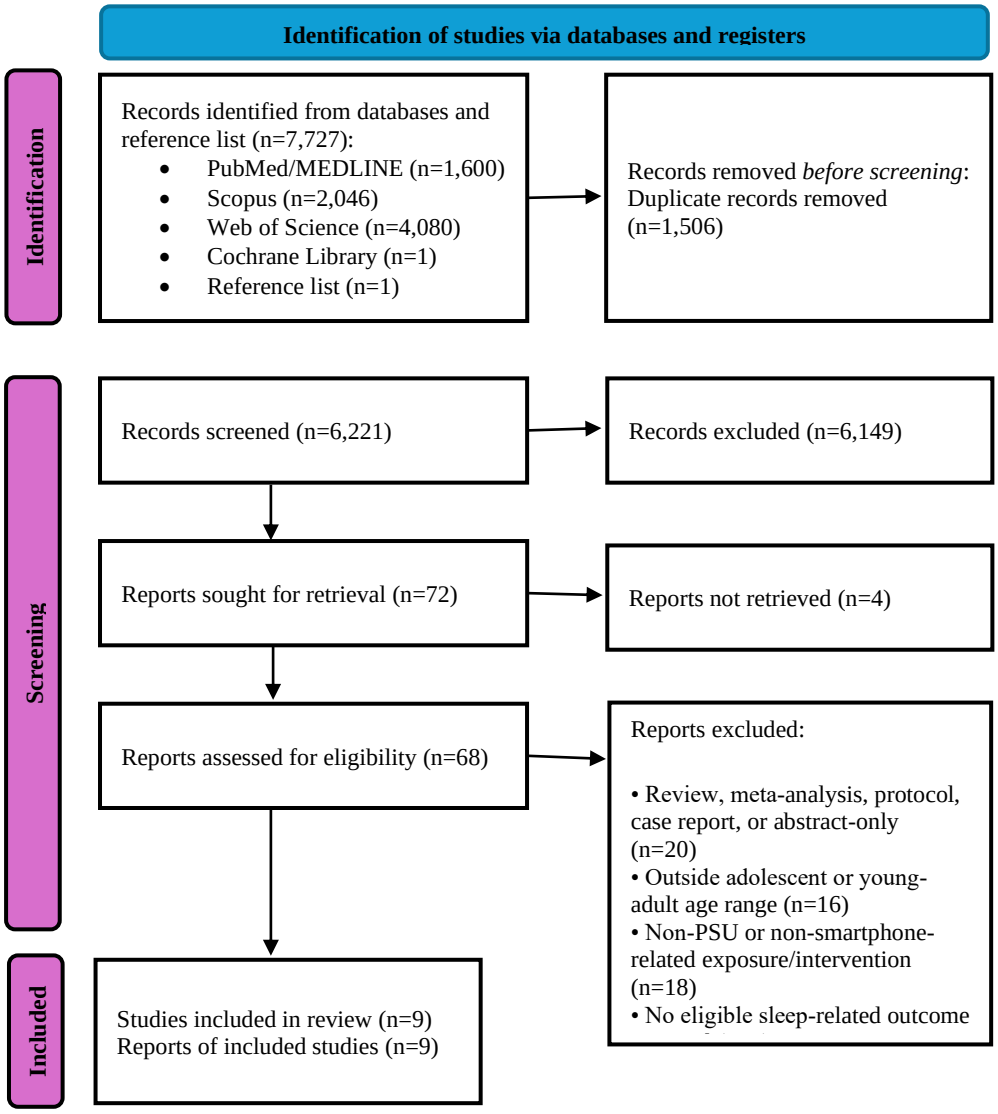

Figure 1. PRISMA 2020 flow diagram for studies on problematic smartphone use and sleep disturbance in adolescents and young adults.

Study characteristics

The nine included studies comprised six prospective cohort studies and three randomized controlled trials (RCTs), with a total of 11,857 participants. Cohort studies were conducted in Switzerland, China, and Taiwan, while randomized trials were conducted in China and Austria. Sample sizes ranged from 782 to 4,237 participants in cohort studies and from 38 to 125 participants in RCTs. The mean age of participants ranged from 12.5 to 22.7 years.

Follow-up or intervention duration varied across studies. In cohort studies, follow-up ranged from five months to two years, while RCTs evaluated short-term behavioral interventions lasting approximately three to four weeks, with some studies including additional follow-up after the intervention.

Exposure was most commonly assessed using the Smartphone Addiction Scale-Short Version (SAS-SV), which was used in four studies (Chen & Wu, 2021; G. Li et al., 2022; J. B. Li et al., 2018; S. Li et al., 2025; Y. Li et al., 2025; Liu et al., 2024; Pieh et al., 2025) . Other exposure measures included the Mobile Phone Addiction Index (MPAI), the Chen Internet Addiction Scale-Revised (CIAS-R), the Online Social Networking Addiction Scale, a nocturnal mobile phone-related awakening questionnaire, and built-in device-based screen-time monitoring (He et al., 2020) .

Sleep-related outcomes were assessed using several instruments, including the Insomnia Severity Index variants (ISI), the Pittsburgh Sleep Quality Index (PSQI), sleep diaries, self-reported sleep items, daytime sleepiness measures, and the Pre-Sleep Arousal Scale. Because exposure instruments, sleep outcome measures, follow-up duration, and effect estimates varied substantially across studies, the findings were synthesized narratively. Full study characteristics are presented in Table 1.

Table 1. Characteristics of included studies on problematic smartphone use and sleep disturbance in adolescents and young adults.

Study (Country)	Design	N	Mean age (years)	Male/Female n (%)	Exposure instrument	Outcome or sleep-related measure	Follow-up	Statistical method
Foerster 2019 (Switzerland)	Prospective cohort (HERMES)	843	13.9	368/475 (43.6/56.4)	HERMES questionnaire; operator-recorded calls; screen time	Swiss Health Survey 4-item sleep scale; KIDSCREEN-52	~1 year	Logistic regression (2 adjusted models)
Li Y 2025 (China)	Prospective cohort (3 waves)	3,088	12.5	1,678/1,410 (54.3/45.7)	SAS-SV (cutoff 31 boys, 33 girls)	PHQ-9, GAD-7; sleep quality discussed as mediator	2 years	Modified Poisson regression (GEE)
Li S 2025 (China)	Prospective cohort	782	12.6	426/356 (54.5/45.5)	CIAS-R (19 items)	Suicide attempts; DASS-21; related mental-health outcome	6 months	Logistic regression (3 models)
Li JB 2018 (China)	Prospective cohort	4,237	13.9	2,105/2,132 (49.7/50.3)	OSNA Scale (8 items)	CES-D depression; bidirectional behavioral-addiction outcome	9 months	Multilevel logistic regression

Li G 2022 (China)	Two-wave longitudinal cohort	1,609	16.5	588/1,021 (36.5/63.5)	MPAI (17 items)	Epworth-derived daytime sleepiness; CES-D; SBQ-R	5 months	Chain mediation (PROCESS macro)
Chen & Wu 2021 (Taiwan)	Longitudinal cross-lagged panel	1,039	13-18	492/547 (47.4/52.6)	SAS-SV (10 items)	ISI-Chinese (ISI-C)	6 months	Cross-lagged SEM (AMOS)
Liu 2024 (China)	RCT, single-blind	94 (IG 45/CG 49)	14.1 / 14.0	44/50 (~47%)	SAS-SV (10 items)	PSQI sleep-disorder dimension	2-month follow-up	Repeated-measures ANOVA; bootstrap mediation
Pieh 2025 (Austria)	RCT, parallel non-blinded	111 (IG 58/CG 53)	22.7	41/70 (36.9/63.1)	Built-in screen-time monitoring; SAS-SV	Insomnia Severity Index (ISI)	9 weeks	Repeated-measures ANOVA (ITT and PP)
He 2020 (China)	RCT pilot	38 (IG 19/CG 19)	21.0 / 21.4	26/12 (~68/32)	Self-report sleep diary; PSQI screening	PSQI total and components; PSAS; sleep diary	4 weeks	Mixed-design ANOVA

SAS-SV, Smartphone Addiction Scale-Short Version; MPAI, Mobile Phone Addiction Index; CIAS-R, Chen Internet Addiction Scale-Revised; OSNA, Online Social Networking Addiction; PSQI, Pittsburgh Sleep Quality Index; ISI, Insomnia Severity Index; PSAS, Pre-Sleep Arousal Scale; SBQ-R, Suicidal Behaviors Questionnaire-Revised; GEE, generalized estimating equations; SEM, structural equation modeling; ITT, intention-to-treat; PP, per-protocol.

Findings on PSU and sleep disturbance

Overall, longitudinal evidence suggested that PSU and related smartphone behaviors were associated with poorer subsequent sleep-related outcomes. In the Swiss HERMES cohort, adolescents who reported at least one nocturnal mobile phone-related awakening per month at both baseline and follow-up had increased odds of developing restless sleep within one year (adjusted odds ratio [aOR] 5.39, 95% confidence interval [CI] 2.13–13.65) and problems falling asleep (aOR 3.44, 95% CI 1.03–11.54). High screen time was also associated with new-onset problems falling asleep (aOR 2.41, 95% CI 1.41–4.13).

Several cohort studies provided broader contextual evidence linking smartphone-related behavioral problems with mental-health outcomes that are clinically relevant to sleep disturbance. Li Y et al. reported that persistent smartphone dependence across three waves over two years was associated with increased risk of incident depressive symptoms (aOR 2.37, 95% CI 1.56-3.61) and anxiety symptoms (aOR 1.88, 95% CI 1.18-3.00), with sleep quality discussed as a potential mediating mechanism. Li S et al. found that adolescents with internet addiction had increased odds of suicide attempts at six months (aOR of 2.65, 95%CI 1.07-6.55) after adjustment for depression, anxiety, and stress. Li JB et al. observed bidirectional longitudinal associations between online social networking addiction and depression, with emerging online social networking addiction associated with a higher incidence of depression at nine months (AOR 4.29, 95% CI 3.17–5.81). Although these outcomes were not direct sleep outcomes, they provide contextual support for the broader behavioral and emotional pathways through which problematic smartphone-related behaviors may interact with adolescent sleep disturbance.

Two studies provided more direct evidence of sleep-related pathways and bidirectionality. Li G et al. reported that mobile phone addiction during the first month of

COVID-19 lockdown predicted daytime sleepiness five months later (β = 0.316, p < 0.001), which subsequently contributed to suicidality through an indirect pathway (indirect effect 0.042, 95% CI 0.023–0.062). Chen and Wu found reciprocal cross-lagged associations between PSU and sleep problems: PSU at Wave 1 predicted sleep problems at Wave 2 (β = 0.08, p < 0.01), while sleep problems at Wave 1 also predicted PSU at Wave 2 (β = 0.09, p < 0.01). These findings support a possible self-reinforcing bidirectional relationship between PSU and sleep disturbance (Hale et al., 2019; L. Li et al., 2020; Lund et al., 2021) .

Three RCTs evaluated behavioral interventions targeting PSU or bedtime smartphone-related behaviors. An eight-session mindfulness-based cognitive therapy program reduced PSU and sleep-disorder scores compared with wait-list control, with a large between-group effect for sleep disorders (Cohen's d = 1.61, p < 0.001); reduced PSU also mediated sleep improvement. A three-week screen-time reduction intervention to two hours or less per day improved Insomnia Severity Index scores compared with usual use (mean difference 2.59, 95% CI 0.66–4.51; p = 0.009).[21] In addition, restricting mobile phone use 30 minutes before bedtime for four weeks improved PSQI scores, sleep latency, sleep duration, and pre-sleep arousal compared with no restriction.

Table 2. Key sleep-related outcomes and relevant pathway findings reported in included studies.

Study	Outcome	Effect estimate (95% CI)	Statistical significance	Adjustments / Notes
Foerster 2019	New onset of restless sleep (nocturnal awakenings exposed)	OR 5.39 (2.13-13.65)	Significant	Adjusted for age, sex, school level, lifestyle, daytime mobile use
Foerster 2019	New onset of problems falling asleep	OR 3.44 (1.03-11.54)	Significant	Same adjustments
Foerster 2019	Problems falling asleep with high screen time	aOR 2.41 (1.41-4.13)	Significant	Sociodemographic and lifestyle adjustments
Li Y 2025	Incident depressive symptoms in persistent smartphone dependence group	OR 2.37 (1.56-3.61)	Significant	Sleep quality discussed as a potential mediator
Li S 2025	Suicide attempts at 6 months in internet addiction group	aOR 2.65 (1.07-6.55)	Significant	Adjusted for anxiety, depression, and stress
Li JB 2018	Incident depression in emerging OSNA group	AOR 4.29 (3.17-5.81)	Significant	Contextual behavioral-addiction outcome; adjusted for sex, grade, academic, and family factors
Li G 2022	MPA at T1 to daytime sleepiness at T2	beta 0.316 (SE 0.026)	Significant (p<0.001)	Adjusted for COVID-19 exposure variables
Li G 2022	Indirect pathway from mobile phone addiction to suicidality via daytime sleepiness	0.042 (0.023-0.062)	Significant	Bootstrap CI excludes zero

Chen & Wu 2021	PSU at T1 predicting sleep problems at T2	beta 0.08, p<0.01	Significant	Reciprocal path from sleep problems to PSU also significant
Liu 2024	Sleep disorders post-intervention (MBCT vs. control)	Cohen d 1.61	p<0.001	Maintained at 2-month follow-up
Liu 2024	Indirect effect of MBCT on sleep via reduced PSU	0.318 (0.073-0.562)	Significant	Bias-corrected bootstrap, 5,000 samples
Pieh 2025	Insomnia severity post-intervention	MD 2.59 (0.66-4.51)	p=0.009	Partial eta squared = 0.048
He 2020	PSQI total score post-intervention	F = 11.92 (time x group)	p<0.01	Reduction approx. 4 points in intervention
He 2020	Sleep latency reduction	F = 6.67	p<0.05	About 12-minute reduction in IG
He 2020	Pre-Sleep Arousal Scale (Cognitive)	F = 6.51	p<0.05	Between-group post-test p=0.001

OR, odds ratio; aOR/AOR, adjusted odds ratio; CI, confidence interval; SPD, smartphone dependence; OSNA, online social networking addiction; MPA, mobile phone addiction; PSU, problematic smartphone use; ISI, Insomnia Severity Index; PSQI, Pittsburgh Sleep Quality Index; MBCT, mindfulness-based cognitive therapy; IG, intervention group; MD, mean difference; SE, standard error.

Risk of bias

Risk of bias assessments are summarized in Table 3 and Figures 2 and 3. Using the Newcastle-Ottawa Scale (NOS), three cohort studies received the maximum score of 9 stars, one study received 8 stars, one study received 7 stars, and one study received 5 stars. Overall, five cohort studies were rated as good quality, while one study was rated as fair quality.

For the RCTs, all three studies were judged as having some concerns overall using the revised Cochrane Risk of Bias tool (RoB 2). These judgements were mainly driven by the absence of participant blinding in behavioral interventions, reliance on self-reported sleep outcomes, and limited pre-registration information or insufficient information regarding selective reporting. Figures 2 and 3 present the RoB 2 traffic-light plot and domain-level summary plot, respectively.

Table 3. Newcastle-Ottawa Scale results for cohort studies.

Study	Selection (max 4)	Comparability (max 2)	Outcome (max 3)	Total (max 9)	Overall quality
Foerster 2019	4	2	3	9/9	Good
Li Y 2025	4	2	3	9/9	Good
Li S 2025	3	2	2	7/9	Good
Li JB 2018	4	2	3	9/9	Good
Li G 2022	2	1	2	5/9	Fair
Chen & Wu 2021	4	1	3	8/9	Good

Quality categories: Good (7 stars or more), Fair (5 to 6), Poor (4 or less).

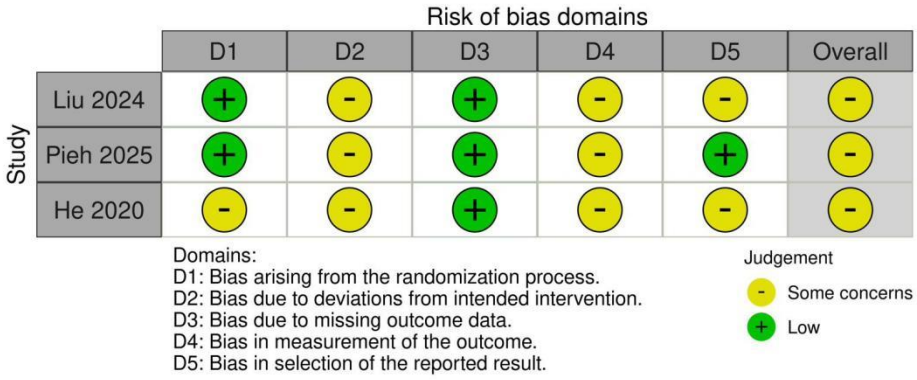

Figure 2. Cochrane RoB 2 traffic-light plot for the three randomized controlled trials.

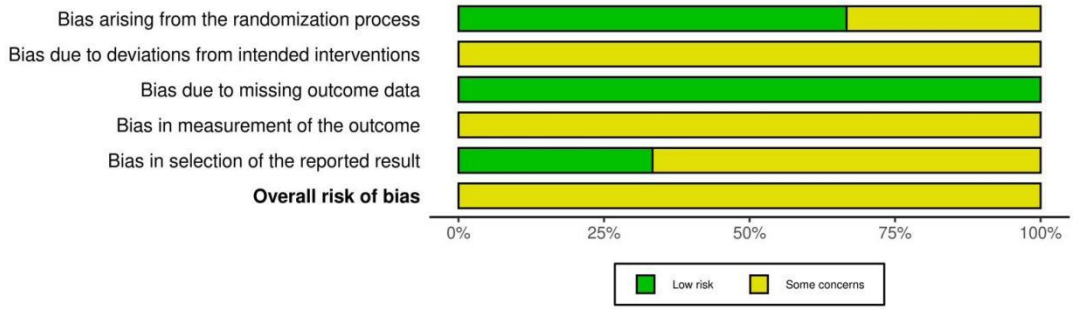

Figure 3. Cochrane RoB 2 domain-level summary plot for the three randomized controlled trials.

This systematic review synthesized evidence from nine longitudinal and experimental studies, including six prospective cohort studies and three randomized controlled trials, with a total of 11,857 participants. Across studies conducted in China, Taiwan, Switzerland, and Austria, problematic smartphone use (PSU) and related smartphone behaviors generally predicted poorer subsequent sleep-related outcomes, including new-onset sleep complaints, restless sleep, daytime sleepiness, and insomnia severity. The included studies had follow-up or intervention durations ranging from 4 weeks to 2 years. The three RCTs further showed that behavioral interventions targeting PSU, screen time, or bedtime smartphone use improved several sleep outcomes. Together, these findings extend previous cross-sectional evidence by supporting temporal precedence and intervention responsiveness.

Several mechanisms may explain how PSU disrupts sleep in adolescents and young adults. First, evening exposure to short-wavelength light from smartphone screens may suppress melatonin secretion and delay circadian phase, which may compound the puberty-related circadian delay commonly observed during adolescence. Second, interactive content, social feedback, and frequent notifications may increase pre-sleep cognitive and emotional arousal. Third, smartphone use may displace sleep time by prolonging wakefulness and delaying bedtime. Fourth, habitual bedtime smartphone use may contribute to bedtime procrastination and nocturnal awakenings. Consistent with these mechanisms, the Swiss HERMES cohort showed that recurrent nocturnal mobile phone-related awakenings with

substantially higher odds of incident restless sleep within one year (Alimoradi et al., 2019; Bozkurt et al., 2024; Carter et al., 2016; Hagenauer et al., 2009) .

Several included studies also addressed bidirectionality. In the cross-lagged study by Chen and Wu, PSU predicted later sleep problems, while sleep problems also predicted later PSU after controlling for autoregressive effects. This reciprocal pattern suggests a self-reinforcing cycle in which poor sleep may increase smartphone reliance for emotional regulation or nighttime coping, while continued smartphone use may further worsen sleep. Therefore, the association between PSU and sleep disturbance may be better understood as a bidirectional process rather than a single causal pathway.

The RCTs reviewed provide clinically relevant evidence that PSU-related sleep disturbance may be modifiable. Mindfulness-based cognitive therapy reduced PSU and sleep-disorder scores, with effects maintained at the 2-month follow-up. Screen-time reduction to two hours or less per day improved insomnia severity compared with usual use. Bedtime mobile phone restriction for 30 minutes before sleep improved PSQI scores, sleep latency, sleep duration, and pre-sleep arousal. These findings suggest that brief and scalable behavioral interventions, including digital sleep-hygiene strategies, may help improve sleep outcomes in adolescents and young adults.

This review has several strengths. The inclusion of prospective cohort studies and RCTs reduced the reverse-causation concerns that commonly limit cross-sectional studies.[8] The total sample size exceeded 11,000 participants, and most cohort studies were rated as good quality using the Newcastle-Ottawa scale. The review also assessed methodological quality using established risk-of-bias tools for both observational and randomized studies.[12]

Nevertheless, several limitations should be considered. First, the included studies were heterogeneous in terms of design, follow up or intervention duration, exposure instruments, sleep outcome measures, and effect-estimate formats, which precluded quantitative pooling. Second, several outcomes were based on self-reported measures, which may be affected by recall bias or reporting bias. Third, all three RCTs were judged as having some concerns, mainly due to the nature of behavioral interventions, limited participant blinding, and reliance on self-reported sleep outcomes. Fourth, the predominance of East Asian samples may limit generalizability to other populations. Finally, some included studies examined broader smartphone-related or behavioral-addiction outcomes that were clinically relevant to sleep disturbance but were not direct sleep outcomes; therefore, these findings should be interpreted as contextual evidence rather than primary sleep outcomes.

The findings have practical implications for clinicians, educators, and policymakers. Screening for PSU, especially bedtime smartphone use and nocturnal device-related awakenings, may help identify adolescents and young adults at risk for sleep disturbance. Brief interventions such as mindfulness training, daily screen-time limits, bedtime device restrictions, and digital sleep hygiene may be integrated into school-based, university-based, and primary-care programs. Future studies should prioritize larger, multi-site RCTs with objective sleep measures, such as actigraphy or polysomnography, pre-registered protocols, and longer follow-up to determine the durability and clinical significance of intervention effects.

CONCLUSION

Problematic smartphone use (PSU) and related smartphone behaviors were associated with the onset and worsening of sleep disturbances among adolescents and young adults. Longitudinal evidence suggested that PSU may precede poorer sleep outcomes, while cross-lagged findings indicated a potential bidirectional relationship in which sleep problems may also contribute to subsequent PSU. Experimental studies further suggested that brief behavioral interventions, including mindfulness-based interventions, screen-time reduction strategies, and bedtime mobile phone restrictions, may improve sleep quality, sleep latency, sleep duration, and pre-sleep arousal. These findings support the integration of PSU screening and digital sleep-hygiene strategies into adolescent and young adult health programs. However, due to heterogeneity in study designs, follow-up durations, exposure measurements, and sleep outcomes, causal interpretations should remain cautious.

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