Effects of Digital Sleep Interventions on Sleep Among College Students and Young Adults: A Systematic Review and Meta-Analysis

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Yi-An Lu[1] MSN; Hui-Chen Lin[1, 2] PhD; Pei-Shan Tsai[1, 3, 4] PhD

[1]School of Nursing, College of Nursing Taipei Medical University Taipei TW
[2]Research Center in Nursing Clinical Practice Wan Fang Hospital Taipei Medical University Taipei TW
[3]Department of Nursing and Center for Nursing and Healthcare Research in Clinical Practice Application Wan Fang Hospital, Taipei Medical University Taipei TW
[4]Research Center of Sleep Medicine Taipei Medical University Hospital Taipei TW

Corresponding Author:
Pei-Shan Tsai PhD
School of Nursing, College of Nursing
Taipei Medical University
250, Wuxing Street, Xinyi District
Taipei
TW

Abstract

Background: College students and young adults (aged 18-25 years) frequently experience poor sleep quality, with insomnia being particularly prevalent among this population. Given the widespread use of digital devices in the modern world, electronic device-based sleep interventions present a promising solution for improving sleep outcomes. However, their effects in this population remain underexplored.

Objective: To synthesize current evidence on the effectiveness of electronic device-based sleep interventions in enhancing sleep outcomes among college students and young adults.

Methods: A comprehensive search of PubMed, CINAHL, Cochrane Library, Embase, and Web of Science was conducted to identify randomized controlled trials (RCTs) on digital sleep interventions. Pooled estimates of postintervention and follow-up effects were calculated using Hedges' g and 95% confidence intervals (CIs) under a random-effects model. Heterogeneity was assessed with I^2 statistics, and subgroup, moderator, and meta-regression analyses were performed to explore sources of heterogeneity. Evidence quality was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluations framework, and data analysis was performed using Comprehensive Meta-Analysis software, version 3.7.

Results: This study included 13 studies involving 5,251 participants (mean age 23.58 years; 69.55% women). Digital sleep interventions significantly improved subjective sleep quality (Hedges' g = -1.249; 95% CI:-1.834, -0.664), sleep efficiency (Hedges' g = 0.617; 95% CI: 0.182, 1.052), insomnia severity (Hedges' g = -4.082; 95% CI: -5.141, -3.022), dysfunctional beliefs and attitudes about sleep (DBAS; Hedges' g = -1.544; 95% CI: -3.329, -0.986), sleep hygiene (Hedges' g = -0.188; 95% CI: -0.343, -0.032), and sleep knowledge (Hedges' g = -0.268; 95% CI: 0.088, 0.447). The follow-up effects were significant for subjective sleep quality (Hedges' g = -0.532; 95% CI: -0.956, -0.107) and insomnia severity (Hedges' g = -2.649; 95% CI: -3.888, -1.409). The evidence quality ranged from moderate to low certainty across measured outcomes.

Conclusions: Digital sleep interventions are effective in improving subjective sleep quality and reducing insomnia severity, with moderate effects on dysfunctional beliefs and attitudes about sleep, sleep hygiene, and sleep knowledge. These interventions offer a viable approach to managing sleep problems in college students and young adults. Clinical Trial: The protocol for this study is registered with PROSPERO (registration number: CRD 42024595126).

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Yi-An Lu[1], MSN; Hui-Chen Lin[1,2], PhD; Pei-Shan Tsai [1,3,4], PhD

[1] School of Nursing, College of Nursing, Taipei Medical University, Taipei, Taiwan

[2] Research Center in Nursing Clinical Practice, Wan Fang Hospital Taipei Medical University, Taipei, Taiwan

[3] Department of Nursing and Center for Nursing and Healthcare Research in Clinical Practice Application, Wan Fang Hospital, Taipei Medical University, Taipei, Taiwan

[4] Research Center of Sleep Medicine, Taipei Medical University Hospital, Taipei, Taiwan

Corresponding Author:

Pei-Shan Tsai, PhD

School of Nursing, College of Nursing

Taipei Medical University

250, Wuxing Street, Xinyi District

Taipei City, 11031

Taiwan

Phone: +886-2-27361661#6321

Email: ptsai@tmu.edu.tw

Abstract

Background: College students and young adults (aged 18-25 years) frequently experience poor sleep quality, with insomnia being particularly prevalent among this population. Given the widespread use of digital devices in the modern world, electronic device-based sleep interventions present a promising solution for improving sleep outcomes. However, their effects in this population remain underexplored.

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Conclusion: Digital sleep interventions are effective in improving subjective sleep quality and reducing insomnia severity, with moderate effects on dysfunctional beliefs and attitudes about sleep, sleep hygiene, and sleep knowledge. These interventions offer a viable approach to managing sleep problems in college students and young adults.

Trial Registration: The protocol for this study is registered with PROSPERO (registration number: CRD 42024595126).

KEYWORDS

College Students; Digital Sleep Interventions; Insomnia; Sleep Quality; Young Adults

Introduction

College students and young adults aged between 18 and 25 years frequently experience poor sleep quality and insufficient sleep duration [1,2] accompanied by a high prevalence of insomnia. Studies have reported that 18.5% of college students have insomnia, whereas 22.6% of young adults experience difficulty falling asleep; these rates are higher than those observed in the general population [3,4]. Adequate sleep is essential for maintaining overall health, cognitive functioning, and overall well-being in college students and young adults [5,6]. Although the recommended sleep duration for individuals aged 18 to 25 years is 7 to 9 hours per night [7], a study indicated that 30% to 50% of college students and young adults fail to meet this recommendation [8].

Short sleep duration is associated with numerous adverse outcomes in college students and young adults. These include poor dietary habits, obesity [9], and an increased risk of mental health problems (e.g., depression, suicidal behavior, and substance abuse) [10-13]. Furthermore, insufficient sleep adversely affects academic performance and may lead to a need for prolonged years of study [14]. Poor sleep in college students and young adults can also contribute to long-term sleep disturbances that may persist into adulthood [15].

Meta-analyses conducted by Friedrich and Schlarb (2018) and Saruhanjan et al. (2021) have indicated that psychological interventions exert a substantial moderate-to-large effect on sleep-related outcomes in college students [16,17]. In recent years, rapid technological advancements and the widespread adoption of electronic media have drawn attention to the relationship between electronic media use and sleep. A study indicated that college students and young adults spend an average of 316 minutes per week using electronic media, such as smartphones, tablets, emails, and video platforms [18]. This demographic also engages with the Internet more frequently than do other age groups, rendering it a central aspect of their daily routines [19]. Internet-based interventions have become a practical and promising solution to sleep problems, offering a form of therapy that individuals can access at their preferred time and location[20]. Although face-to-face interventions are highly effective [21], they are often costly, time-intensive, and impractical in many college or other settings [22,23] By contrast, electronic device-based interventions offer numerous advantages, including convenience, affordability, privacy, ease of distribution, and consistent content delivery [24] These interventions have demonstrated comparable effectiveness to face-to-face methods in addressing sleep difficulties among college students and young adults [17].

Several studies have systematically reviewed the effectiveness of digital psychological interventions for college students [25-27]. However, these reviews did not specifically evaluate sleep-related outcomes. One review included only two studies on sleep, neither of which focused on

sleep as a primary outcome[26], thereby limiting the specificity of the analysis regarding sleep-related interventions. Furthermore, the effects of electronic device-based sleep interventions on sleep outcomes in college students remains underexplored. Four systematic reviews have examined the effectiveness of digital cognitive behavioral therapy for insomnia (CBT-i [28-31]. Among these reviews, two [30,31] have included college students. Tsai et al. (2022) reviewed four studies, one of which included adolescents and three of which focused on college students. However, certain forms of digital CBT-i, such as interactive therapy and CBT-i delivered using mobile applications, were not analyzed, which considerably limits the applicability of their findings. Additionally, Zhang et al. (2023) analyzed digital sleep interventions in individuals aged 18 years and older with insomnia or poor sleep quality. Although the review included diverse populations, only two studies specifically focused on college students. The other two reviews [28,29] focused on a broad range of participants aged 18 years and older, including adults and patients with sleep disorders. In addition, these reviews exclusively relied on subjective sleep outcome measures, not including objective data in their analyses [28,29]. Although these studies have provided strong evidence indicating improvements in sleep quality and insomnia symptoms, the heterogeneity in the characteristics of their participants may have affected the internal validity of their results, thereby limiting the generalizability of their findings.

Research indicates that psychological interventions can substantially improve sleep quality and mental health in college students. However, the impact of digital interventions on sleep among college students and young adults remains underexplored. Given the high prevalence of sleep difficulties in this population and their widespread use of digital devices and mobile applications, investigating the effectiveness of digital sleep interventions is both relevant and crucial. The current systematic review and meta-analysis focused on college students and young adults aged 18 to 25 years [32]; this is a critical developmental stage often marked by poor sleep health [33]. This review and meta-analysis synthesized the available evidence on the effectiveness of electronic device-based interventions in improving sleep outcomes within this demographic compared with control groups.

Methods

Study Design

This systematic review and meta-analysis of randomized controlled trials (RCTs) investigated the effects of digital sleep interventions on college students and young adults aged 18 to 25. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [34]. The review protocol was registered with PROSPERO (CRD 42024595126).

Data Sources and Search Strategy

Two reviewers (Y.A.L and H.C.L) independently conducted a comprehensive search across five electronic databases, namely PubMed, CINAHL, Cochrane Library, Embase, and Web of Science, to identify relevant studies published from each database's inception to October 2024. The search strategy involved the use of the following keywords: (college OR university AND students OR young adults) AND (digital OR sleep AND intervention OR internet OR web-based OR online OR email OR mobile OR smartphone OR virtual reality) AND (sleep OR sleep quality OR insomnia) AND (randomized controlled trial). Details regarding the search strategies are provided in Multimedia Appendix 1-Table S1. In addition, the reference lists of related articles were manually screened for further eligible studies. No restrictions regarding the language of publication were applied.

Inclusion and Exclusion Criteria

In this systematic review, we included RCTs (1) that reported both pre-intervention and postintervention outcome measures; (2) recruited participants who were college/university students or young adults (aged 18-25, as defined by the Society for Adolescent Health and Medicine); (3) investigated the effects of sleep interventions delivered through electronic technologies, such as the Internet, computers, tablets, mobile devices, telehealth, or virtual reality; (4) included control groups comprising waiting-list control, placebo, no intervention, or standard/usual care groups or individuals receiving interventions delivered face-to-face through in-person coaching; and (5) assessed sleep outcomes of interest by using either subjective measurements (e.g., sleep questionnaires or sleep diaries) or objective measurements (e.g., actigraphy). No limitations regarding the language of publication were applied. Studies involving participants prescribed medication for sleep, given a diagnosis of a sleep disorder (e.g., sleep apnea), or given a diagnosis of a psychiatric disorder (e.g., major depressive disorder, bipolar disorder, or schizophrenia) were excluded.

Primary and Secondary Outcomes

The primary outcomes of this review were subjective sleep quality and objective sleep parameters. The secondary outcomes included insomnia severity, dysfunctional beliefs and attitudes about sleep (DBAS), sleep hygiene, sleep knowledge, and pre-sleep arousal in both cognitive and somatic domains.

Study Selection and Data Extraction

Duplicate articles were identified and removed using EndNote software. Two independent reviewers (Y.A.L and H.C.L) screened the titles and abstracts of the remaining studies. Full-text reviews were conducted for studies meeting the inclusion criteria. Any disagreements between the two reviewers were resolved through discussion with a third reviewer (P.S.T).

Data were extracted using a standardized form. Information on the following parameters was collected: study characteristics (e.g., first author, publication year, country, number of participants, mean age, number of female participants, and baseline sleep problems), intervention type (e.g., duration and delivery mode), postintervention dropout rates, use of intention-to-treat analysis, comparison groups, and outcome measurements (e.g., subjective sleep quality and objective sleep parameters). Study authors were contacted if any data were missing or incomplete. Available data were used when no response was received from corresponding authors.

Assessment of Methodological Quality

Two researchers (Y.A.L and H.C.L) independently evaluated the quality of the included studies by using the Cochrane Risk of Bias (RoB 2.0) tool for RCTs [35]. This tool is used to evaluate bias across five domains: (1) bias arising from the randomization process, (2) bias due to deviations from the intended intervention, (3) bias due to missing outcome data, (4) bias in the measurement of the outcome, and (5) bias in the selection of reported results. The overall risk of bias was determined by synthesizing findings across these domains, and studies were categorized as having a low risk of bias, some concerns, or a high risk of bias. Discrepancies between the researchers were resolved through discussion or, if necessary, consultation with a third reviewer (P.S.T).

Data Synthesis and Analysis

We conducted a meta-analysis of the pooled quantitative data by using Comprehensive Meta-Analysis software, version 3.7. Effect sizes were calculated on the basis of reported means and standard deviations for each outcome. We analyzed preintervention to postintervention improvements and between-group differences in sleep-related outcomes. In addition, effect sizes for

available follow-up measurements were calculated by comparing the intervention and control groups. A minimum of two studies per outcome was required to pool data for quantitative analyses.

A random-effects model was applied to account for anticipated heterogeneity across studies. The primary effect size, Hedges' g, was calculated for continuous outcomes and reported with 95% confidence intervals (CIs) [36]. Effect sizes were interpreted as small (0.2), moderate (0.5), or large (0.8) [37] Heterogeneity was assessed using the I^2 statistic, with values of 0%, 25%, 50%, and 75% indicating no, low, moderate, and high heterogeneity, respectively [38]. Subgroup analyses were conducted when substantial heterogeneity ($I^2 \geq 50\%$) was observed to explore potential sources of the variability. For outcomes with high heterogeneity and significant effects, we performed moderator analyses (for categorical variables) and meta-regression (for continuous variables) to identify potential sources of heterogeneity. Moderator analyses were limited to subgroups represented in at least three studies. A p value of <0.05 was considered significant for both the moderator and the meta-regression analyses.

To ensure the robustness of our findings, sensitivity analyses were conducted by excluding studies with a high risk of bias and evaluating their effects on the overall results. High-risk studies were defined as those with severe systematic biases, such as unclear reporting of the randomization process, deviations from intended interventions, missing outcome data, problems with outcome measurements, or selective reporting of results [35]. Publication bias was assessed using Egger's test and a funnel plot [39]. For outcomes reported in at least 10 studies, the trim-and-fill method was applied to estimate the potential impact of missing studies [40].

Assessment of the Certainty of Evidence

The quality of evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework. The quality of evidence was categorized as high, moderate, low, or very low on the basis of a comprehensive assessment of several factors, including risk of bias, inconsistency, indirectness, imprecision, and other relevant considerations [41].

Results

Study Selection

A total of 4,699 records were identified through database searches, and 1,572 duplicates were removed. After the titles and abstracts were screened, 3,093 records were deemed irrelevant and excluded. This process resulted in 34 studies being included for full-text review. Of these, 22 did not meet the inclusion criteria and were excluded from the systematic review. In addition, one study was identified through a manual search of reference lists in related articles. Finally, 13 studies were included in the meta-analysis [42-54]. The study selection process is summarized in Figure. 1.

Study Characteristics

The included studies involved a total of 5,251 college students and young adults with a mean age of 23.58 years. Most studies were conducted in the United States (n = 6), followed by in the United Kingdom (n = 3), Asia (n = 3), and the Middle East (n = 1). The sample sizes ranged from 40 to 3,755 participants. The average dropout rate was 17.73% in the intervention group and 12.62% in the control group. Nearly 75% of the participants (n = 3,924) reported sleep problems at baseline. The diagnostic criteria for assessing sleep problems included the Insomnia Severity Index (ISI) in two studies [52,53], the Sleep Condition Indicator (SCI) in one study [44], and the Sleep Quality Score in one study [49].

Most of the studies employed a two-arm trial design, whereas two studies adopted a three-arm trial design [48,49]. Jones et al. (2020) compared “text message–based sleep intervention” with “placebo” and “no intervention.” Additionally, Kim et al. (2024) compared “virtual reality-based meditation” with “concentration meditation” and “no intervention”.

The effectiveness of digital sleep interventions was evaluated in terms of various outcomes: 15 studies assessed subjective sleep quality, 5 examined objective sleep parameters, 4 evaluated insomnia severity, 2 focused on dysfunctional beliefs and attitudes regarding sleep, 4 assessed sleep hygiene, 3 evaluated sleep knowledge, and 2 analyzed pre-sleep arousal. The instruments used to assess subjective sleep quality included the Pittsburgh Sleep Quality Index (PSQI), the Korean Modified Leeds Evaluation Questionnaire, the Patient Reported Outcomes Measurement Information System (PROMIS), and sleep diaries. Objective sleep parameters were assessed using actigraphy. Insomnia severity was evaluated using the ISI or SCI. DBAS was measured using the Dysfunctional Beliefs and Attitudes about Sleep-16. Sleep hygiene and knowledge were assessed using the Sleep Hygiene Index or the Sleep Hygiene Practice Scale. Pre-sleep arousal was measured using the Pre-Sleep Arousal Scale (PSAS). The details of the included studies are presented in Table 1.

Quality Assessments

Six studies had a low overall risk of bias, three had a high overall risk of bias, and four had some concerns. Among the high-risk studies, two[42,46] did not report their randomization methods. In addition, one of these studies [46] had a high rate of missing data, compromising the integrity of the results because of its excessive data loss without explanation. Another study [47] was classified as high risk because it explicitly stated that blinding of participants and assessors was not feasible.

Four studies were categorized as having some concerns because of unclear information regarding specific domains. These included uncertainties about the randomization process [44], blinding of participants [50,54], and outcome measurement procedures [49]. All studies demonstrated a low risk of bias concerning selective reporting, and none provided sufficient information to evaluate other potential sources of bias. The details of the risk of bias assessment are illustrated in Figure. 2

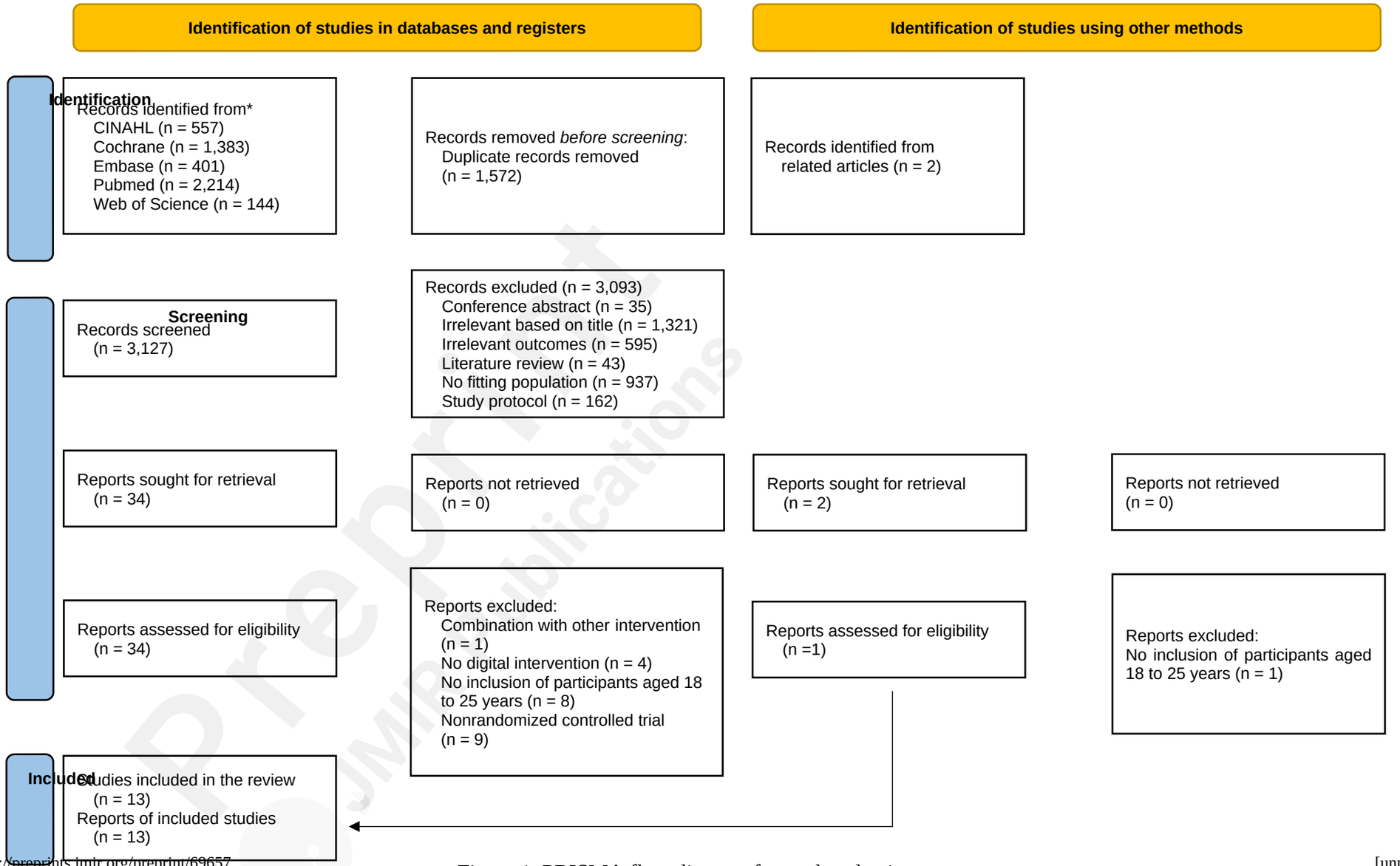


Figure 1. PRISMA flow diagram for study selection

No	Author(s), year, country	No. of participants (I/C)	Age (Mean ± SD)	Women [n (%)]	Baseline sleep problems	Digital Intervention			Dropout [PI (%)]	Use of ITT	Comparison	Outcome measurements
						Type	Duration	Mode of delivery				
1	Baber et al., (2017), USA	43/35	I: 20.67 ± 2.52 C: 20.33 ± 1.66	I: 29 (37.2) C: 18 (23.1)	No	Sleep hygiene	1 week (22 min and 33 s)	Online (through PowerPoint)	I: 0 C: 0	Yes	Passive (waiting list)	1. Actigraphy* 2. SHI 3. Sleep quality
2	Denis et al., (2020), UK	99/100	I: 19.73 ± 2.94 C: 20.22 ± 5.69	I: 99 (100) C: 100 (100)	No	Virtual therapist–led CBT-i (cognitive techniques, relaxation techniques, sleep hygiene, sleep restriction, stimulus control)	6 weeks (6 sessions/week, 20–25 min/session)	Online (through a video platform)	I: 32.3 C: 22.0	No	Active (puzzles)	1. DBAS-16 2. MCQ 3. PSAS 4. PSQI 5. SCI
3	Freeman et al., (2017), UK	1,891/1,864	I: 24.83 ± 7.70 C: 24.60 ± 7.60	I: 1,361 (72.0) C: 1,315 (71.0)	Yes	CBT-i (cognitive techniques, psychoeducation, relaxation techniques, sleep hygiene, sleep restriction, stimulus control)	10 weeks (6 sessions, average of 20 min/session)	Online (through a website)	I: 59.1 C: 38.7	No	Passive (usual practice)	1. ISI 2. SCI 3. Sleep diaries
4	Fucito et al., (2017), USA	21/21	I: 24.83 ± 7.7 C: 24.60 ± 7.6	I: 10 (48.0) C: 10 (48.0)	No	CBT-i (cognitive techniques, psychoeducation, relaxation techniques, sleep hygiene, stimulus control)	4 weeks (intervention consisted of four modules; 1 module/week)	Online (web-based)	I: 9.5 C: 9.5	Yes	Active (healthy behaviors)	1. Actigraphy* 2. PSQI 3. PROMIS-SRI-SF 4. Sleep diaries
5	Hershner et al., (2018), USA	254/295	I: 21.90 ± 4.01 C: 22.00 ± 4.35	I: 140 (55.8) C: 176 (60.5)	No	Sleep education (a personality profile, two videos on sleep hygiene and its effects, and information on sleep behavior)	8 weeks (intervention consisted of sleep modules of 20 min)	Online (through a website)	I: 42.9 C: 30.2	No	Passive (no intervention)	1. ESS 2. MEQ 3. PSQI 4. SHI

Table 1. Summary of characteristics of included articles

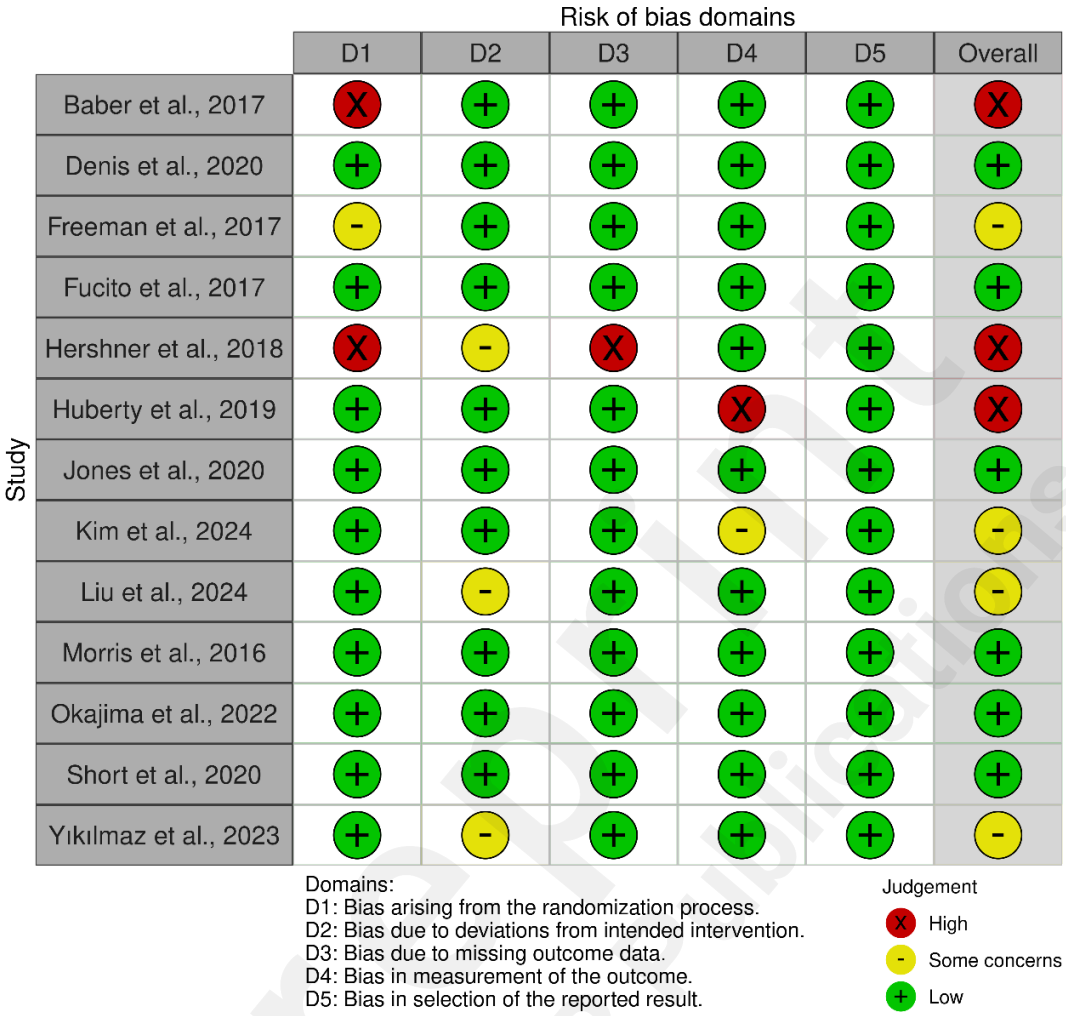
Table 1. (*continued*)

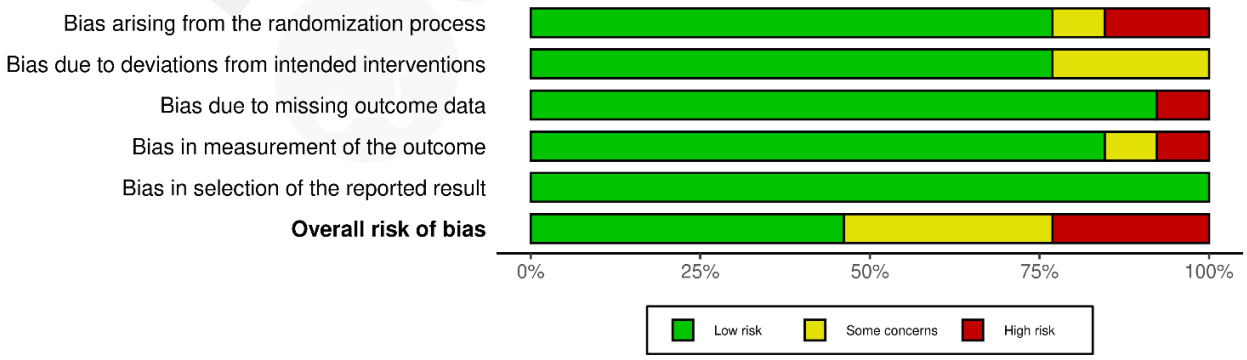
No	Author(s), year, country	No. of participants (I/C)	Age (Mean ± SD)	Women [n (%)]	Baseline sleep problems	Digital Intervention			Dropout [PI (%)]	Use of ITT	Comparison	Outcome measurements
						Type	Duration	Mode of delivery				
6	Huberty et al., (2019), USA	56/53	I: 20.41 ± 2.31 C: 21.85 ± 6.3	I: 36 (41.0) C: 43 (49.0)	No	Mindfulness meditation (body scan, breath focus, and kindness)	8 weeks (at least 10 min/session)	Mobile phone (application)	I: 26.8 C: 11.3	No	Passive (waiting list)	PROMIS
7	Jones et al., (2020), USA	53/C_1:52/C_2:51	I: 18.16 ± 0.37 C_1: 18.17 ± 0.38 C_2: 18.03 ± 0.17	I: 38 (79.2) C_1: 29 (69.1) C_2: 36 (80.0)	No	Health belief model education (theory based)	6 weeks (2 texts [first 2 weeks]; 1 text [second 2 weeks]; 1 text every other day [final 2 weeks])	Online (through a text message)	I: 9.4 C_1: 19.2 C_2: 11.8	No	C_1: Passive (placebo) C_2: Passive (no intervention)	1. PSQI 2. SHI
8	Kim et al., (2024), Korea	20/C_1:20/C_2:20	I: 21.60 ± 1.47 C_1: 21.75 ± 1.48 C_2: 22.35 ± 1.35	I: 15 (75.0) C_1: 13 (65.0) C_2: 13 (65.0)	Yes	Meditation (4 video types: sea, night sky, walking through a forest in the fall, and a green forest)	5 days (30 min/day)	VR-based (through a video)	I: 0 C_1: 0 C_2: 0	Yes	C_1: Active (concentration meditation) C_2: Passive (no intervention)	1. KMLSEQ-LSEQ 2. Actigraphy*
9	Liu et al., (2024), Singapore	30/29	I: 21.6 ± 4.26 C: 22.4 ± 1.31	I: 12 (40.0) C: 9 (31.0)	No	Sleep QA system with health coaching	4 weeks (30 min/week)	Online (through text)	I: 6.7 C: 10.0	No	Active (sleep QA system)	1. Actigraphy* 2. PSQI 3. Sleep diaries
10	Morris et al., (2016), UK	48/47	I: 20.69 ± 2.61 C: 20.27 ± 1.56	I: 29 (60.4) C: 33 (70.2)	No	CBT-i (psychoeducation, relaxation techniques, sleep hygiene, sleep restriction, stimulus control)	6 weeks (intervention consisted of 7 modules; 20 min/week)	Online (through text and email)	I: 25 C: 6.4	Yes	Passive (waiting list)	PSQI

Table 1. (*continued*)

No	Author(s), year, country	No. of participants (I/C)	Age (Mean ± SD)	Women [n (%)]	Baseline sleep problems	Digital Intervention			Dropout [PI (%)]	Use of ITT	Comparison	Outcome measurements
						Type	Duration	Mode of delivery				
11	Okajima et al., (2022), Japan	24/24	I and C: 19.56 ± 1.56	I: 16 (66.67) C: 16 (66.67)	Yes	CBT-i (cognitive techniques, relaxation techniques, sleep hygiene, sleep restriction, stimulus control)	8 weeks (30 min/session; 8 sessions/week)	Online (through an email with PDF files)	I: 12.5 C: 16.67	Yes	Passive (self-monitoring)	1. DBAS-16 2. FIRST 3. ISI 4. PSAS 5. SHPS 6. Sleep diaries
12	Short et al., (2020), USA	32/29	I and C: 19.43 ± 2.04	I and C: 51 (84.0)	Yes	Motivation, psychoeducation, behavioral tools, and behavior change modules	1 week (intervention consisted of four modules of 45 min)	Online (through text)	I: 6.3 C: 10.3	No	Active (physical health education)	1. ISI 2. SRBQ
13	Yıkılmaz et al., (2023), Turkey	20/20	I: 20.70 ± 1.21 C: 21.05 ± 0.94	I: 3 (15.0) C: 2 (10.0)	No	Physiotherapist-led, Internet-based BBAT intervention program	6 weeks (60 min/session; 3 sessions/week)	Videoconferencing	I: 0 C: 0	Yes	Passive (no intervention)	PSQI

BBAT = basic body awareness therapy, C = control group, CBT-i = cognitive behavioral therapy for insomnia, DBAS-16 = Dysfunctional Beliefs and Attitudes about Sleep-16, ESS = Epworth Sleepiness Scale, FIRST = Ford Insomnia Response to Stress Test, I = intervention group, ISI = Insomnia Severity Index, ITT = intention-to-treat analysis, KMLSEQ = Korean Modified Leeds Evaluation Questionnaire, PI = postintervention, PROMIS = Patient Reported Outcomes Measurement Information System, PROMIS-SRI-SF = Patient Reported Outcomes Measurement Information System Sleep-Related Impairment Short-Form, PSAS = Pre-Sleep Arousal Scale, PSQI = Pittsburgh Sleep Quality Index, QA = question answering, SCI = Sleep Condition Indicator, SD = standard deviation, SHI = Sleep Hygiene Index, SHPS = Sleep Hygiene Practice Scale, SRBQ = Sleep-Related Behaviors Questionnaire, UK = the United Kingdom, USA = the United States of America, VR = virtual reality, *Objective measures.


Risk of bias domains
D1
D2
D3
D4
D5
Overall
Study
Baber et al., 2017
Denis et al., 2020
Freeman et al., 2017
Fucito et al., 2017
Hershner et al., 2018
Huberty et al., 2019
Jones et al., 2020
Kim et al., 2024
Liu et al., 2024
Morris et al., 2016
Okajima et al., 2022
Short et al., 2020
Yıkılmaz et al., 2023
Domains:
D1: Bias arising from the randomization process.
D2: Bias due to deviations from intended intervention.
D3: Bias due to missing outcome data.
D4: Bias in measurement of the outcome.
D5: Bias in selection of the reported result.
Judgement
High
Some concerns
Low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Bias due to missing outcome data
Bias in measurement of the outcome
Bias in selection of the reported result
Overall risk of bias
0%
25%
50%
75%
100%
Low risk
Some concerns
High risk

Figure 2. Risk of bias graph for included studies

Digital Sleep Interventions for College Students and Young Adults

The components of the digital sleep interventions varied across the included studies. Among the 13 studies, 5 (38.46%) employed CBT-i, 5 (38.46%) focused on sleep-related education or information, 2 (15.38%) incorporated meditation, and 1 (7.69%) used body awareness therapy. The intervention durations ranged from 5 days to 10 weeks, with four studies [43-45,53] also assessing follow-up effects after the intervention period. Approximately half of the studies (n = 7, 53.84%) were exclusively conducted in university settings. The detailed results are provided in Table 1 and Multimedia Appendix 1-Table S2.

Comparators

The majority of the included studies (n = 10, 66.67%) included a passive control group. In these studies, participants in the control group received usual or standard care, were placed on a waiting list, or did not receive any intervention. By contrast, the active control groups participated in sleep programs, received information on sleep education and healthy behaviors, or engaged in concentration meditation. The detailed results are provided in Table 1.

Effectiveness of Digital Sleep Interventions

Subjective Sleep Quality

The effects of digital sleep interventions on subjective sleep quality were analyzed for both postintervention and follow-up periods. The pooled results revealed a large and significant postintervention effect (Hedges' g = -1.249; 95% CI: -1.834, -0.664; $p < 0.001$; $I^2 = 97.17\%$) and a moderate but significant follow-up effect (Hedges' g = -0.532; 95% CI: -0.956, -0.107; $p = 0.014$; $I^2 = 77.97\%$). The detailed results are provided in Table 2. Substantial heterogeneity was observed between the

studies. Subgroup analyses revealed the type of sleep questionnaire to be a significant source of heterogeneity (Multimedia Appendix 1-Table S3). Although subjective sleep quality is a critical outcome for college students and young adults, the certainty of evidence for the postintervention effects was rated as “low” (Multimedia Appendix 1-Table S4). This rating was downgraded because of risks of bias, inconsistency, and imprecision but upgraded because of the large magnitude of the effect. For follow-up effects, the evidence was rated as having “moderate” certainty. These findings suggest that digital sleep interventions are likely to significantly improve sleep quality in both postintervention and follow-up assessments.

Objective Sleep Parameters

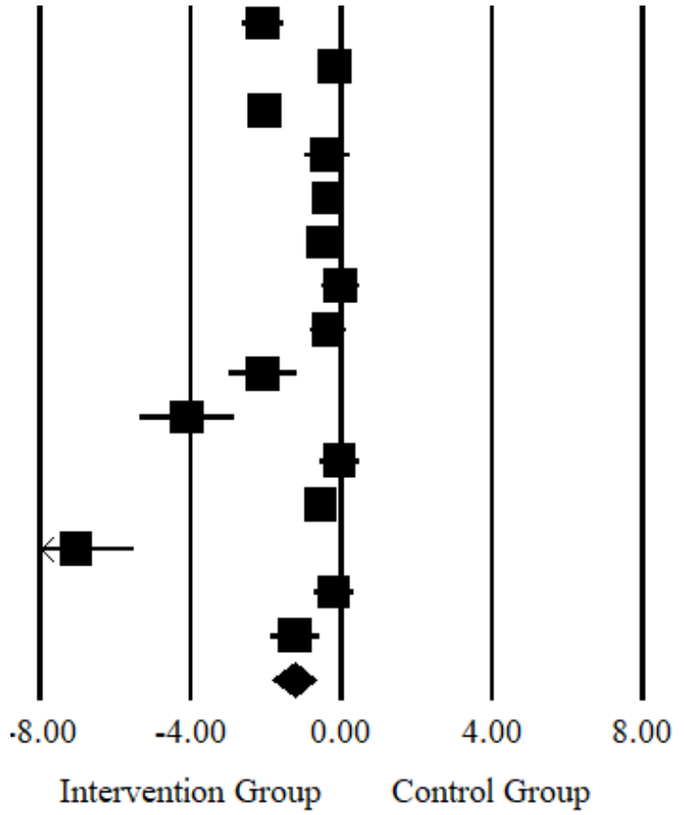
The pooled effects on objective sleep parameters, including sleep efficiency (SE), total sleep time (TST), wake after sleep onset (WASO), and the number of awakenings (NWAK), were analyzed. Digital sleep interventions demonstrated a significant medium effect on SE (Hedges’ g = 0.617; 95% CI: 0.182, 1.052; $p = 0.005$; $I^2 = 60.43\%$), with substantial heterogeneity among studies. However, nonsignificant effects were observed for NWAK ($p = 0.265$), TST ($p = 0.071$), and WASO ($p = 0.179$). The detailed results are provided in Table 2. Subgroup analyses revealed that the heterogeneity in SE could be attributed to intervention duration (1 week vs. 4 weeks; Multimedia Appendix 1-Table S3). Although objective sleep parameters are crucial outcomes, the certainty of the evidence ranged from “very low” to “low” (Multimedia Appendix 1-Table S4). This low rating was because of increased risks of bias, inconsistency, and imprecision primarily resulting from variations in measurement methods for objective sleep parameters. Overall, the evidence remained highly uncertain regarding the postintervention effects of digital sleep interventions

on objective sleep parameters.

Table 2. Effect sizes for outcomes of interest in studies evaluating digital sleep interventions.

Subjective Sleep Quality

Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Short-term effect: Postintervention (n = 15)						
Baber et al., 2017	−2.080	0.280	−0.079	−2.629, −1.531	<0.001	
Denis et al., 2020	−0.167	0.166	0.028	−0.493, 0.158	0.313	
Freeman et al., 2017	−2.047	0.057	0.003	−2.159, −1.935	<0.001	
Fucito et al., 2017	−0.372	0.305	0.093	−0.971, 0.226	0.223	
Hershner et al., 2018	−0.352	0.107	0.011	−0.561, −0.142	0.001	
Huberty et al., 2019	−0.502	0.215	0.046	−0.924, −0.080	0.020	
Jones et al., 2020 [a]	−0.038	0.253	0.064	−0.533, 0.458	0.881	
Jones et al., 2020 [b]	−0.352	0.252	0.063	−0.845, 0.142	0.162	



Kim et al., 2024 [a]	−2.089	0.463	0.215	−2.988, −1.181	<0.001
Kim et al., 2024 [b]	−4.109	0.651	0.423	−5.384, −2.834	<0.001
Liu et al., 2024	−0.041	0.266	0.071	−0.562, 0.480	0.877
Morris et al., 2016	−0.548	0.207	0.043	−0.955, −0.142	0.008
Okajima et al., 2022	−7.036	0.722	0.596	−8.550, −5.523	<0.001
Short et al., 2020	−0.202	0.265	0.070	−0.722, 0.317	0.445
Yıkılmaz et al., 2023	−1.231	0.339	0.115	−1.895, −0.566	<0.001
Total	−1.249	0.298	0.089	−1.834, −0.664	<0.001
Test for heterogeneity: Q value = 495.09, df = 14 ($p < 0.001$), $I^2 = 97.17\%$					
Test for overall effect: Z = −4.18 ($p < 0.001$)					

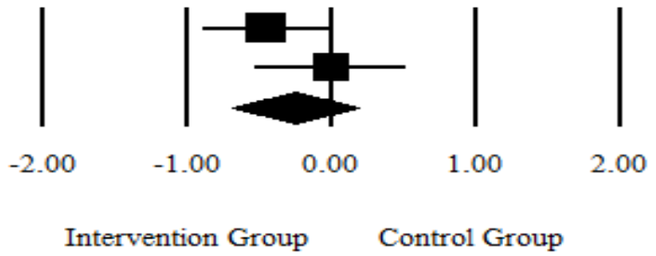
Table 2. (*continued*)

Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Long-term effect: Follow-up (n = 3)						
Denis et al., 2020	−0.091	0.192	0.037	−0.468, 0.286	0.636	
Freeman et al., 2017	−0.662	0.053	0.003	−0.776, −0.557	<0.001	
Fucito et al., 2017	−0.925	0.319	0.102	−1.551, 0.300	0.004	
Total	−0.532	0.216	0.047	−0.956, −0.107	0.014	
Test for heterogeneity: Q value = 9.01, df = 2 ($p = 0.011$), $I^2 = 77.97\ \%$						
Test for overall effect: Z = −2.46 ($p = 0.014$)						

Table 2. (*continued*)

Objective Sleep Parameters

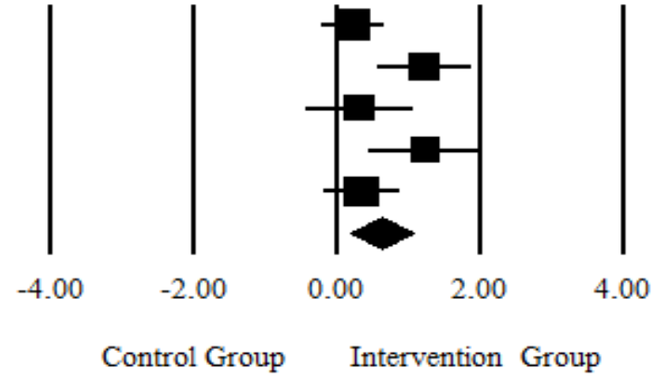
Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Short-term effect: Postintervention						
A) Number of awakenings (n = 2)						
Baber et al., 2017	−0.449	0.228	0.052	−0.896, −0.001	0.049	
Liu et al., 2024	−0.004	0.266	0.071	−0.525, −0.518	0.989	
Total	−0.247	0.222	0.049	−0.681, 0.187	0.265	



Test for heterogeneity: Q value = 1.61, df = 1 (*p* = 0.204), I^2 = 37.99 %

Test for overall effect: Z = −1.12 (*p* = 0.265)

B) Sleep efficiency (n = 5)					
Baber et al., 2017	0.211	0.226	0.051	−0.232, 0.654	0.351
Fucito et al., 2017	1.211	0.334	0.109	0.573, 1.869	<0.001
Kim et al., 2024 [a]	0.314	0.379	0.144	−0.428, 1.057	0.407
Kim et al., 2024 [b]	1.236	0.409	0.167	0.434, 2.038	0.003
Liu et al., 2024	0.350	0.268	0.072	−0.175, 0.875	0.192
Total	0.617	0.222	0.049	0.182, 1.052	0.005

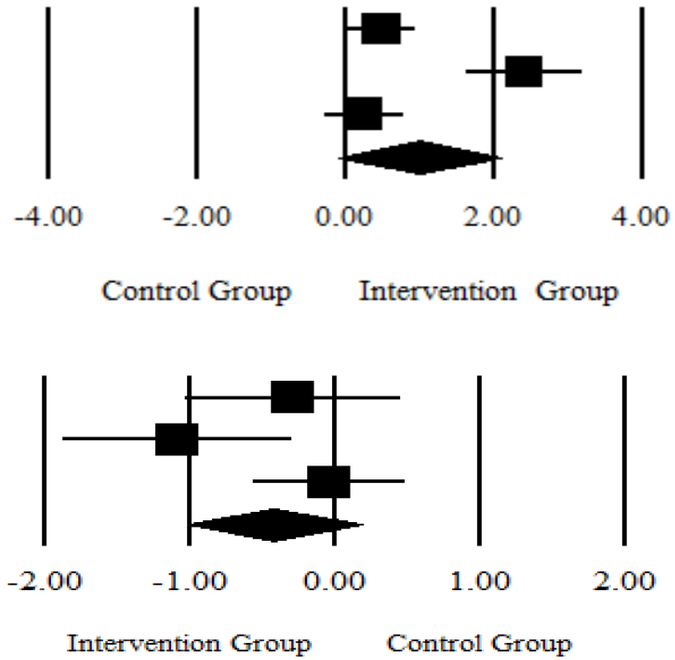


Test for heterogeneity: Q value = 10.11 df = 4 (*p* = 0.039), I^2 = 60.43%

Test for overall effect: Z = 2.78 (*p* = 0.005)

Table 2. (*continued*)

Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Short-term effect: Postintervention						
C) Total sleep time (n = 3)						
Baber et al., 2017	0.486	0.229	0.052	0.037, 0.934	0.034	
Fucito et al., 2017	2.416	0.401	0.161	1.629, 3.203	<0.001	
Liu et al., 2024	0.247	0.267	0.071	−0.276, 0.071	0.354	
Total	1.003	0.555	0.308	−0.084, 2.091	0.071	
Test for heterogeneity: Q value = 22.02, df = 2 (*p* = 0.011), I^2 = 90.92%						
Test for overall effect: Z = 1.81 (*p* = 0.071)						
D) Wake after sleep onset (n = 3)						
Kim et al., 2024 [a]	−0.287	0.379	0.143	−1.029, 0.456	0.449	
Kim et al., 2024 [b]	−1.077	0.402	0.161	−1.864, −0.290	0.007	
Liu et al., 2024	−0.030	0.266	0.071	−0.551, 0.491	0.909	
Total	−0.413	0.307	0.094	−1.014, −0.189	0.179	
Test for heterogeneity: Q value = 4.74, df = 2 (*p* = 0.093), I^2 = 57.82%						
Test for overall effect: Z = −1.35 (*p* = 0.179)						



Insomnia Severity

The pooled effects of digital sleep interventions on insomnia severity, as assessed using the ISI or SCI questionnaires, were analyzed for both postintervention and follow-up periods. The results indicated significant reductions in insomnia severity at postintervention (Hedges' g = -4.082; 95% CI: -5.141, -3.022; $p < 0.001$; $I^2 = 98.92\%$) and follow-up assessments (Hedges' g = -2.649; 95% CI: -3.888, -1.409; $p < 0.001$; $I^2 = 99.34\%$). The detailed results are provided in Table 2. The heterogeneity in the insomnia severity outcomes was primarily attributable to the type of questionnaire used (ISI vs. SCI; Multimedia Appendix 1-Table S3). Insomnia severity is a critical outcome, and the evidence supporting the postintervention and follow-up effects of digital sleep interventions was rated as having a "moderate" level of certainty (Multimedia Appendix 1-Table S4). This rating was downgraded because of inconsistency and imprecision but was then upgraded because of the large magnitude of the observed effects. These findings suggest that digital sleep interventions are likely to significantly reduce insomnia severity in both postintervention and follow-up assessments.

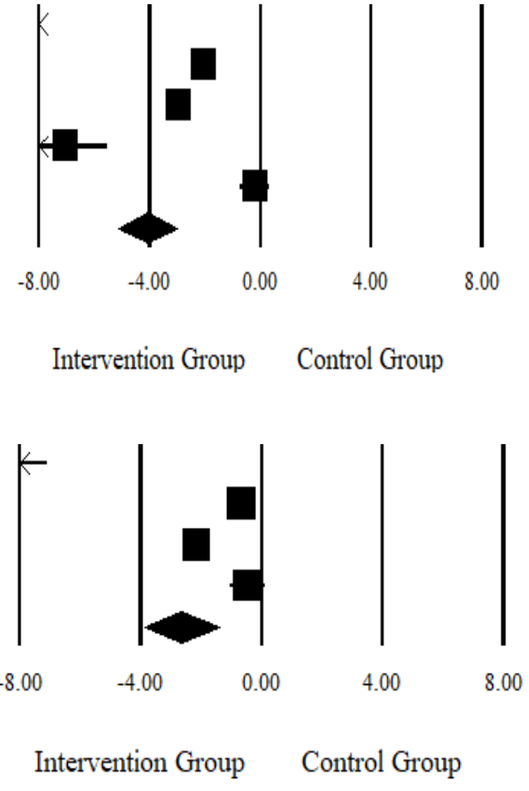
Dysfunctional Beliefs and Attitudes about Sleep

The pooled results of two studies reporting the postintervention effects of digital sleep interventions on DBAS indicated a large and significant effect (Hedges' g = -2.113; 95% CI: -3.329, -0.986; $p < 0.001$; $I^2 = 86.36\%$). The detailed results are provided in Table 2. The certainty of evidence for this outcome was rated as "low," reflecting the limited importance of DBAS as a measure (Multimedia Appendix 1-Table S4). This rating was downgraded due to inconsistency and imprecision in the findings. Although the evidence suggested that digital sleep interventions moderately affected DBAS in postintervention assessments, the clinical significance of this outcome remained uncertain.

Table 2. (*continued*)

Insomnia Severity

Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Short-term effect: Postintervention						
A) Insomnia (n = 5)						
Denis et al., 2020‡	−10.399	0.633	0.400	−11.639, −9.159	<0.001	
Freeman et al., 2017†	−2.047	0.057	0.003	−2.159, −1.935	<0.001	
Freeman et al., 2017‡	−2.954	0.067	0.004	−3.084, −2.823	<0.001	
Okajima et al., 2022 †	−7.036	0.772	0.596	−8.550, −5.523	<0.001	
Short et al., 2020 ‡	−0.202	0.265	0.070	−0.722, 0.317	0.445	
Total	−4.082	0.541	0.292	−5.141, −3.022	<0.001	
Test for heterogeneity: Q value = 371.45, df = 4 ($p < 0.001$), I^2 = 98.92%						
Test for overall effect: Z = −7.55 ($p < 0.001$)						
Long-term effect: Follow-up						
B) Insomnia (n = 3)						
Denis et al., 2020‡	−8.265	0.592	0.350	−9.425, −7.105	<0.001	
Freeman et al., 2017†	−0.662	0.053	0.003	−0.766, −0.557	<0.001	
Freeman et al., 2017‡	−2.145	0.065	0.004	−2.274, −2.017	<0.001	
Short et al., 2020	−0.459	0.297	0.088	−1.041, 0.123	0.122	
Total	−2.649	0.633	0.400	−3.888, −1.409	<0.001	
Test for heterogeneity: Q value = 457.18, df = 2 ($p < 0.001$), I^2 = 99.34%						
Test for overall effect: Z = −4.187 ($p < 0.001$)						

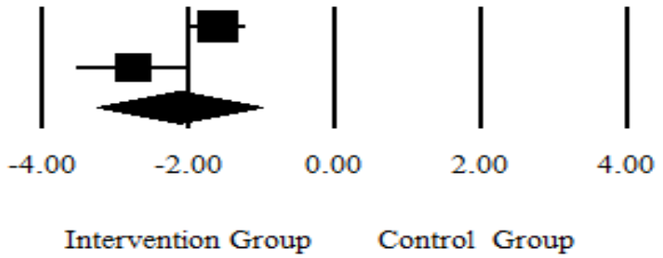


†Insomnia Severity Index questionnaire, ‡Sleep Condition Indicator questionnaire

Table 2. (*continued*)

Dysfunctional Beliefs and Attitudes Regarding Sleep

Study (year)	Statistics for each study				
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*
Short-term effect: Postintervention (n = 2)					
Denis et al., 2020	−1.589	0.190	0.036	−1.961, −1.216	<0.001
Okajima et al., 2022	−2.743	0.399	0.159	−3.524, −1.961	<0.001
Total	−2.113	0.575	0.330	−3.329, −0.986	<0.001

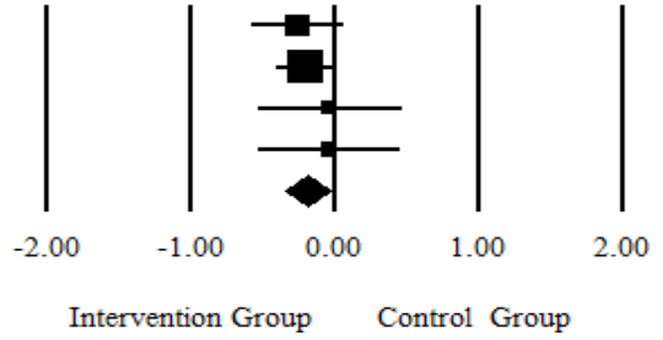


Test for heterogeneity: Q value = 6.83, df = 1 (p = 0.009), I^2 = 85.36%

Test for overall effect: Z = −3.68 (p < 0.001)

Sleep Hygiene

Study (year)	Statistics for each study				
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*
Short-term effect: Postintervention (n = 4)					
Baber et al., 2017	−0.263	0.162	0.026	−0.580, 0.054	0.104
Hershner et al., 2018	−0.208	0.106	0.001	−0.417, −0.000	0.050
Jones et al., 2020 [a]	−0.036	0.253	0.064	−0.531, 0.460	0.887
Jones et al., 2020 [b]	−0.041	0.250	0.062	−0.531, 0.449	0.870
Total	−0.188	0.079	0.006	−0.343, −0.032	0.018



Test for heterogeneity: Q value = 0.96, df = 3 (p = 0.811), I^2 = 0%

Test for overall effect: Z = −2.36 (p = 0.018)

Sleep Hygiene

Analysis of the pooled postintervention effects of digital sleep interventions on sleep hygiene revealed a small but significant improvement (Hedges' g = -0.188; 95% CI: -0.343, -0.032; p = 0.018; I^2 = 0%). The detailed results are provided in Table 2. The evidence for this outcome was rated as having a "moderate" level of certainty, although sleep hygiene was considered an outcome of limited importance (Multimedia Appendix 1-Table S4). The certainty rating was downgraded because of an increased risk of bias. These findings suggest that digital sleep interventions led to a slight improvement in sleep hygiene following the intervention.

Sleep Knowledge

The pooled results indicated a small but significant postintervention effect of digital sleep interventions on sleep knowledge (Hedges' g = -0.268; 95% CI: 0.088, 0.447; p = 0.003; I^2 = 0%). The detailed results are provided in Table 2.

The evidence for this outcome was rated as having a "moderate" level of certainty, although sleep knowledge was considered an outcome of limited importance (Multimedia Appendix 1-Table S4). The certainty rating was downgraded because of an increased risk of bias. These findings suggest that digital sleep interventions led to a slight improvement in sleep knowledge following the intervention.

Pre Sleep Arousal

The effects of digital sleep interventions on pre sleep arousal, including cognitive and somatic domains, were analyzed. The pooled results indicated nonsignificant postintervention effects for both the cognitive domain (Hedges' g = -2.021; 95% CI: -5.860, 1.819; p = 0.302; I^2 = 98.21%) and the somatic domain (Hedges' g = -1.902; 95% CI: -5.035, 1.231; p = 0.234; I^2 = 97.69%). The detailed

results are provided in Table 2.

The certainty of evidence for these outcomes was rated as “low,” reflecting the limited importance of pre sleep arousal (cognitive and somatic domains) as a measure (Multimedia Appendix 1-Table S4). The rating was downgraded because of inconsistency and imprecision in the findings. Overall, the evidence remained uncertain regarding the postintervention effects of digital sleep interventions on pre sleep arousal in both domains.

Moderator Analysis

Moderator analyses revealed that the type of intervention (digital CBT-i vs. other therapies, $p < 0.001$), therapist-provided instructions (guided vs. unguided, $p < 0.001$), intervention duration (≤6 weeks vs. >6 weeks, $p < 0.001$), mode of delivery (email/text message vs. video materials, $p = 0.002$), type of participants (with sleep problems vs. without sleep problems, $p < 0.001$), and use of intention-to-treat analysis (yes vs. no, $p = 0.001$) significantly influenced the effectiveness of digital sleep interventions. The results of the moderator (subgroup) analyses are presented in Multimedia Appendix 1-Table S5.

Meta-regression analyses indicated that the heterogeneity of digital sleep interventions on subjective and objective sleep quality, sleep hygiene, and insomnia was not significantly associated with age, sex, or intervention duration ($p > 0.05$). The results of the meta-regression analyses are presented in Multimedia Appendix 1-Table S6.

Table 2. (*continued*)

Sleep Knowledge

Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Short-term effect: Postintervention (n = 3)						
Hershner et al., 2018	0.208	0.106	0.011	0.000, 0.417	0.050	
Jones et al., 2020 [a]	0.513	0.257	0.066	0.009, 1.016	0.046	
Jones et al., 2020 [b]	0.364	0.252	0.063	−0.129, 0.858	0.148	
Total	−0.268	0.092	0.008	0.088, 0.447	0.003	

Test for heterogeneity: Q value = 1.37, df = 2 (p = 0.505), I^2 = 0%

Test for overall effect: Z = 2.93 (p = 0.003)

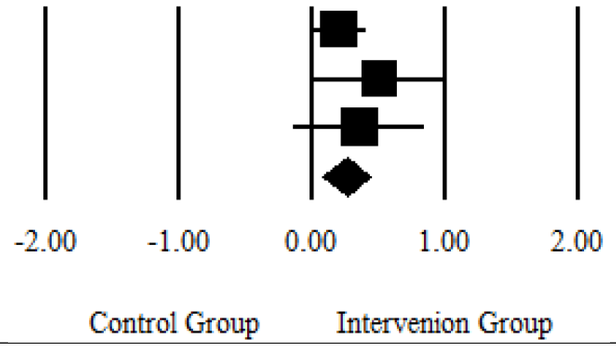
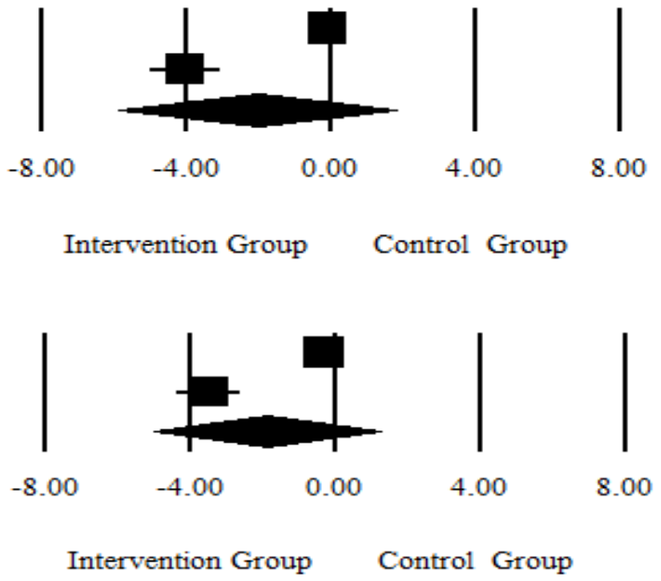


Table 2. (*continued*)

Pre Sleep Arousal

Study (year)	Statistics for each study					Hedges' g and 95% confidence interval
	Hedges' g	Standard error	Variance	Lower, upper limit	*p*	
Short-term effect: Postintervention						
A) Cognitive (n = 2)						
Denis et al., 2020	−0.089	0.166	0.027	−0.414, 0.235	0.590	
Okajima et al., 2022	−4.008	0.498	0.248	−4.984, −3.032	<0.001	
Total	−2.021	1.959	3.838	−5.860, 1.819	0.302	
Test for heterogeneity: Q value = 55.75, df = 1 ($p < 0.001$), $I^2 = 98.21\%$						
Test for overall effect: Z = −1.03 ($p = 0.302$)						
B) Somatic (n = 2)						
Denis et al., 2020	−0.331	0.167	0.028	−0.658, 0.004	0.047	
Okajima et al., 2022	−3.529	0.459	0.210	−4.428, −2.630	<0.001	
Total	−1.902	1.599	2.555	−5.035, 1.231	0.234	
Test for heterogeneity: Q value = 42.93 df = 1 ($p < 0.001$), $I^2 = 97.67\%$						
Test for overall effect: Z = −1.19 ($p = 0.234$)						



Sensitivity Analysis

Sensitivity analyses were conducted to assess the robustness of the findings of the meta-analysis. Exclusion of the data of three high-risk studies from the pooled data on subjective sleep quality had a minimal impact on the results ($p < 0.001$), despite the substantial heterogeneity observed in postintervention subjective sleep quality ($I^2 = 96.91\%$). Additionally, a sensitivity analysis in which the data of one high-risk study were excluded from the pooled data on SE for objective sleep parameters revealed negligible changes in the results ($p = 0.004$), further supporting the robustness of the findings. The detailed results are provided in Multimedia Appendix 1-Table S7.

Publication Bias

Publication bias for subjective sleep quality was assessed using Egger's test and a funnel plot. Egger's test indicated no significant publication bias ($p = 0.243$). The funnel plot is presented in Figure 3.

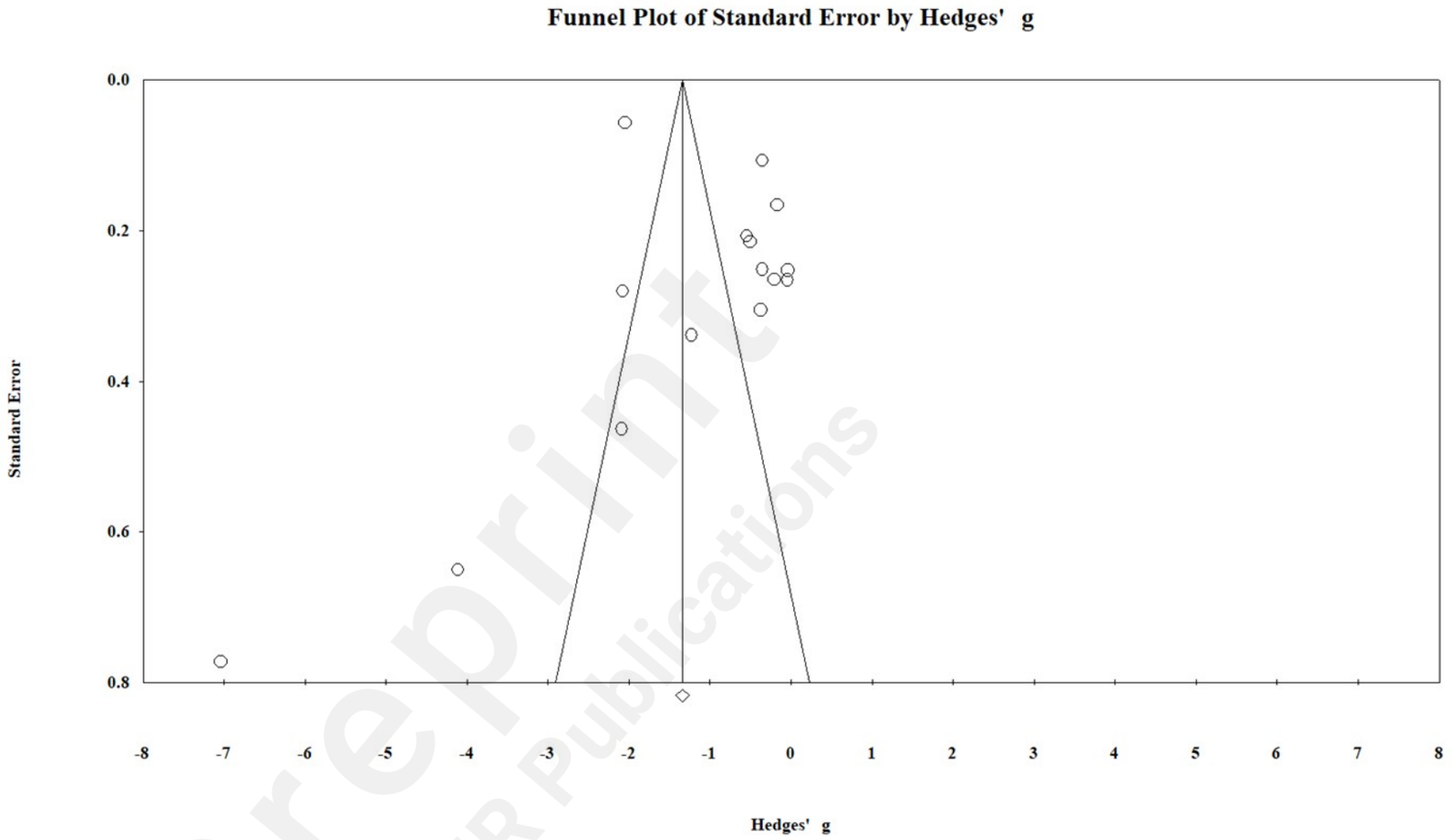


Figure 3. Funnel plot for publication bias

Egger's test results: t = 1.22 and df = 13, $p = 0.24$.

Discussion

Overview

This systematic review and meta-analysis evaluated the effects of digital sleep interventions on sleep-related outcomes in college students and young adults (aged 18 to 25 years). The findings demonstrate that digital sleep interventions significantly improved subjective sleep quality, SE as an objective sleep parameter, insomnia severity, DBAS, sleep hygiene, and sleep knowledge. These results indicate the value of evidence-based digital sleep interventions for addressing sleep problems in this population.

Subjective Sleep Quality and Insomnia Severity

Our results are consistent with those of previous studies demonstrating that digital sleep interventions [28,31]effectively alleviate sleep disturbances. Reviews have reported moderate-to-large effect sizes for improvements in subjective sleep quality and reductions in insomnia severity. These results are particularly relevant given the high prevalence of poor sleep quality and insomnia among college students and young adults [55,56]. Digital interventions offer accessible and scalable solutions for managing sleep problems. The present review noted that the beneficial effects of digital sleep interventions on subjective sleep quality were sustained for 3 to 6 weeks postintervention, whereas improvements in insomnia severity persisted for up to 1 to 6 months. These findings highlight the potential of digital sleep interventions as a sustainable and effective treatment option for this demographic.

Objective Sleep Parameters

Digital sleep interventions significantly improved SE but demonstrated limited effects on other objective sleep parameters. These findings are in line with those

reported by Maurer et al. (2024) who examined the impact of digital CBT-i on objective sleep parameters in individuals with insomnia disorder [57]. The observed improvements in SE suggest that digital interventions can meaningfully enhance the proportion of time spent asleep while in bed. However, no significant effects were found for other objective measures, such as NWAK, TST, and WASO. This lack of consistency may be attributable to the variability in the methods used to measure objective sleep parameters across studies, which could have affected the outcomes [58]. Future research should prioritize standardizing objective sleep measures to improve consistency and reliability.

Dysfunctional Beliefs and Attitudes about Sleep

Digital interventions effectively reduced DBAS, consistent with findings reported by Thakral et al. (2020) who indicated the effectiveness of CBT-i in helping individuals develop healthier sleep-related beliefs and attitudes [59]. However, this result contrasts with that reported by Linardon et al. (2024), whose meta-analysis found that smartphone app-based interventions for insomnia and sleep disturbances did not effectively reduce DBAS [60]. A potential explanation for this discrepancy is that the intervention in Linardon et al. did not specifically address participants' individual sleep-related beliefs and attitudes, which may have reduced the persuasiveness and impact of the CBT-i components. Our findings highlight the critical role of CBT-i as a core element in digital sleep interventions, given its demonstrated effectiveness in improving DBAS outcomes [61-63].

Sleep Hygiene and Sleep Knowledge

Although the improvements in sleep hygiene and sleep knowledge were smaller than those for other outcomes, they remain significant. Consistent with findings

reported by Bauducco et al. (2020) and Inhulsen et al. (2022), Chehri et al. (2023) demonstrated that sleep hygiene practices are closely linked to sleep quality [64-66]. Promoting better sleep hygiene and increasing awareness of healthy sleep habits are essential strategies for addressing sleep problems. Sleep-related education that promotes knowledge and encourages behavioral changes is particularly effective at addressing sleep problems [67]. Such initiatives are especially valuable for raising awareness and establishing healthier sleep routines among college students and young adults (aged 18-25 years).

Pre Sleep Arousal

The effect sizes for PSAS scores related to pre sleep arousal in both cognitive and somatic domains were nonsignificant, likely because the number of eligible RCTs was limited. Pre sleep arousal is a known predisposing factor for insomnia, with high levels in either domain commonly observed in individuals with sleep disorders, which considerably interferes with the ability to fall asleep [68-69]. Future interventions should incorporate additional components such as mindfulness or relaxation techniques to more effectively address this aspect of sleep disruption.

Moderator

Moderator (subgroup) analyses revealed that digital CBT-i had greater effects on improving sleep quality than did other digital sleep interventions, and therapist-guided interventions outperformed unguided ones. These findings suggest that therapist-guided digital CBT-i is a particularly effective approach to managing sleep problems [28]. Unlike the review by Hasan et al. (2022), which focused on general populations, we incorporated both subjective and objective sleep data and specifically targeted college students and young adults. This focused approach provided deeper insights

into the effectiveness of therapist-guided digital CBT-i in improving sleep outcomes for this population.

Strengths and Limitations

To the best of our knowledge, this study is the first to comprehensively investigate the effects of various digital sleep interventions on sleep parameters among college students and young adults. By examining multiple sleep-related outcomes, we provided a holistic understanding of how digital interventions affect different aspects of sleep. However, several limitations of this study should be acknowledged. First, significant heterogeneity was observed across the studies due to variations in intervention regimens and outcome measures, which likely contributed to the inconsistencies in the results. Second, the inclusion of studies with a high risk of bias may have reduced the overall quality of evidence and affected the validity of the findings. However, sensitivity analyses in which high-risk studies were excluded revealed no significant changes in the outcomes, reinforcing the reliability of the results. Third, most studies relied heavily on self-reported measures, which are prone to biases, and objective assessments were underutilized. Finally, the lack of long-term follow-up data in many of the studies limits our ability to provide insights into the sustained impact of these interventions over time.

Relevance for Implementation

We obtained robust evidence indicating that digital sleep interventions are an effective approach to addressing a variety of sleep problems among college students and young adults. These interventions offer a convenient and accessible method for managing sleep disturbances, serving as a low-intensity, cost-effective alternative for

individuals who cannot or prefer not to access traditional sleep treatments. By helping users develop effective sleep-related skills, digital interventions can significantly improve sleep outcomes in this population. However, further research is required to enhance their effectiveness. Personalized digital tools that tailor interventions to individuals' specific sleep patterns and behaviors should be explored. In addition, incorporating both subjective and objective measures can provide a more comprehensive understanding of the interventions' impact. Longer follow-up periods are also required to enable assessment of the durability of intervention effects, ensuring these tools optimize their potential to improve sleep outcomes for college students and young adults.

Conclusion

This review provides up-to-date evidence on the effectiveness of digital sleep interventions in improving various sleep-related outcomes among college students and young adults. According to the GRADE assessment, the certainty of evidence ranged from moderate to low. We conclude that digital sleep interventions can improve overall perceived sleep quality and insomnia severity in both postintervention and follow-up assessments. They may also have a slight impact on DBAS, sleep hygiene, and sleep knowledge in postintervention assessments. However, the evidence remains highly uncertain regarding their effects on objective sleep parameters and somewhat uncertain concerning their impact on pre-sleep arousal in both cognitive and somatic domains.

Acknowledgments

None.

Data Availability

All raw data required to produce the aforementioned findings are available upon request.

Authors' Contributions

Yi-An Lu contributed to writing-original draft, visualization, methodology, software, formal analysis, data curation, conceptualization. Hui-Chen Lin contributed to writing-review and editing, validation, software, data curation. Pei-Shan Tsai contributed to writing-review and editing, validation, supervision, conceptualization. All the authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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Abbreviations

CBT-i: cognitive behavioral therapy for insomnia

CIs: confidence intervals

DBAS: dysfunctional beliefs and attitudes about sleep

GRADE: grading of recommendations, assessment, development, and evaluations

ISI: insomnia severity index

NWAK: number of awakenings

PSAS: pre sleep arousal scale

PRISMA: preferred reporting items for systematic reviews and meta-analyses

PROMIS: patient reported outcomes measurement information system

PSQI: pittsburgh sleep quality index

RCTs: randomized controlled trials

RoB: risk of bias

SCI: sleep condition indicator

SE: sleep efficiency

TST: total sleep time

WASO: wake after sleep onset

Supplementary Files

Multimedia Appendixes

Table S1. Search strategy Table S2. Detailed description of digital sleep interventions based on the TiDIER checklist Table S3. Forest plot of subgroups for subjective and objective sleep quality Table S4. Summary of GRADE assessment for certainty of evidence Table S5. Summary of moderator analysis (subgroup analysis) Table S6. Summary of moderator analysis (meta-regression) Table S7. Sensitivity analyses for outcomes of interest.
URL: http://asset.jmir.pub/assets/ea125406e3cd7d1a020d18f75d9b309b.docx

CONSORT (or other) checklists

PRISMA 2020 Checklist.
URL: http://asset.jmir.pub/assets/967dbdc7aa4f25c13a353cdba6cea20b.pdf