Effectiveness of digitally delivered sleep interventions on sleep and mental health outcomes in post-secondary students: Preliminary findings of a systematic review

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Abstract

Introduction/Background: Sleep problems, including disrupted sleep, are increasingly recognized as a risk factor for many mental health problems. Students pursuing post-secondary education are a population at risk for both significant sleep problems and poor mental health outcomes such as depression and anxiety. Interventions such as sleep hygiene education and cognitive behavioural therapy (CBT) are commonly used treatments for sleep problems and have been effective in improving sleep and mental health in the university student population. Digitally-delivered CBT has also shown to be effective in improving sleep in youth, however it has not been evaluated in the post-secondary student population. In an effort to address the growing sleep challenges faced by students, some institutions have moved to providing care through a digital platform. However, the effectiveness of delivering sleep interventions digitally to post-secondary students to improve sleep and mental health outcomes is unknown.

Objectives: We aimed to systematically search, critically appraise and synthesize the quantitative and qualitative evidence on the effectiveness and user experiences of digitally delivered sleep interventions to improve sleep and mental health outcomes in post-secondary students. Our specific questions are: 1) What is the effectiveness of sleep interventions delivered digitally for improving sleep and mental health outcomes in post-secondary students? 2) What are the students’ experiences, views, expectations and beliefs of sleep interventions delivered digitally? 3) What can be hypothesized from the integration of the quantitative and qualitative evidence about the effectiveness of sleep interventions delivered digitally to post-secondary students?

Method and analysis: We searched MEDLINE, CINAHL, Embase, and APA PsycInfo for peer-reviewed empirical studies published from 2000. We will include randomized controlled studies (RCTs), cohort studies, case-control studies, qualitative studies, and mixed methods studies. We will assess risk of bias using appropriate critical appraisal tools and extract data about study and participant characteristics, interventions, context and setting, sleep and mental health outcomes, themes and methodological quality assessment. We will use a sequential approach at the review level to synthesize and integrate the different types of data: a thematic synthesis of findings from the qualitative studies will be performed to develop evidence statements. These findings will be triangulated with the findings of the quantitative synthesis to understand the fit between the end-user perspective (e.g., student, provider) of interventions delivered digitally and the appropriateness of the tested interventions to address those perspectives.

Ethics and Knowledge Dissemination: Ethical approval is not required for this knowledge synthesis. Findings will be disseminated through knowledge translation activities including: 1) presentations at national and international conferences and scientific meetings; 2) presentations to provincial and national stakeholders; 3) publications in peer-reviewed journals; and 4) dissemination through posts on organizational websites.

Conclusion: Our review provides knowledge users (post-secondary students, healthcare providers and managers, administrators, mental health advocacy groups, and researchers) with the best and most up-to-date available evidence regarding effective sleep interventions delivered digitally. Moreover, as the COVID-19 situation evolves, this synthesis allows us to be proactive in adapting methods to deliver sleep-related mental health services. Our study addresses an important existing gap, since no systematic reviews located to date have examined the effectiveness and appropriateness of sleep interventions delivered digitally in post-secondary students. Furthermore,
our review is the first to combine quantitative and qualitative evidence to better understand not only “what works” for this population, but also “how” and “why” it works.

OSF (Open Science Framework): https://osf.io/td3pc

Key words: systematic review, sleep, post-secondary student, interventions, mental health

Introduction
Healthy sleep is a critical component for overall health and wellbeing and has been deemed an important behaviour to improve public health\(^1\). Healthy sleep is comprised of many dimensions including sleep timing, adequate sleep duration and good sleep quality. Seven to 9 hours of sleep per night is recommended for young adults\(^2\), yet a considerably large proportion of the population does not meet these guidelines, sleeping either less than seven or more than nine hours per night\(^3\). Sleep problems, including disrupted sleep, are increasingly recognized as a risk factor for many mental health problems\(^4,5\). There is growing recognition and concern that students pursuing postsecondary education are a population group at risk for both significant sleep problems and mental health conditions\(^6,7\) including suicidal ideation, depression, and anxiety\(^8\). Many university students have poor sleep (i.e., insomnia symptoms of difficulty initiating or maintaining sleep, early morning awakening, or non-restorative sleep at any given time), and sleep disturbances\(^14\) with about 60% who report suffering from poor sleep quality\(^15\). The unhealthy sleep reported in university students is associated with substantial distress and psychiatric morbidity\(^16,17\). Students reporting chronic insomnia, report significantly more fatigue, depression, anxiety, stress and stimulant use than students without insomnia\(^18\). Furthermore, those with poor sleep quality also reported delayed bed- and risetimes during the weekend, more anger, confusion, depression, fatigue and tension, more physical illness, daytime sleepiness as well as more drug and alcohol consumption compared to good quality sleepers\(^15\). Furthermore, the dimension of circadian typology of circadian preference has also been associated with psychological symptoms such as depression and anxiety within the postsecondary population\(^19\).

Non-pharmacological interventions such as sleep hygiene education and cognitive behavioural therapy (CBT) are common first line treatment options for sleep problems\(^20,21\). CBT is effective and has been demonstrated to be superior to any single component treatment such as stimulus control, relaxation training, and educational programs in the general population\(^20\), the university student population\(^22\), and in adults without sleep disorders\(^23\). CBT for insomnia (CBT-I) has been established as an effective treatment for primary insomnia in adults when delivered in person\(^24,25\), over the telephone\(^26\), as a self-help intervention mailed weekly to participants\(^27\), or internet-delivered\(^28\). Furthermore, digitally-delivered CBT has also been shown to be effective in improving sleep in youth\(^29\). However, this has not been adequately evaluated in the postsecondary population; although a feasibility study reports CBT delivered by e-mail to college students may improve sleep and reduce depressive symptoms\(^30\). Digital mental health interventions delivered to college students have demonstrated moderate effectiveness in improving depression, anxiety, and psychological well-being, and usability and acceptability outcomes were generally favorable\(^31\). Digital sleep intervention delivery, such as those delivered via mobile- and Web-based platforms, may be an attractive feature and a good fit with the culture of the postsecondary student population. Such interventions may widen the accessibility and circumvent many existing barriers to receiving traditional services.

Given the current global pandemic of COVID-19, post-secondary students may face additional challenges with their sleep and mental health\(^32,33\). As a result of the physical distancing
measures put in place and closures of many industries leading to significant disruptions in their academic endeavours, pre-existing sleep problems are exacerbated, which in turn amplifies mental health outcomes such as anxiety and depressive symptomatology. Symptoms of anxiety, depression and stress have increased during this pandemic and are associated with sleep problems34. Furthermore, in-person mental health resources provided by post-secondary institutions to students have closed. In an effort to address this gap, some institutions have moved to providing care through a virtual platform, or tele-health services. However, the effectiveness of delivering sleep interventions virtually to the post-secondary population is unknown. Also, we lack knowledge about the end user’s (i.e., student, provider) experience, perspectives, attitudes and beliefs of sleep interventions being delivered virtually or digitally. Given this paucity of information – especially in a climate that may be forced to embrace virtual care options for service delivery in perpetuity as we slowly enter a ‘new normal’, we propose a systematic review of the literature to synthesize the best available evidence on the effectiveness of non-pharmacological sleep interventions delivered through a technology-based platform. While we will examine interventions that target sleep specifically, we know that healthy sleep is critical for overall mental health and is also a symptom of many mental illnesses. Therefore, we will also report on mental health outcomes if reported.

**Objectives**

We aimed to systematically search, critically appraise and synthesize the quantitative and qualitative evidence on the effectiveness and user experiences of digitally delivered sleep interventions to improve sleep and mental health outcomes in post-secondary students. Our specific questions are:

1) What is the effectiveness of sleep interventions delivered digitally for improving sleep and mental health outcomes in post-secondary students?

2) What are the students’ and/or providers’ experiences, views, expectations and beliefs of sleep interventions delivered digitally?

3) What can be hypothesized from the integration of the quantitative and qualitative evidence about the effectiveness of sleep interventions delivered digitally to post-secondary students?

Knowledge gained from this study will inform university policy makers and mental health providers in delivering and planning interventions virtually. Given the rapid nature of the review, we report on preliminary findings from our search in one database (MEDLINE) and only report on the effectiveness of the intervention (research question #1).

**Methods**

We registered our systematic review with OSF (Open Science Framework; Registration available publicly at: [https://osf.io/td3pc](https://osf.io/td3pc)). We conducted and reported our systematic review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines35.

**Eligibility Criteria**

**Population**

We targeted studies including postsecondary students at any age. The term ‘postsecondary’ may refer to college, university, professional programs, technical schools (e.g., apprenticeship or trades
All studies were included regardless of whether the study investigated students with healthy sleep, sleep disturbance or impaired sleep, or disordered sleep (with the exception of breathing-related sleep disorders). We did not include age range limitations, as age of entry may vary between countries or programs.

**Intervention**
The quantitative component of this review (partially reported here) included studies that investigated the effectiveness of non-pharmacological interventions aimed at improving sleep outcomes in the postsecondary population including but not limited to: i) sleep education (e.g., sleep hygiene education or psychoeducation); ii) cognitive-behavioural therapy (CBT) or elements of CBT (e.g., stimulus control; sleep restriction); iii) relaxation and mindfulness (e.g., music therapy, progressive muscle relaxation); iv) multi-modal interventions (e.g., sleep education and relaxation techniques). To be included, sleep interventions had to be digitally delivered. Digitally delivered interventions are defined as those that use digital technology to support behavior change. We included digital interventions that were delivered in a synchronous or asynchronous manner. Synchronous digital interventions involve a two-way flow of information and require real-time interaction between the patient and provider (e.g. videoconferencing, live chat, voice call). An asynchronous digital intervention involves a one-way flow of information and does not require real-time interaction between the patient and provider (e.g. email, mobile messaging, smart device applications, web-based platforms). Some behavioral interventions may have targeted multiple behaviors such as sleep, physical activity, and diet. In those instances, only the information relevant to a digitally delivered sleep intervention was included. The interventions were not restricted to a specific dose, frequency, intensity, duration or trainer qualification, but were recorded.

**Comparison Groups**
Studies comparing a sleep intervention to other non-pharmacological or pharmacological interventions, placebo or sham interventions, wait list, or no intervention were considered.

**Outcomes**
The quantitative component of this review includes studies that evaluated at least one sleep outcome (e.g., sleep knowledge, sleep habits, sleep hygiene, sleep duration, sleep onset latency, sleep quality, sleep efficiency). Sleep outcomes collected through self-report measures (e.g., Pittsburgh Sleep Quality Index, Insomnia Severity Index), or through objective measures (e.g., actigraphy) were included. Given that sleep and mental health are strongly associated, we also collected mental health outcomes if reported (e.g., depressive symptomatology, anxiety, stress).

**Study Design**
For the quantitative component of this systematic review, we included randomized controlled studies (minimum 30 participants per arm at baseline), cohort studies and case-control studies (minimum 100 participants per exposed group). Qualitative studies exploring user experiences of sleep interventions delivered virtually (e.g., phenomenology, grounded theory, ethnography, action research and descriptive qualitative studies) were not identified for this knowledge synthesis, but will be reported in subsequent updates. Mixed methods studies will only be considered if data from the quantitative or qualitative components could be clearly extracted, and we will report our findings in subsequent updates.
Exclusion Criteria
We excluded studies of participants with breathing-related sleep disorders (e.g., obstructive sleep apnea [OSA]) given that such disorders cannot be treated solely with non-pharmacological psychological interventions. Studies that do not investigate the effect of a specific intervention but focused on correlations or incidence/prevalence rates were also excluded. Study designs such as pilot studies assessing feasibility, protocol studies, cross-sectional studies, case report, case series, systematic reviews and other review papers, clinical practice guidelines, cadaveric or animal studies and conceptual papers were excluded. Finally, publication types including letters, editorials, commentaries, unpublished manuscripts, dissertations, government reports, books and book chapters, conference proceedings, meeting abstracts, lectures and addresses, consensus development statements and guideline statements were also excluded.

Search Strategy
We developed the search strategy in collaboration with a health sciences librarian. A second librarian reviewed the search strategy using the Peer Review Electronic Search Strategy (PRESS) checklist. We conducted an electronic search of the following databases from 2000 to present: MEDLINE (Ovid), Embase (Ovid), PsycINFO (Ovid), and CINAHL (Cumulative Index to Nursing and Allied Health Literature, EBSCOhost). The results presented in this synthesis are from MEDLINE only. We will continue to update our findings in subsequent reports. We will also search the reference lists of all eligible articles for additional relevant studies. We did not limit studies by language. The searches will include a combination of subject headings specific to databases (e.g., MeSH in MEDLINE) and free text words to capture interventions directed at sleep.

Study Records
Data Management
Electronic search results were downloaded into Endnote X9 reference manager software (Clarivate Analytics, Philadelphia, Pennsylvania, USA). We removed duplicates and the remaining references were uploaded to the Evidence for Policy and Practice Information (EPPI) and Coordinating Centre Reviewer software for the data extraction stages (EPPI-Reviewer V.4, UCL Institute of Education, University of London, UK). EPPI-Reviewer software store references, manages and monitors the data extraction process and provides an audit trail for the review.

Selection Process
Pairs of trained, independent reviewers screened articles in two phases to determine eligibility. In phase I, paired reviewers screened titles and abstracts to determine possibly relevant and irrelevant citations based on the inclusion and exclusion criteria. In phase II, paired reviewers screened possibly relevant citations from phase I using the full-text article to determine eligibility. Any disagreements were resolved by discussion between the paired reviewers to reach consensus. If consensus could not be reached, a third reviewer independently appraised the article and discussed it with the other two reviewers to reach consensus. We conducted training exercises prior to initiating the screening process to ensure high inter-rater reliability. Review members met often to discuss progress and any unanticipated problems.

Quality Assessment
Pairs of trained, independent reviewers critically appraised all relevant studies using the Scottish Intercollegiate Guidelines Network (SIGN) criteria for randomized controlled trials and cohort studies\textsuperscript{39}. The SIGN criteria were used to determine the studies’ internal validity (i.e., to evaluate the presence and impact of selection bias, information bias, and confounding on study results). If necessary, study authors were contacted for additional information needed to complete the critical appraisal. Reviewers reached consensus through discussion. An independent third reviewer was used to resolve disagreements if consensus could not be reached. Studies with adequate internal validity (i.e., low risk of bias) were included in our best evidence synthesis. We will develop a risk of bias table indicating the areas of bias for all relevant studies.

Data extraction and synthesis of results
The quantitative synthesis from the first database (MEDLINE) to be searched is reported here. One reviewer extracted data from the low risk of bias studies into EPPI-Reviewer, which was used to build an evidence table. A second reviewer reviewed the data to ensure accuracy. We used the Synthesis without Meta-Analysis (SWiM) guidelines to report our findings.

Results
For our preliminary synthesis, we searched MEDLINE from 2000 to June 10, 2020 and screened 2011 records. Of these, nine studies reported in eight publications\textsuperscript{40-47} were critically appraised and two had a low risk of bias and were included in our preliminary synthesis (Figure 1)\textsuperscript{40,41}. We have since contacted the authors of three high risk of bias RCT’s\textsuperscript{42-44} for clarification and two\textsuperscript{43,44} responded, resulting in one additional RCT\textsuperscript{44} being rated as low risk of bias. Our synthesis has been updated to include all three low risk of bias studies. Following our initial synthesis, we searched the remaining databases (Embase, PsychINFO, and CINAHL) and updated our MEDLINE search from 2000 to July 3, 2020. To date, we have screened 3373 additional titles and abstracts; 24 articles were deemed possibly relevant and are currently being screened in full text.

Study Characteristics of included studies
The included studies used an RCT design or cohort study design. Admissible studies (n=3) used the RCT design and were conducted in Australia (AUS)\textsuperscript{44}, the United Kingdom (UK)\textsuperscript{40} and the United States (US)\textsuperscript{41}. Hershner et al. (2018) assessed the effect of a sleep education website (Sleep to Stay Awake) on sleep knowledge and behaviours. Freeman et al. (2017) assessed the effect of Cognitive Behavioral Therapy for Insomnia (CBT-I) on insomnia mental health outcomes. Finally, Mairs et al. (2015) looked at the impact of an online exercise in implementation intentions on sleep behaviours, sleep quality and insomnia symptoms (Table 1).

Risk of bias
Full details of our risk of bias assessment for all studies are outlined in Tables 2 and 3.

We identified three RCTs with a low risk of bias reporting on the effectiveness of web-based interventions to improve sleep in post-secondary students. These studies reported on participant selection, had clearly defined eligibility criteria, described their randomization methods, had adequate allocation concealment, had baseline comparability, blinding where possible, adequately described the treatment protocol for the experimental and control groups, and used Intention-to-treat analysis (ITT). Two studies reported high drop-outs in one\textsuperscript{44} or both\textsuperscript{41} groups; however it was
determined that the impact of drop-outs would not be significant enough to decrease overall confidence in the study findings.

Five RCTs had a high risk of bias with the following limitations: 1) were unclear about randomization procedures used; 2) did not report on allocation concealment methods or did not appear to conceal allocation; 3) did not report on comparability of groups at baseline; 4) did not use valid and/or reliable methods of outcome assessment; 5) did not report on proportions of those lost to follow-up within each group or reported a high drop-out that was different between groups; and 6) did not use an ITT analysis.

One cohort study had a high risk of bias with the following sources of bias: 1) selection bias (lack of similarity between groups at baseline; 2) attrition bias (high drop out without a comparison between full participants and those lost to follow-up by exposure status); 3) detection bias (validity and reliability of outcome assessment); and 4) confounding (no consideration for confounding factors).

We contacted the authors of three RCTs for additional information required to assess risk of bias. Two authors responded, resulting in the overall risk of bias determination to change for one RCT from high risk to low risk.

**Synthesis of Evidence**

Three low risk of bias studies reported on the effectiveness of a digitally delivered sleep intervention to improve sleep knowledge or sleep hygiene behaviors, to reduce sleep difficulties or to improve mental health outcomes (Table 3).

**Web-based Sleep Education**

Hershner et al. (2018) assessed the effectiveness of a sleep education website (Sleep to Stay Awake) on the sleep knowledge and behaviors of US post-secondary students. The online sleep education module had several components including a sleep personality profile (composite score of two questionnaires: Epworth Sleepiness Scale [ESS] and the Morningness-Eveningness Questionnaire [MEQ]), two videos (i.e., aspects of sleep hygiene and the effect of sleep deprivation on memory, learning, and driving) and information on healthy sleep behaviours (including information on studying, daytime alertness, naps etc.). Students (mean age 21.9 ± 4.1 years), were randomized to a control (n=295) or intervention group (n=254). At 8 weeks, a greater percentage of those in the intervention group (n=74; 50.3%) reported changes in their sleep and wake behaviours compared to the control group (n=77; 39.5%) (odds ratio [OR] 1.50, 95% CI 1.00-2.30) such as stopping electronics earlier, keeping a more regular sleep schedule, and waking earlier during the week.

Sensitivity analysis performed on intervention subjects who reported utilization of the intervention at 8 weeks supported that the sleep education intervention increased the likelihood that subjects made positive changes to their sleep and wake behaviours. Compared to participants who did not use the intervention, those who positively affirmed using the intervention were more likely to report behaviour change (OR 1.7, 1.00-2.70) stopping the use of electronics (OR 3.3, 2.00-5.30) and having a more regular sleep schedule (OR 3.4, 2.10-5.50). Improvements were found in the intervention group for sleep knowledge (measured by a questionnaire developed by the researchers) (mean difference 0.88, 0.31-1.55), sleep quality (measured with the Pittsburgh
Sleep Quality Index [PSQI]) (mean difference -1.09, -1.65 to -0.51), and depression scores (measured by the Patient Health Questionnaire [PHQ9]) (mean difference -1.60, -2.67 to -0.29)).

**Digital Cognitive Behavioral Therapy**
Freeman et al. (2017) assessed whether reducing insomnia (using CBT for insomnia [CBT-I]) would also improve mental health outcomes in UK college students. The digital CBT-I intervention included behavioural techniques such as sleep restriction, stimulus control, and relaxation; cognitive techniques including paradoxical intention, belief restructuring, mindfulness and imagery; and educational components covering information about the processes of sleep and sleep hygiene. A total of 26 universities participated. Participants (n=3755) were randomized to usual practice (n=1864, mean age 24.6, SD 7.6) or digital CBT-I (n=1891, mean age 24.8, SD 7.7). CBT-I was associated with significant reductions at all timepoints (Week 3, 10, and 22) in insomnia, paranoia, and hallucinations compared with the control group (Table 3). Change in sleep over 3 weeks explained 30% of the intervention effect on paranoia and 21% on hallucinations at 10 weeks, with change in sleep over 10 weeks accounting for 58% of the treatment effect on paranoia and 39% of the intervention effect on hallucinations. Furthermore, CBT-I also led to improvements in depression (as measured by PHQ9) (mean difference -2.83, -3.30 to -2.35) and anxiety (as measured by General Anxiety Disorder [GAD7]) (-1.86, -2.29 to -1.43) and were maintained over time (Week 22).

**Online Implementation Intentions**
Mairs and Mullen (2015) looked at the impact of an online implementation intentions exercise on sleep hygiene behaviours, sleep quality and insomnia symptoms in a group of Australian university students (n=104; mean age 20.7, SD 5.8, range 17-49). Implementation intentions is a behaviour change technique often provided as part of CBT in which individuals plan ahead for an action they will take to help them reach their goals. In this study, all students were encouraged to improve four areas of sleep hygiene: making the sleep environment restful, avoiding going to bed hungry or thirsty, avoiding stress and anxiety-provoking activities before bed, and avoiding caffeine within eight hours of bedtime. Participants were then randomly assigned into one of two groups: the implementation intentions group (n=51) were guided through an online exercise in which they created two implementation intention statements for each of the four target sleep hygiene behaviours; the active control group (n=53) was asked to self-monitor their progress on sleep hygiene behaviours with a daily online sleep diary. Two weeks post-intervention, there were no statistically or clinically significant differences in sleep hygiene behaviours (as assessed by number of days in the past two weeks that the participants practiced each of the four target sleep hygiene behaviours) between the two groups (Table 3). There were also no statistically or clinically significant differences between the two groups with respect to sleep quality (as measured by the PSQI) or insomnia symptom severity (as measured by the Insomnia Severity Index [ISI]). This study did not explore the impact of these interventions on mental health outcomes.

**Discussion**
This is the first systematic review to evaluate the effectiveness of digitally delivered sleep interventions to improve sleep outcomes in a post-secondary student population. Only three studies had a low risk of bias and were included in this preliminary knowledge synthesis. Both online sleep education and digitally delivered CBT-I show promise in improving sleep and mental health outcomes in post-secondary students. Online delivery of a single component of CBT
implementation intentions) was no more effective than an online sleep diary for the adoption of healthy sleep behaviours or for improvements in sleep quality or symptoms of insomnia. Rather than provide information about a useful intervention for the treatment of sleep per se, the Mairs and Mullen (2015) study instead explores the use of tools to support behavior change itself – creating intentions or self-monitoring progress – and found that neither tool was superior. Furthermore, effect of self-monitoring may have been overestimated in this study as there was high attrition in this group. We hypothesize that this is attributable to the burden of completing a daily online diary. While not describing stand-alone treatments for sleep, this study offers information about adjunct treatments that may facilitate intervention programs. We are unable to generalize these results to a Canadian population, since none of the studies critically appraised were Canadian. We did not find studies that used synchronous or live one-on-one sleep intervention delivery. However, the results presented in this synthesis are from MEDLINE only. We will continue to update our findings in subsequent reports.

**Conclusion**
This study is preliminary as the search was only completed in one database (MEDLINE). Three high quality RCTs indicated that web-based sleep education and digital cognitive behavioural therapy for insomnia were effective at improving sleep and mental health outcomes in post-secondary students.
References

19. Papaconstantinou EA, Shearer H, Fynn-Sackey N, Smith K, Taylor-Vaisey A, Côté P. The Association Between Chronotype and Mental Health Problems in a University...


42. Barber LK, Cucalon MS. Modifying the Sleep Treatment Education Program for Students to include technology use (STEPS-TECH): Intervention effects on objective and subjective sleep outcomes. *Stress Health.* 2017;33(5):684-690.


Figure 1: PRISMA Diagram

Citations identified through search (n=5619)

Duplicates removed (n=258)

Citations screened using titles and abstracts (n=5361)

Ineligible citations (n=5305)

Citations screened for eligibility using full-text (n=56)**

Full-text articles excluded: 24**

Primary reasons for exclusion*:
- Not available in English = 1
- Ineligible publication type = 2
- Not a post-secondary population = 1
- Not a sleep intervention = 8
- No comparison group = 1
- Not delivered digitally = 14
- Sample size = 4

Relevant Publications (n=8)

Critically Appraised Studies (n=9) ***

8 RCT’s
1 Cohort

High Risk of Bias (n=6)

5 RCT’s
1 Cohort

Low Risk of Bias (n=3)

*Categories not exclusive
**24 full text articles still in screening phase
***One study reported on 2 RCTs
<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparison</th>
<th>Outcomes</th>
<th>Key Results</th>
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<tbody>
<tr>
<td>Freeman (2017)</td>
<td>University students from UK with insomnia</td>
<td>Web-based CBT-I (Sleepio): 6 interactive online sessions (20 min each) delivered by an animated therapist and personalized using algorithms driven by initial assessment and daily sleep diaries; <em>behavioural</em> (e.g., sleep restriction, stimulus control, and relaxation); <em>cognitive</em> (paradoxical intention, belief restructuring, mindfulness, imagery, and putting the day to rest); and <em>educational</em> (e.g., information about the processes of sleep and sleep hygiene) components. Participants had access to moderated online community and online library of sleep information. (n=3755)</td>
<td>Treatment as usual: current care that participants were receiving. (n=1864)</td>
<td>3 weeks (primary outcome only), 10 weeks (end of therapy), 22 weeks post-randomization</td>
<td>3 weeks: adjusted mean difference, (95% CI)</td>
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<td>Primary Outcomes:</td>
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<td>Insomnia — Sleep Condition Indicator (SCI-8); range 0-32; higher scores indicate better sleep; score of less than 17 identifies probable insomnia disorder</td>
<td>Insomnia (SCI-8): 2.62, (2.19, 3.06) [favoring intervention]</td>
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<td>Paranoia — Green et al Paranoid Thought Scales (GPTS), part B; 16-items each rated on a scale of 1 (not at all) to 5 (totally); high scores indicate higher levels of paranoia</td>
<td>Paranoia (GPTS): -1.81, (-2.49, -1.13) [favoring intervention]</td>
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<td>Hallucinations — Specific Psychotic Experiences Questionnaire (SPEQ) - Hallucinations subscale; 9-items - rated on a scale of 0 (not at all) to 5 (more than once per day); higher scores indicate greater occurrences of hallucinatory experiences</td>
<td>Hallucinations (SPEQ): -0.79, (-1.15, -0.42) [favoring intervention]</td>
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<td>Secondary Outcomes:</td>
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<td>Insomnia (SCI-8): 4.78, (4.29, 5.26) [favoring intervention]</td>
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<td>Paranoia (GPTS): -2.22, (-2.98, -1.45) [favoring intervention]</td>
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<td>Hallucinations (SPEQ): -1.58, (-1.98, -1.18) [favoring intervention]</td>
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<td>Hersher (2018) RCT</td>
<td>University students from the University of Michigan (US) broadly representative of the student population from freshman to professional students (medicine, dentistry, PhD) and included students living on and off campus.</td>
<td>Sleep to Stay Awake - online sleep education module (20 min duration): sleep personality profile (Epworth Sleepiness Scale, the Morning-Eveningness Questionnaire), two videos (sleep hygiene; effect of sleep deprivation on memory, learning, and driving), information</td>
<td>No education (n=295)</td>
<td>Sleep – Insomnia Severity Index (ISI); Disturbing Dreams; and Nightmare Severity</td>
<td>22 weeks: adjusted mean difference (95% CI)</td>
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<td>Psychotic Experiences – Prodromal Questionnaire</td>
<td>Insomnia (SCI-8): 4.81, (4.29, 5.33) [favouring intervention]</td>
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<td>Affective Symptoms – Patient Health Questionnaire (PHQ-9); Generalized Anxiety Disorder (GAD-7); Altman Mania Scale.</td>
<td>Paranoia (GPTS): -2.78, (-3.60, -1.96) [favouring intervention]</td>
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<td>Psychological wellbeing – Warwick–Edinburgh Mental Wellbeing Scale (WEMWBS); Work and Social Adjustment Scale (WSAS)</td>
<td>Hallucinations (SPEQ): -1.56, (-1.99, -1.14)</td>
</tr>
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<td>Serious Adverse Events – Defined as deaths, suicide attempts, serious violent incidents, admissions to secure units, formal complaints about the online intervention</td>
<td>8 weeks: mean difference, (95% CI)</td>
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<tr>
<td></td>
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<td></td>
<td>1 week and 8 weeks post intervention</td>
<td>Sleep Quality – Pittsburgh Sleep Quality Index (PSQI): score of 5 or higher indicates poor sleep quality.</td>
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<td></td>
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<td></td>
<td>Sleep Knowledge: 0.88, (0.31, 1.55). [favouring intervention]</td>
<td>Depression – Patient Health Questionnaire (PHQ-9): none (0-4), mild (5-9), moderate (10-14), moderately severe (15-19), and severe (20-27)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Sleep Quality (PSQI): -1.09, (-1.65,-0.51). [favoring intervention]</td>
<td>Depression (PHQ-9): -1.60, (-2.67, -0.29). [favoring intervention]</td>
</tr>
</tbody>
</table>
Inclusion criteria:
all students age 18 years and older
(n=549)
on healthy sleep behaviours; information on studying, daytime alertness, and naps linked to participant’s sleep personality profile.
(n=254)

Sleep Knowledge – 14 questions related to sleep hygiene, physiology of sleep, effect of technology on sleep, interaction of sleep on learning, memory, and grades

Sleep Hygiene – Sleep Hygiene Index (SHI): range of 13-65; higher score indicates worse sleep hygiene.

Sleepiness – Epworth Sleepiness Scale (ESS): score of 10 or higher indicates sleepiness.

Morningness-Eveningness – Morning-Eveningness Questionnaire (MEQ): circadian preference and score: definitely morning type (70-86), moderately morning type (59-69), neither type (42-58), moderately evening type (31-41), definitely evening type (16-30)

General Health – General Health Questionnaire (GHQ-12): likert scale, 12 items coded as 0, 1, 2, or 3 with a final summary answer.

*No primary outcome specified.

Sleep Hygiene (SHI): -2.10, (-3.34, -1.00). [favoring control]

Sleepiness (ESS): -0.55, (-1.51, 0.39). [favoring intervention]

General Health (GHQ-12): -0.34, (-1.00, 0.63). [favoring intervention]

*results were not reported for the 1-week follow-up
<p>| Mairs (2015) RCT | Australian university students (n=104) | Implementation Intentions (delivered online): Day 1: participants guided through process of formulating 2 implementation intentions for each of the 4 target sleep hygiene behaviours (making the sleep environment restful, avoiding going to bed hungry or thirsty, avoiding stress and anxiety-provoking activities before bed, avoiding caffeine within eight hours of bedtime) and framing each intention in the form &quot;If [insert situation], then I will [insert solution]&quot;; Day 2 and Day 8: participants emailed &quot;if-then&quot; statements, asked to confirm and edit as desired; Total time spent ~30 min. (n=51) | Online Sleep Diary—participants completed daily online sleep diary accessed via an email weblink sent on days 1 to 8; regular email reminders provided; diary items from the Pittsburgh sleep diary (bed, sleep and wake times, sleep disturbances/awakenings, overall subjective rating of sleep quality and mood and alertness upon waking); participants also asked whether they completed the 4 target sleep behaviours the previous day and to reflect upon their influence on waking during the night; identified strengths and areas for improvement in their sleep; reflected on sleep preparation and quality. (n=53) | 2 weeks | *Primary outcome not specified | Sleep hygiene behaviours - number of days during past 2 weeks that participants performed each of the 4 target sleep hygiene behaviours | Sleep quality - Pittsburgh Sleep Quality Index (PSQI); range 0-21; higher scores reflect poorer sleep quality; cut-off scores denote &quot;good&quot; (0-5) and &quot;poor&quot; sleepers (&gt;5) | Insomnia - Insomnia Severity Index (ISI); range 0-28; cut-offs denote no &quot;clinically significant insomnia&quot;, &quot;sub-threshold insomnia&quot;, &quot;moderate&quot; and &quot;severe clinical insomnia&quot; | No statistically significant differences between groups on any of the selected outcomes |</p>
<table>
<thead>
<tr>
<th></th>
<th>Implementation intentions</th>
<th>Daily diary</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviour - Caffeine</td>
<td>-</td>
<td></td>
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<tr>
<td>(number of evenings in</td>
<td>pre-intervention mean</td>
<td>pre-intervention mean</td>
<td></td>
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<tr>
<td>past 14 days)</td>
<td>(SD)</td>
<td>(SD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.49 (4.71); 11.05 (4.38)</td>
<td>8.98 (4.74); 9.47 (4.66)</td>
<td>0.928</td>
</tr>
<tr>
<td></td>
<td>Daily diary</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>9.72 (3.80); 9.34 (3.71)</td>
<td>9.47 (4.74); 9.47 (4.66)</td>
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</tr>
<tr>
<td></td>
<td>p value: 0.016</td>
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<tr>
<td></td>
<td>Sleep quality (PSQI)</td>
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<td></td>
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<tr>
<td></td>
<td>pre-intervention mean</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(SD)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>6.68 (2.92); 5.05 (2.45)</td>
<td>7.02 (3.19); 6.19 (2.77)</td>
<td>0.129</td>
</tr>
<tr>
<td></td>
<td>Daily diary</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.02 (3.19); 6.19 (2.77)</td>
<td>7.02 (3.19); 6.19 (2.77)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p value: 0.129</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Insomnia (ISI)</td>
<td></td>
<td></td>
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<td></td>
<td>pre-intervention mean</td>
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<tr>
<td></td>
<td>(SD)</td>
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<td></td>
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<tr>
<td></td>
<td>9.26 (4.56); 6.84 (4.91)</td>
<td>9.26 (4.56); 6.84 (4.91)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Daily diary</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Abbreviations: Cognitive Behavioural Therapy for Insomnia (CBT-I); Confidence Interval (CI); Epworth Sleepiness Scale (ESS); General Health Questionnaire (GHQ-12); Generalized Anxiety Disorder (GAD-7); Green et al. Paranoid Thought Scales (GPTS); Insomnia Severity Index (ISI); Morningness-Eveningness Questionnaire (MEQ); Patient Health Questionnaire (PHQ-9); Pittsburgh Sleep Quality Index (PSQI); Sleep Condition Indicator (SCI-8); Sleep Hygiene Index (SHI); Warwick Edinburgh Mental Wellbeing Scale (WEMWBS); Work and Social Adjustment Scale (WSAS)

<table>
<thead>
<tr>
<th>Daily diary</th>
<th>11.02 (5.07); 9.54 (4.95)</th>
</tr>
</thead>
<tbody>
<tr>
<td>p value</td>
<td>0.083</td>
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</tbody>
</table>
## TABLE 2

Risk of Bias – Randomized Controlled Trials

<table>
<thead>
<tr>
<th>Study</th>
<th>2.1 RQ</th>
<th>2.2 Randomization</th>
<th>2.3 Allocation Concealment</th>
<th>2.4-2.5 Blinding</th>
<th>2.6 Baseline Similarity</th>
<th>2.7 Differences Between Groups</th>
<th>2.8-2.9 Outcome Measures</th>
<th>2.10 Attrition</th>
<th>2.11 ITT</th>
<th>2.12 Site Comparison</th>
<th>3.1 Overall Risk of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeman (2017)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Similarity at baseline: Y</td>
<td>Outcomes are measured in a reliable way. Y</td>
<td>Y</td>
<td>3 weeks: Web-based CBT-I: 45% Control: 25%</td>
<td>Y</td>
<td>NA</td>
<td>Low</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Adjusted analysis: NA</td>
<td></td>
<td></td>
<td>10 weeks: Web-based CBT-I: 61% Control: 39%</td>
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<td></td>
<td></td>
<td>22 weeks: Web-based CBT-I: 68% Control: 48%</td>
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<tr>
<td>Hershner (2018)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Subjects NP Treatment provider Y Outcome assessor Y Bio-statistician CS</td>
<td>Similarity at baseline: Y</td>
<td>Outcomes are measured in a reliable way. Y</td>
<td>1 week: Online Education group: 43% Control: 31%</td>
<td>Y</td>
<td>NA</td>
<td>Some Concerns</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Adjusted analysis: NA</td>
<td></td>
<td></td>
<td>8 weeks: Online Education: 37% Control: 34%</td>
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</tr>
<tr>
<td>Study</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Subjects</td>
<td>Treatment provider</td>
<td>Outcome assessor</td>
<td>Bias statistician</td>
<td>Similarity at baseline</td>
<td>Adjusted analysis</td>
<td>Outcome assessment</td>
<td>Outcomes measured in a reliable way</td>
</tr>
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</tr>
<tr>
<td>Mairs (2015)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>NA</td>
<td>Y</td>
<td>NA</td>
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<tr>
<td>Barber (2017)</td>
<td>Y</td>
<td>CS</td>
<td>N</td>
<td>NP</td>
<td>NP</td>
<td>CS</td>
<td>CS</td>
<td>CS</td>
<td>CS</td>
<td>Y</td>
<td>CS</td>
</tr>
<tr>
<td>Gipson (2019)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>NP</td>
<td>CS</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>NA</td>
</tr>
<tr>
<td>Study</td>
<td>Subjects</td>
<td>Treatment Provider</td>
<td>Outcome Assessor</td>
<td>Bio-statistician</td>
<td>Similarity at Baseline</td>
<td>Adjusted Analysis</td>
<td>Outcomes are Measured in a Valid Way</td>
<td>Post-intervention</td>
<td>Duration</td>
<td>Results</td>
<td></td>
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<tr>
<td>Robbins (2017)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>No</td>
<td>CS</td>
<td>Cannot say</td>
<td>Y</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td>Outcomes are measured in a reliable way. CS</td>
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<td></td>
<td>Outcomes are measured in a valid way. CS</td>
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<td></td>
<td></td>
<td>CS Outcomes are measured in a valid way. Y</td>
<td></td>
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</tr>
</tbody>
</table>

| Valshtein (2020)    | Y        | Y                  | CS               | Yes              | CS                     | N                 | Y                                    |                   |          |         |
|                     |          |                    |                  |                  |                        |                   | Post-intervention: Positive-talk: 7% No-chat: 6% Natural chat: 28% Negative chat: 21% |                   |          |         |
|                     |          |                    |                  |                  |                        |                   | 3 weeks: MCII: 18% Positive Thinking: 21% |                   |          |         |
|                     |          |                    |                  |                  |                        |                   | NA                                   |                   |          |         |

<p>| Valshtein (2020)    | Y        | Y                  | N                | No               | CS                     | CS                | 1 week: MCII: 19% |                   |          |         |
|                     |          |                    |                  |                  |                        |                   | CS Outcomes are measured in a valid way. Y |                   |          |         |
|                     |          |                    |                  |                  |                        |                   | NA                                   |                   |          |         |</p>
<table>
<thead>
<tr>
<th>Study 2</th>
<th>Treatment provider</th>
<th>CS</th>
<th>Outcome assessor</th>
<th>CS</th>
<th>Bio-statistician</th>
<th>CS</th>
<th>Outcomes are measured in a valid way.</th>
<th>N</th>
<th>Sleep Hygiene: 20%</th>
</tr>
</thead>
</table>

BCT: Behaviour Change Technique (Implementation Intentions); CBT-I: Cognitive Behavioural Therapy for Insomnia; CS: Cannot Say; ITT: Intention-to-treat; MCII: Mental Contrasting with Implementation Intentions; N: No; NA: Not Applicable; NP: Not Possible; RQ: Research Question; Y: Yes
<table>
<thead>
<tr>
<th>Study</th>
<th>1.1 RQ</th>
<th>1.2 Similarity of Source Populations</th>
<th>1.3 Participation Rate</th>
<th>1.4 Outcome Status at Enrollment</th>
<th>1.5 Attrition</th>
<th>1.6 Dropout Comparison</th>
<th>1.7 Defined Outcome</th>
<th>1.8 Blinding</th>
<th>1.9 Recognition Where Blinding Not Possible</th>
<th>1.10 Reliability of Exposure Assessment</th>
<th>1.11 Validity/Reliability of Outcome Assessment</th>
<th>1.12 Multiple Exposure Assessments</th>
<th>1.13 Confounders</th>
<th>1.14 CI’s</th>
<th>Overall Risk of Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quan (2013)</td>
<td>Y</td>
<td>CS</td>
<td>Y</td>
<td>Y</td>
<td>CS</td>
<td>Y</td>
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<td>Y</td>
<td>CS</td>
<td>NA</td>
<td>CS</td>
<td>N</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

Sleep test:
SS: 78%
SI: 57%
Post-test:
SS: 19%
SI: 11%

CS: Cannot say; N: No; NA: Not Applicable; RQ: Research Question; SI: Standard instruction plus access to informational website; SS: Standard instruction plus access to a supplemental sleep module website; Y: Yes