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REVIEW ARTICLE

The role of behaviour-change theory in sleep interventions with emerging adults (aged 18–29 years): a systematic review and meta-analysis

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Summary

Previous systematic reviews and meta-analysis of sleep interventions with young adults have not reached consensus on what contributes to their efficacy. Behaviour-change theories may influence the efficacy of interventions; hence, the aim of this research was to investigate the role of such theories in sleep interventions with this population. Six electronic databases and reference lists were searched (April–May 2021) for published sleep behaviour-change interventions with emerging adults (aged 18–29 years) that used control groups. A selection of 20 studies fulfilled the inclusion criteria, but only six were based on behaviour-change theories. Meta-analysis was run with eight studies, as the others had a high risk of bias or did not present the necessary data to calculate Hedges' g. The estimation of a random effects model for the studies showed a small effect in the sleep quality of the participants in the experimental group ($g = -0.26$; 95% confidence interval −0.42 to −0.09), with low levels of heterogeneity ($I^2 = 21\%$), and a small 95% prediction interval (−0.59 to 0.08). Although we could not examine theory or any other moderators of the effect, a qualitative analysis of the behaviour-change techniques present in the interventions leads us to hypothesise that there is not a direct link between behaviour-change techniques and the success of the intervention. Other characteristics of the interventions may be linked to their variable levels of efficacy and should be investigated in the future, as for now there are no answers as to what the key is for successful sleep interventions.

KEYWORDS
behaviour modification, emerging adulthood, sleep health, sleep promotion, sleep quality

1 | INTRODUCTION

Emerging adults (aged 18–29 year) have been described as a group facing the challenges of entering adulthood, such as increasing responsibility for oneself and making autonomous decisions that may have specific implications on one's health (Arnett et al., 2014). The multiple roles and demands faced by people in this developmental phase (Aldwin, 2007), especially the ones that derive from going to college, increase experimentation, uncertainty, and stress levels. Emotional and academic stress seem to be the most significant

predictors of sleep quality in this phase of life, to an even greater extent than caffeine and alcohol use, exercise frequency, or computer/television use (Lund et al., 2010), showing how some challenges specific to emerging adulthood may impact sleep in a negative way.

Although the National Sleep Foundation's recommendations for sleep duration are the same both for emerging adults and adults, i.e., 7–9 h/night (Hirshkowitz et al., 2015), there are significant differences between their sleep determinants. The 'Perfect Storm' of factors impacting teenagers' sleep (Crowley et al., 2018) may still lead some emerging adults to go to sleep later; these factors would include hormonal changes, social pressures, caffeine and alcohol ingestion, and the allure of technology (e.g. Adams et al., 2017; McKnight-Eily et al., 2011; Rosen et al., 2016), with serious consequences for health and well-being. Poor sleep affects academic performance (American College Health Association, 2019), grades (Gomes et al., 2011), health (Steptoe et al., 2006), and well-being (Peach et al., 2016), making sleep interventions a relevant issue for this population.

Sleep behaviour-change interventions for young adults range from those that provide sleep knowledge and promote better sleep habits and behaviours (i.e., sleep education), to those that help manage emotions and stress (e.g., mindfulness-based programmes), or even to those that focus on dysfunctional cognitions and maladaptive sleep-related behaviours in treating insomnia (cognitive behavioural therapy for insomnia [CBT-i]). A previous systematic review on sleep interventions with college students found some positive effects, especially from CBT-i interventions (Friedrich & Schlarb, 2018). However, a more recent meta-analysis did not find efficacy differences between different types of interventions (Saruhanjan et al., 2021), raising the question of which elements are fundamental to their efficacy. Also, both reviews failed to analyse the medium- or long-term effects of the interventions, as most of the studies they found reported no follow-up measures, which limits the possibility to draw conclusions about the long-lasting efficacy of the interventions.

Interventions are often designed according to the ISLAGIATT principle ('It Seemed Like a Good Idea At The Time'), meaning they are constructed according to common-sense ideas, lacking a solid behavioural science background (i.e., conceptual framework) or adopting a favoured theoretical point of view instead of conducting a comprehensive appraisal of the behavioural target and analysing the path that leads more effectively to behaviour change (Michie et al., 2016). It is widely known that behavioural health research benefits from the use of theory in understanding health behaviours and delivering effective interventions (Prestwich et al., 2014), and a recent review on sleep studies concluded that health behaviour theories predict numerous outcomes such as sleep duration and sleep hygiene behaviours (e.g., engaging in physical activity or avoiding caffeine or alcohol consumption) (Mead & Irish, 2020), which led us to hypothesise that having a theoretical background may be a key factor in making sleep interventions more effective.

2 | OBJECTIVE

The aim of this study was to analyse the short- and medium-term effects and efficacy when using behaviour-change theory in sleep behaviour-change interventions in emerging adults, with the intention of improving future interventions. For this purpose, quantitative and qualitative analysis were employed. Sleep interventions were characterised using concepts from the 'Behaviour Change Wheel' (Michie et al., 2011), behaviour-change techniques (BCTs) and mechanisms of action (MoAs). The BCTs are defined as the replicable components of the interventions (the 'active ingredients') responsible for altering the processes that regulate the behaviour (Michie & Johnston, 2013), and the MoAs are the processes through which a BCT exerts influence over the behaviour (Carey et al., 2019). These links may facilitate explaining how behaviour change ultimately takes place in each intervention, by proposing how these 'ingredients' relate to the efficacy of the interventions.

3 | METHOD

This review was conducted in agreement with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines (Moher et al., 2009) and was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021246604).

3.1 | Eligibility criteria

The eligibility criteria were developed in accordance with the 'Participants, Interventions, Comparators, Outcomes, and Study design' (PICOS) framework (for full exclusion criteria, see the supplementary file, Table S1 in Appendix S1).

3.1.1 | Participants

Emerging adults (aged 18–29 years) reporting poor sleep or symptoms of insomnia. Because some studies use 'young adults' terminology and college student as samples, this review focused on interventions that used the terminology 'emerging adults', 'young adults', and also 'college students'. We included references to insomnia because psychological interventions are proven to be the most successful in these cases, as *'chronic insomnia disorders as a whole are typically associated with maladaptive cognitions and behaviours that represent major perpetuating factors'* (Sateia, 2014). Studies were excluded if they did not specifically refer to the age range of 18 to 29 years, or if they included clinical conditions or specific populations (e.g., athletes or pregnant women).

3.1.2 | Interventions

Interventions that had the purpose of changing behaviours in order to improve sleep: psychological interventions targeting sleep (e.g., CBT-i);

sleep education and hygiene; broad health promotion initiatives that also target sleep; interventions to change lifestyle habits to improve sleep; mindfulness or relaxation interventions that consider sleep as an outcome. Interventions that included pharmacological support, manual treatments, or ingestion/inhalation of herbal remedies were out of the scope of this review.

3.1.3 | Comparator

Interventions with an active control group (i.e., a group exposed to an alternative type of treatment) or a passive control group (i.e., a group that was not exposed to any type of treatment).

3.1.4 | Outcomes

Objective and subjective sleep outcomes, changes in sleep hygiene behaviours, as well as measures of mental health, as these are usually the most reported primary and secondary outcomes of sleep interventions in this age group (see Dietrich et al., 2016; Friedrich & Schlarb, 2018; Saruhanjan et al., 2021 for the outcomes reported by other sleep reviews in this age group).

3.1.5 | Study type

Randomised controlled trials (RCTs) and non-RCTs written in English, Portuguese, and Spanish, published as articles in peer-reviewed journals or as theses in specific databases. We did not define any publication date limits.

3.2 | Search strategy

Searches were conducted between April and May 2021 and were performed on *EBSCOhost web*, *SCOPUS*, *Web of Science*, *La Referencia*, *PROSPERO*, and *ProQuest Dissertations and Theses*. Literature written in Portuguese (European and Brazilian) and Spanish was specifically searched for directly in *La Referencia*, as well as indirectly in the *EBSCOhost web*, through secondary access to *SciELO* and *RCAAP – Repositórios Científicos de Acesso Aberto de Portugal (Scientific Repositories of Open Access in Portugal)*. The search string was developed with input from several sources: the American Psychological Association (APA) Thesaurus, terms derived from the eligibility criteria, and keywords imported from previous systematic reviews on this topic. Some synonyms were used. We selected the advanced search option and used Boolean operators, but some adaptations of the search strategy were specific to each database. For instance, on *EBSCOhost web* the search was performed within the abstract for participant and outcome descriptors, but within the subject terms for intervention descriptors, to guarantee that results generated were mostly relevant. A search of previous systematic reviews on sleep interventions within this age group and reference lists from selected studies was also carried out at the end of the study selection phase, as well as a forward search on Google Scholar (i.e., search on subsequent studies that cited the selected studies). Table S2 in Appendix S1 the online supplementary materials contains the full search strategy.

The search phase ended with 1705 documents after the removal of duplicates on *Mendeley* (Figure 1 PRISMA flowchart). The screening phase was accomplished using a platform to assist on systematic reviews – *Rayyan QCRI* (Ouzzani et al., 2016). Two authors (A.P. and M.J.A.) conducted the screening of 30% of all studies independently as a practise round to ensure eligibility criteria were clear and well-defined. Some adjustments were made after discussion, then a new pool of 30% of studies was selected for independent screening by the same authors and the agreement rate was calculated. There were some doubts at the end of this phase, but no disagreements (Cohen's $\kappa = 1.0$). The studies that posed questions were considered for further reading in the full-text phase. The remaining 70% were screened by one reviewer (A.P.).

The full-text reading phase began with 68 studies to review. This phase was conducted by one reviewer (A.P.) and any doubts were resolved through discussion with a second reviewer (M.J.A.). The main reason for exclusion concerned the population targeted by the interventions, as most interventions did not report the age range or did not present disaggregated data by age range. Even though some interventions stated that they had been applied to 'college students' or 'young adults', without the age range we could not possibly know if they targeted only adults between the ages of 18 and 29 years.

3.3 | Data collection

The main features of each intervention were synthesised and defined in accordance with the PRISMA recommendations on data items (Moher et al., 2015).

One author (A.P.) extracted the data to a table containing relevant data such as general information (title, authors, year), methodological features (study design, measures used, control condition), sample details (total *N*, gender%, country), intervention details (theory, description of activities, delivery mode, duration) and outcomes, and a second researcher fully read all the articles and checked if the data were complete; if not, this researcher would make suggestions or additions. Some studies did not provide detailed enough descriptions of what had been done. Authors were contacted twice to provide missing data, but no relevant information was gathered through this method.

3.4 | Data analysis

3.4.1 | Quantitative analysis

Two authors (A.P. and M.S.R.) independently analysed the studies for risk of bias using the Cochrane Risk of Bias, version 2 tool for

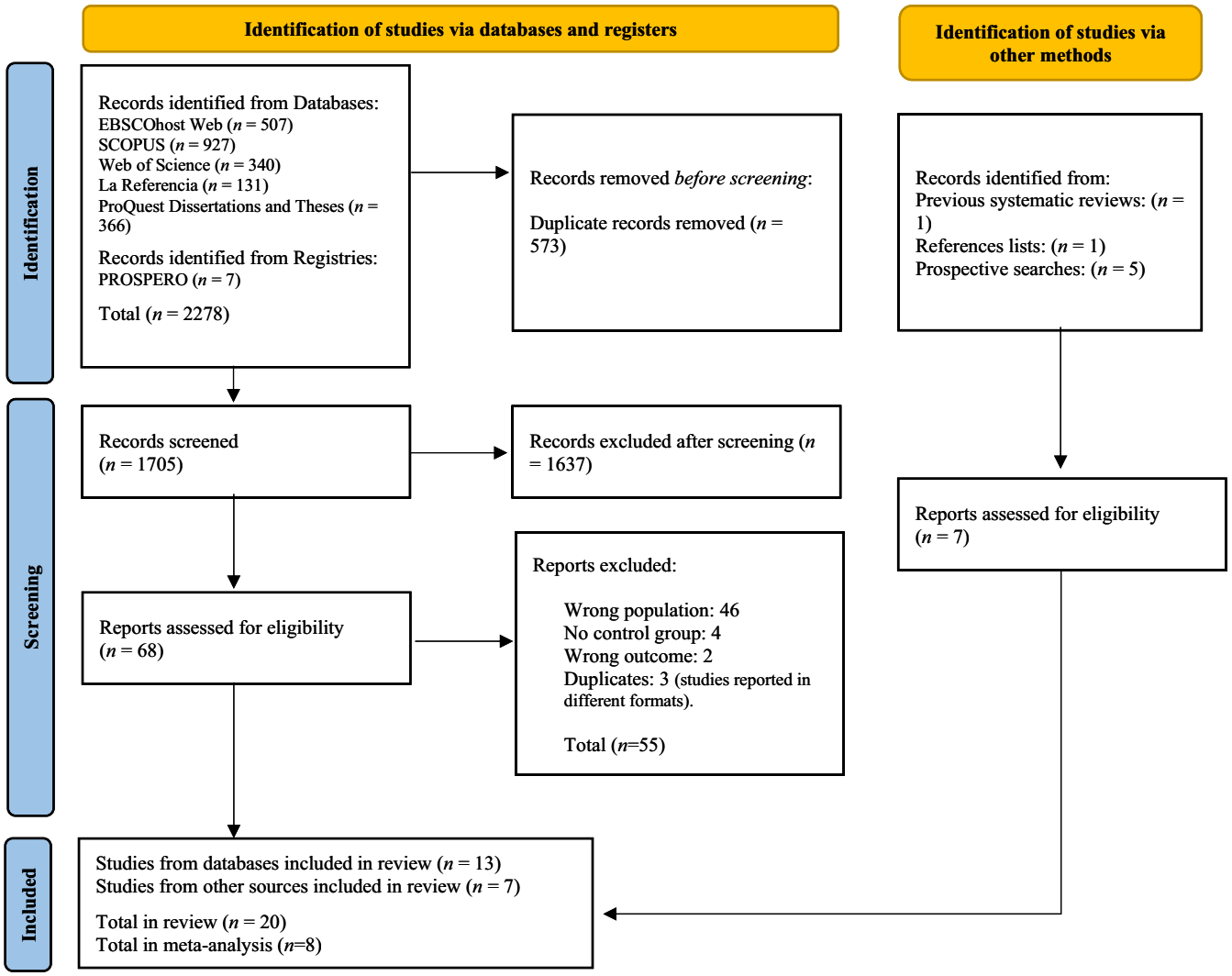


FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart reporting the data collection process.

randomised trials (Sterne et al., 2019) and the Risk of Bias in Non-Randomised Studies-of Interventions (ROBINS-I) (Sterne et al., 2016). Each randomised study was assessed as showing a 'low risk of bias', 'some concerns' or 'high risk of bias', considering the following aspects: the randomisation process, deviations from the intended interventions, incomplete outcome data, measurement of the outcome, and selective outcome reporting. Each non-randomised intervention was classified as having a slow risk of bias', 'moderate risk of bias', 'serious risk of bias', 'critical risk of bias', or 'no information', concerning the following domains: confounding variables, selection of participants, classification of interventions, deviations from intended interventions, missing outcome data, measurement of outcomes, and selective outcome reporting. Doubts were resolved in a meeting between both authors, and there were no conflicts to be resolved. Graphics summarising the results of these risk of bias assessments were computed using the R software package *robvis*. Studies with a high risk of bias were not included in the meta-analysis.

Meta-analysis was performed using R software (R Core Team, 2020). Intervention estimates were extracted, using the *esc* package (Lüdecke, 2018), and the effects converted to Hedges' *g* using sleep quality outcomes – Pittsburgh Sleep Quality Index (PSQI) scores. Results were computed only with the post-intervention measures (i.e., short-term effects), because only three of the studies included in the meta-analysis had follow-up measures, which invalidated the possibility to compute the medium-term effects of the interventions. Studies using other measures were excluded from the quantitative synthesis, as were studies that did not present enough data for the quantitative analysis. In one study (Perucho et al., 2019), the standard deviations had to be computed from confidence intervals (CIs) before converting to Hedges' *g*.

As the behaviour-change interventions included were very different from one another, a model of random effects was computed, informing about the overall effect and its prediction interval. The significance of the estimated effect was considered when the 95% CI did not include zero. Heterogeneity was assessed through the I^2 statistic (I^2 < 50% low heterogeneity; I^2 > 75% high heterogeneity) (Higgins et al., 2003) and the 95% prediction interval to identify the expected range of effect size values for future studies

TABLE 1 Summary table of the characteristics of the included studies ($N = 20$).

Authors (year); country	Participants (age range, years; *N* total; *N* of women)	Intervention (type; aims; delivery mode; duration)	Methodological features ($_1$theoretical framework?; $_2$study type; $_3$control condition; $_4$follow-up?)	Outcomes (sleep measures, key reported outcomes, Hedges' *g*)
Bruehlman-Senecal et al. (2020); USA	18–25 221 participants 131 women	Broad health intervention. To address the psychological and behavioural foundations of loneliness in transition to college (sleep quality is one of the mental health indicators). Self-administered via *Nod app*. 4 weeks.	$_1$No. $_2$RCT. $_3$Wait-list control group. $_4$Yes, at 8 weeks.	Sleep was measured by PSQI. There were no significant overall improvements in any outcome variables, but there were significant benefits for students exhibiting higher indicators of loneliness, depression, and sleep quality at baseline. $g = -0.24$
Chang et al. (2021); USA[c]	18–24 85 participants 42 women	Psychological intervention (CBT-i). To promote the change of beliefs and attitudes on sleep, sleep quality, daytime sleepiness, sleep hygiene, and alcohol use, using CBT-i. Self-administered via email. 6 weeks.	$_1$Yes: cognitive-behaviour theory. $_2$Quasi-experimental. $_3$Active control group (CG was directed to a website with sleep hygiene information). $_4$No.	Sleep measures used: ISI, DBAS, PSQI, ESS and SH. There were significant improvements in sleep quality and sleep hygiene. EG improved from baseline to post-test on beliefs and attitudes about sleep, sleep quality, daytime sleepiness, and sleep hygiene. $g = -0.63$
David (2017); USA[c]	18–27 97 participants 61 women	Psychoeducational intervention. To improve sleep by changing sleep hygiene practises through sleep hygiene education. Two experimental conditions: One-time lecture only + one lecture (50 min.) and four individual sessions. 4 weeks.	$_1$No. $_2$Quasi-experimental. $_3$Passive control group. $_4$Yes, at 3 months.	Sleep measures used: PSQI, ESS, SH, and sleep diaries. There was some improvement in sleep hygiene practises in the EG who attended the lecture and the individual sessions over the other groups, but not in the long term (at follow-up). The differences between groups on other outcome measures over time were not significant. $g = 0.32$
Dvorakova (2017); USA	18–19 109 participants 72 women	Mindfulness intervention. To stimulate a mindful attitudes and behaviours and improve mental health indicators (including sleep). Eight 80-min group sessions. 6 weeks.	$_1$No. $_2$RCT. $_3$Wait-list control group. $_4$Yes, at 3 months.	Sleep was measured by PSQI. There was a significant decrease in levels of depression and anxiety, and an increase in levels of life satisfaction. The EG reported slightly significant lower levels of sleep disturbances than the CG. $g = -0.14$
Ehrampoush et al. (2019); Iran	18–20 104 participants 74 women	Psychological intervention (CBT-i) To promote a change in cognitive and emotion regulation, anxiety, depression, and sleep quality. Two experimental conditions: 'perseverance, willpower or intention workshop' and	$_1$Yes: cognitive-behaviour theory. $_2$RCT. $_3$Passive control group (inferred, not clearly stated). $_4$No.	Sleep was measured by PSQI. There was a significant decrease in anxiety and depression in both the EG, but not in sleep quality, when comparing between all groups. (not possible to compute Hedges' *g*)

(Continues)

TABLE 1 (Continued)

Authors (year); country	Participants (age range, years; *N* total; *N* of women)	Intervention (type; aims; delivery mode; duration)	Methodological features ($_1$theoretical framework?; $_2$study type; $_3$control condition; $_4$follow-up?)	Outcomes (sleep measures, key reported outcomes, Hedges' *g*)
		'sleep and wakefulness workshop'. 9 months.		
Ezati et al. (2020); Iran	18–26 80 participants All women	Lifestyle change intervention (physical activity). To improve sleep quality and decrease fatigue levels through mild and moderate physical exercise. 31-h group sessions/week. 8 weeks.	$_1$No. $_2$Quasi-experimental. $_3$Passive control group. $_4$No.	Sleep was measured by PSQI. There was a significant improvement in sleep quality and its components (except for sleep duration after 4 weeks of intervention) and decrease in fatigue levels when comparing between groups. $g = -1.08$
Gipson (2016); USA	18–26 120 participants 80 women	Psychoeducational intervention. To target sleep knowledge, sleep hygiene, self-efficacy for sleep hygiene, and sleep quality through sleep hygiene education. Self-administered via SMS. 6 weeks.	$_1$Yes: social cognitive theory. $_2$RCT. $_3$Active control group (CG received text messages about healthy habits). $_4$No.	Sleep was measured by PSQI. Measures of sleep related behaviours, knowledge and beliefs were also used. There were some improvements for sleep knowledge, sleep hygiene, sleep quality, sleep influences, but not significantly nor consistently throughout the intervention. $g = 0.09$
Harmat et al. (2008); Hungary[a]	19–28 94 participants 73 women	Music therapy intervention. To foster sleep quality while controlling for the confounding effects of relaxation and positive expectations. Two experimental conditions, both self-administered at home: listening to music or to an audiobook daily for 45 min at bedtime. 3 weeks.	$_1$No. $_2$RCT. $_3$Passive control group. $_4$No.	Sleep was measured by PSQI and ESS. There was a significant improvement in sleep quality in the music group but not in the audiobook group. (not possible to compute Hedges' *g*).
Hurdiel et al. (2017); France[b]	18–24 19 participants All women	Lifestyle change intervention (physical activity). To improve sleep quality through the practise of sports (biking, roller-skating, walking, running, and playing baseball). Biweekly 1.5-h group sessions. 12 weeks.	$_1$No. $_2$RCT. $_3$Passive control group. $_4$No.	Sleep was measured by PSQI, sleep diaries, and actigraphy. There was a significant improvement in sleep quality in the EG. $g = -1.51$
Kloss et al. (2015); USA	18–28 120 participants 73 women	Psychological intervention (CBT-i). To address sleep quality, maladaptive beliefs and attitudes about sleep and healthy sleep practises, using CBT-i.	$_1$Yes: cognitive-behaviour theory. $_2$RCT. $_3$Active control group (CG completed sleep logs and was handed the brochure on sleep hygiene).	Sleep measures used: DBAS, PSQI, SH, ISI, and sleep diaries. There was a significant improvement in the EG in beliefs and attitudes about sleep, sleep hygiene and a

TABLE 1 (Continued)

Authors (year); country	Participants (age range, years; *N* total; *N* of women)	Intervention (type; aims; delivery mode; duration)	Methodological features ($_1$theoretical framework?; $_2$study type; $_3$control condition; $_4$follow-up?)	Outcomes (sleep measures, key reported outcomes, Hedges' *g*)
		Brochure on sleep hygiene practises and 2 weeks of sleep logs + two 90-min group sessions. 4 weeks.	$_4$No.	decrease on sleep onset latency. Sleep quality improvements were not significant. $g = -0.19$
Koenig et al. (2013); Germany[c]	20–29 20 participants 13 women	Music therapy intervention. To investigate the impact of music listening on people without sleep problems. Self-administered at home: listening to music daily for 45 min at bedtime. 3 weeks.	$_1$No. $_2$RCT. $_3$Passive control group. $_4$No.	Sleep was measured by PSQI. There was no significant change in sleep quality after the intervention. $g = 0$
Li et al. (2015); China	18–25 206 participants 170 women	Lifestyle change intervention (physical activity). To improve physical and mental health (including sleep) through the practise of baduanjin. 1-h group sessions, 5 days a week. 12 weeks.	$_1$No. $_2$RCT. $_3$Passive control group. $_4$Yes, at 25 weeks.	Sleep was measured by PSQI. There were improvements in several measures of physical indicators (e.g., cardiorespiratory function or flexibility). Sleep quality did not improve significantly. $g = -0.2$
Olsen (2014); USA[c]	18–21 52 participants 19 women	Psychoeducational intervention. To change the sleep habits of college students through sleep hygiene education, thus improving sleep. Two experimental conditions: Half of the EG was assigned to a sleep focused reflection group while the other half was assigned to a non-sleep focused reflection group. One 30-min group session (one-time only).	$_1$No. $_2$Quasi-experimental. $_3$Passive control group. $_4$Yes, at 2 and 4 weeks.	Sleep was measured by PSQI, SH and ESS. Measures of sleep related behaviours (technology use), attitudes and beliefs were also used. There were no significant improvements in sleep quality nor technology use in the EG versus CG. There were no significant differences between both EG. (not possible to compute Hedges' *g*).
Perucho et al. (2019); Singapore	18–24 70 participants 43 women	Psychoeducational intervention. To change sleep habits by highlighting the immediate consequences of sleep deprivation on physical appearance on digitally altered photos (i.e., physical appearance changes as a function of lack of sleep). One 30-min individual session (one-time only).	$_1$No. $_2$RCT. $_3$Active control group (CG participants were only shown a slideshow containing sleep education materials). $_4$Yes, at 4 and 5 weeks.	Sleep measures used: DBAS, PSQI, SH, actigraphy, and sleep diaries. There were significant improvements in SH, but not on sleep duration. Sleep quality and sleep related beliefs remained stable throughout the trial. $g = -0.14$
Sharma & Sharma, (2015); India[c]	18–25 44 participants ? women	Music therapy intervention. To address sleep and self-worth issues through music listening (instrumental flute). Self-administered at home: listening to music for 30 min daily. 3 weeks.	$_1$No. $_2$RCT. $_3$Passive control group (inferred, not clearly stated). $_4$No.	Sleep was measured by PSQI (but no total score was provided). There were significant improvements in the EG on subjective sleep quality, sleep latency, sleep duration, sleep efficiency,

(Continues)

TABLE 1 (Continued)

Authors (year); country	Participants (age range, years; *N* total; *N* of women)	Intervention (type; aims; delivery mode; duration)	Methodological features ($_1$theoretical framework?; $_2$study type; $_3$control condition; $_4$follow-up?)	Outcomes (sleep measures, key reported outcomes, Hedges' *g*)
				sleep disturbances, and daytime dysfunction and dimensions of self-worth. (not possible to compute Hedges' *g*).
Taylor et al. (2014); USA	18–27 34 participants 14 women	Psychological intervention (CBT-i). To improve the sleep of people with symptoms of insomnia, with a CBT-i intervention. Six individual sessions. 6 weeks.	$_1$Yes: cognitive-behaviour theory. $_2$RCT. $_3$Wait-list control group. $_4$Yes, at 3 months.	Sleep was measured by PSQI, polysomnography, actigraphy, sleep diaries, DBAS, ESS, and ISI. There was a significant improvement in several sleep indicators (e.g., sleep onset latency or sleep quality) in the EG, but not on sleep duration objectively measured. $g = -1.67$
Trockel et al. (2011); USA	18–22 125 participants 61 women	Psychological intervention (CBT-i). To address the cognitive and behavioural aspects of sleep health, improving sleep quality and symptoms of depressed mood. Self-administered via email: Refresh programme (participants were encouraged to spend 30 min/week in each session). 8 weeks.	$_1$Yes: cognitive-behaviour theory. $_2$Quasi-experimental. $_3$Active control group (CG attended a program to help cope with stress and emotional health—Breathe). $_4$No.	Sleep was measured by PSQI. There were only significant improvements in sleep and depressive mood for participants who showed poorer sleep at baseline. (not possible to compute Hedges' *g*).
Tsai & Li (2004); Taiwan	18–28 306 participants 143 women	Psychoeducational intervention. To promote changes in sleep patterns through sleep hygiene education. 100-min weekly classroom sessions. 3 months.	$_1$No. $_2$Quasi-experimental. $_3$Passive control group. $_4$No.	Sleep was measured with sleep diaries. There were some significant improvements in sleep quality and nap time in the EG. (not possible to compute Hedges' *g*).
Weis et al. (2021); USA	19–21 32 participants 16 women	Mindfulness intervention. To help students cope with COVID-19-related stress and anxiety (and thus improve sleep). Four 75-min weekly group sessions. 6 weeks.	$_1$No. $_2$Quasi-experimental. $_3$Wait-list group. $_4$Yes, 7 weeks after post-test.	Sleep was measured by MOSSS. There was a significant increase in mindfulness, self-compassion, and sleep quality in the EG. There was also a significant decrease in anxiety, stress, and sleep latency. (not possible to compute Hedges' *g*).
Werch et al. (2008); USA	18–21 299 participants 178 women	Broad health intervention. To prevent risk and promote multiple health-promoting behaviours (including sleep).	$_1$No. $_2$RCT. $_3$Active control group (CG received a standard brochure on health behaviour).	Sleep was measured by items related to sleep in the Fitness and Health Survey. There was a significant decrease in alcohol and

TABLE 1 (Continued)

Authors (year); country	Participants (age range, years; *N* total; *N* of women)	Intervention (type; aims; delivery mode; duration)	Methodological features ($_1$theoretical framework?; $_2$study type; $_3$control condition; $_4$follow-up?)	Outcomes (sleep measures, key reported outcomes, Hedges' *g*)
		One 25-min individual session (one-time only).	$_4$Yes, at 3 months.	marijuana consumption. The largest effects were increased sleep, improved social and spiritual health-related quality of life, and a decrease in heavy drinking. (not possible to compute Hedges' *g*).

Abbreviations: CBT-i, cognitive behavioural therapy for insomnia; CG, Control group; COVID-19, coronavirus disease 2019; DBAS-SF, Dysfunctional Beliefs and Attitudes about Sleep; EG, Experimental group; ESS, Epworth Sleepiness Scale; FU, follow-up; ISI, Insomnia Severity Index; MOSSS, Medical Outcomes Study Sleep Scale; PSQI, Pittsburgh Sleep Quality Index; RCT, randomised controlled trial; SH, sleep hygiene (multiple indexes were used).
[a]Identified from secondary searches (previous systematic reviews): Friedrich & Schlarb, 2018.
[b]Identified from secondary searches (included studies' reference lists): Ezati et al., 2020
[c]Identified from secondary searches (prospective searches: newfound studies which cited included studies): Tsai & Li, 2004; Harmat et al., 2008; Trockel et al., 2011; Taylor et al., 2014

(Harrer et al., 2021). An analysis of possible moderators of the effect (number and type of BCTs, type of intervention, intervention length, and delivery mode) was also computed through a subgroup analysis. The use of behaviour-change theory could not be included as a moderator because of the small number of studies found to be based on theory. To examine the publication bias, a contour-enhanced Funnel plot (Peters et al., 2008) was used. Both plots, Forest and Funnel, were made using the *meta* (Schwarzer, 2007) package.

3.4.2 | Qualitative analysis

The use of BCTs had to be inferred through a thematic analysis of the provided descriptions of the interventions, as none of the interventions used this framework in its conception. The BCTs coding process was conducted independently by two trained researchers (A.P. and J.D.) on BCTs taxonomy using NVivo software. First, all segments concerning the description of the interventions in the articles were collected by one researcher. For one article the description of the intervention was coded independently by both researchers, attributing BCTs to the techniques employed and then discussing it to clarify any doubts. As the agreement rate on this first coding was fair ($\kappa = 0.75$), both researchers proceeded coding the descriptions in all articles independently and then met again at the end of the process to check if their coding was similar or not. As there were a few differences in coding at the end not resolved between the researchers, a third researcher was called to help solve them (M.J.A.).

After the coding of the BCTs, an analysis of the MoAs was conducted using *The Theory and Techniques Tool* (https://theoryandtechniquetool.humanbehaviourchange.org/tool) developed by the Human Behaviour Change Project led by Prof. Susan Michie. The establishment of these BCT-MoA links was expected to give some depth to the quantitative results, through their interpretation under a common theoretical framework.

4 | RESULTS

4.1 | Descriptive synthesis

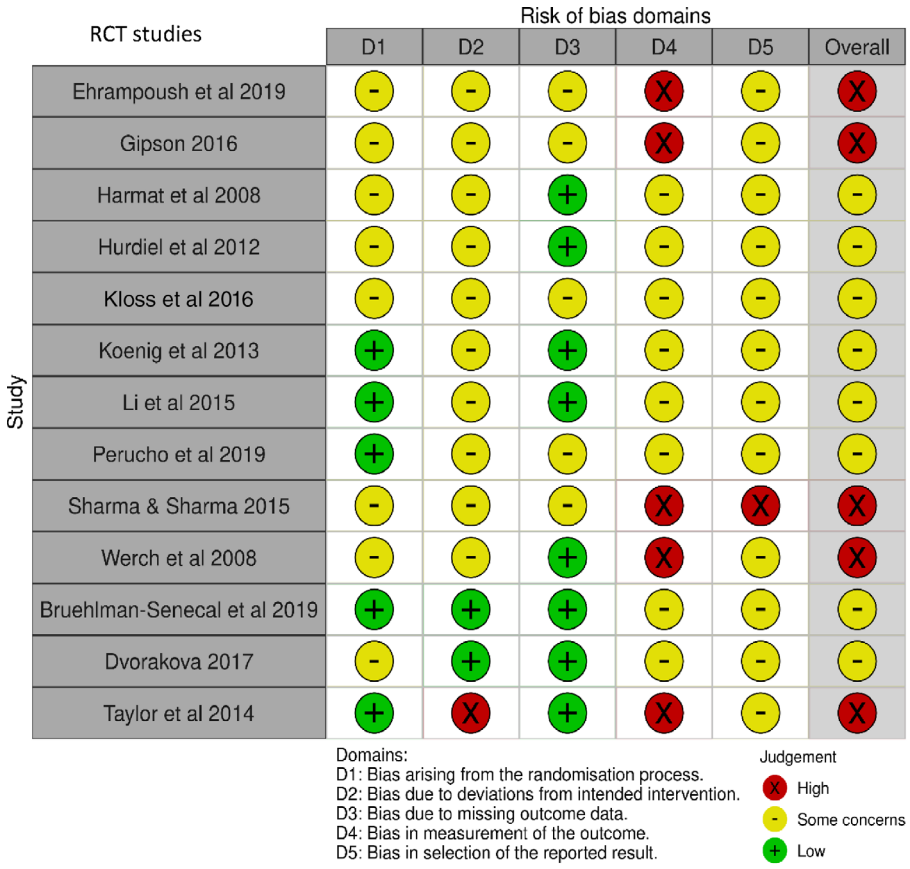
Table 1 contains detailed information concerning the included studies ($N = 20$). All studies were written in English, most were published after 2011 (excluding: Tsai & Li, 2004; Harmat et al., 2008; Werch et al., 2008), and nearly half the studies were conducted in North America ($n = 11$), while the rest were conducted in several different countries in Europe ($n =$ three) and Asia ($n =$ six). The majority were published as articles and only four were published as dissertations or theses. Two of the studies published in a dissertation, Dvorakova, 2017 and Gipson, 2016, were also published as peer reviewed papers, but consulting the dissertations provided valuable information to describe both.

4.1.1 | Participants

Included studies involved 2237 participants, mostly women ($n = 1371$), all college students (aged 18–29 years).

4.1.2 | Interventions

Interventions varied in nature, so they were grouped in six different types: *lifestyle change (physical activity)*, *psychological (CBT-i)*, *psychoeducational*, *mindfulness*, *music therapy*, and *broad health interventions*.



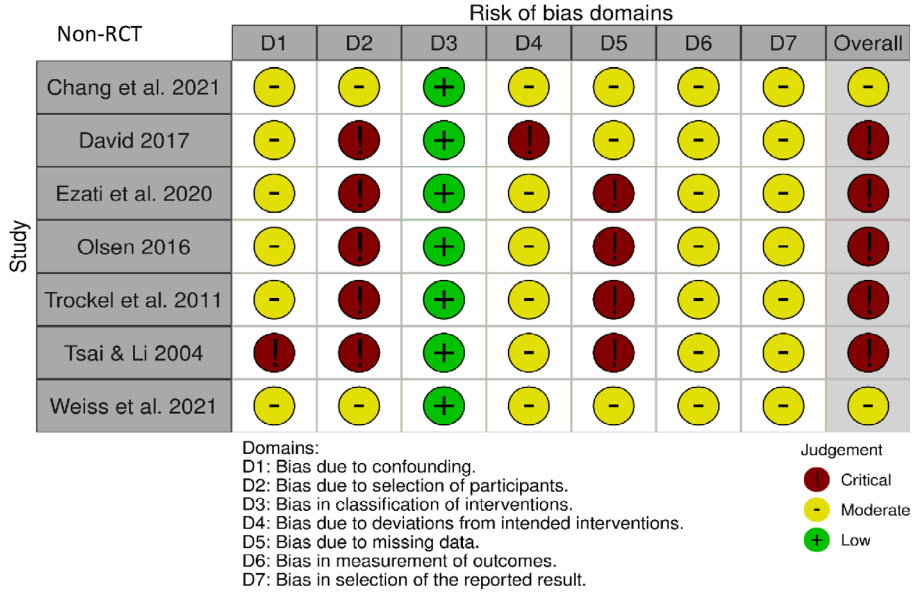


FIGURE 2 Semaphore graphic results from the risk of bias analysis concerning several domains of potential bias for randomised controlled trials (RCTs) and non-RCTs included in this review.

Lifestyle-change interventions (physical activity) are very simple structured interventions, based on group practise of physical activities led by sports professionals. The rationale behind this type of interventions is that physical activity is one of the lifestyle-change recommendations on sleep hygiene guidelines, so sleep is benefited by the increase of the level of daily activity.

Psychological interventions (*CBT-i*) address the cognitions and behaviours that impair sleep, being especially relevant for people with symptoms of insomnia. These interventions often include sleep hygiene education, sleep-restriction protocols, stimulus control strategies, relaxation and/or mindfulness training, and strategies to change maladaptive cognitions about sleep.

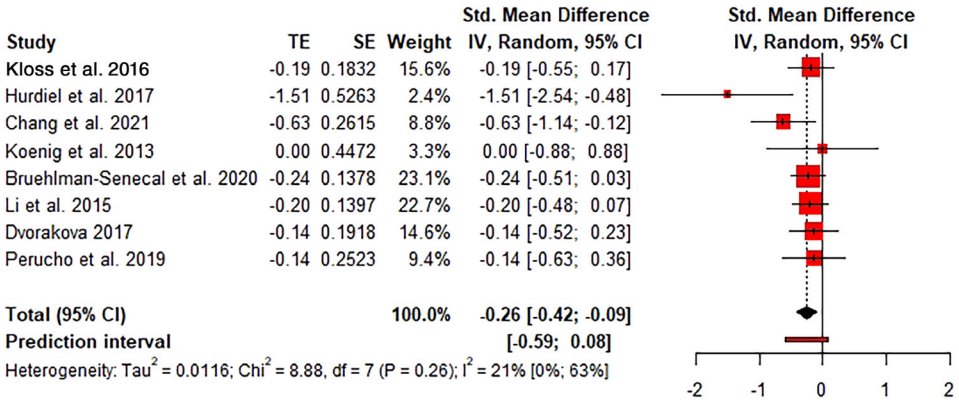


FIGURE 3 Forest plot for the studies included in the meta-analysis, including treatment effects (TE), standard error (SE), studies' weights and standardised mean differences (SMDs) at 95% confidence interval (CI) and heterogeneity indicators (Tau^2, Chi^2, I^2 and prediction interval).

Psychoeducational interventions include sleep education and behaviour-change strategies, primarily targeting a change in sleep hygiene behaviours. The sleep hygiene behaviours are conveyed in multiple ways (e.g., through speech, brochures, text messages, or images), focusing on different motivational strategies.

Mindfulness interventions promote emotion regulation skills and decrease stress by focusing on breathing and bodily sensations, through meditation practises or body awareness exercises. By diminishing stress, helping cope with anxiety and other sleep impairing emotions, these interventions ultimately improve sleep.

Music therapy interventions are simple interventions where people are exposed to music before bedtime, with the expected outcome of improving sleep from its soothing effect.

Broad health interventions are multi-behaviour interventions, designed to impact several different health outcomes (mental and physical). Health domains are interrelated, so for instance if mental health is addressed, e.g., the psychological and behavioural foundations of loneliness, as in Bruehlman-Senecal et al., 2020, sleep may also be impacted.

Six interventions were found to be theoretically based. One intervention, Gipson, 2016, was explicitly framed within a behaviour-change theory. The text-messages contained in this intervention were designed considering the cognitive, behavioural, and environmental influences on sleep, posited by the social cognitive theory. Although not explicitly characterised as such by the authors, the CBT-i interventions (Chang et al., 2021; Ehrampoush et al., 2019; Kloss et al., 2015; Taylor et al., 2014; Trockel et al., 2011) were also considered to be theoretically based because they are grounded in well-defined behavioural-cognitive models that have been extensively studied and applied to several behavioural domains.

Sleep diaries were employed in six studies. Most of the studies used the PSQI as a sleep measure ($n = 17$), which is widely used as a sleep questionnaire in many countries, and only three studies used objective sleep measures (actigraphy or polysomnography). Three studies assessed insomnia symptoms using a specific measure for that purpose. Several other indicators related to sleep were compiled in some studies (e.g., sleep hygiene, sleepiness, fatigue), as well as additional markers of mental health (e.g., depression, anxiety).

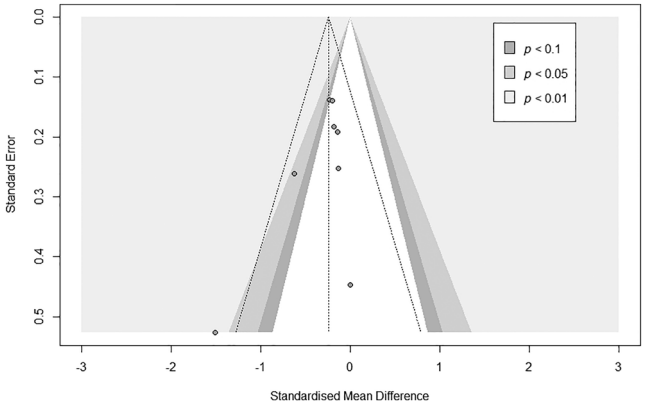


FIGURE 4 Funnel plot of the studies' effects sizes plotted against standard error.

The interventions comprised different delivery modes: self-administered (via app, email, or SMS), or group or individual sessions led by one of the researchers. The length of the studies varied extensively (between one-time-only interventions and 9 months).

4.1.3 | Methodological features

There were 13 RCTs and seven non-RCTs. Eight studies had a passive control group, and only four had a wait-list control group. The remaining studies had active control groups in which participants took part either in interventions of a different nature that also targeted sleep (e.g., being handed a sleep education flyer or being directed to a website about sleep hygiene information) or in interventions that targeted other variables (e.g., stress or healthy habits). More than half the studies ($n = 12$) had no follow-up measure.

4.1.4 | Outcomes

Interventions were mildly effective. Most studies reported significant improvements in sleep after the interventions, but when the Hedges' *g* was analysed, it was found that only some of the *Lifestyle change*

TABLE 2 Links between behaviour-change techniques (BCTs) and mechanisms of action (MoAs).

Study	BCT	Excerpts	MoA	Explanation
Kloss et al. (2015)	5.1. Information about health consequences	5.1. Information about health consequences	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
			Beliefs about consequences	They probably also work by altering the perceptions about what will be attained and/or lost by undertaking a behaviour, as well as the probability that a behaviour will lead to a specific result.
			Intention	Even more, they try to prompt a conscious decision to perform a behaviour or a resolve to act in a certain way.
			Attitude towards the behaviour	These interventions promote a change in the individual's evaluation of the behaviour. Changing the cognitive component of the attitudes towards the behaviour promotes a change in the behaviour itself.
			Perceived susceptibility/ vulnerability	Such interventions also operate through change in perceptions of the likelihood that one is vulnerable to a threat
	2.4. Self-monitoring of outcome(s) of behaviour	'*Given another week of sleep logs to continue to monitor their sleep onset latency and asked to return the following week*'	(no conclusive evidence)	–
	13.2. Framing/ reframing	'*Help participants (…) form alternative cognitions for these maladaptive thoughts*' '*For example, participants were presented with the maladaptive thought, When I have trouble sleeping, I should just stay in bed and try harder. Participants were instructed to identify cognitive errors that included making faulty assumptions in response. Maladaptive behaviours that may follow as a consequence of that thought were then discussed* (i.e., *staying in bed when unable to sleep may lead to a negative association between bed and sleep). Next, alternative thoughts were described, including the suggestion, 'It is best*	Attitude towards the behaviour	Interventions that include this BCT are thought to work by promoting a change in the individual's evaluation of the behaviour. Changing the cognitive component of the attitudes towards the behaviour promotes a change in the behaviour itself.

TABLE 2 (Continued)

Study	BCT	Excerpts	MoA	Explanation
		to spend less time in bed when not sleeping and sleep more efficiently'		
	1.2. Problem solving	'*Relapse prevention'*	Beliefs about capabilities	These interventions probably work by enhancing beliefs about one's ability to successfully carry out a behaviour.
			Behavioural regulation	They also promote behavioural, cognitive, and/or emotional skills for managing or changing behaviour.
Perucho et al. (2019)	5.1. Information about health consequences	'*Were shown the same slideshow presentation as the information group: the functions of sleep, the consequences of sleep curtailment, behavioural signs of insufficient sleep, and sleep hygiene principles to promote sleep'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
			Beliefs about consequences	They probably also work by altering the perceptions about what will be attained and/or lost by undertaking a behaviour, as well as the probability that a behaviour will lead to a specific result.
			Intention	They try to prompt a conscious decision to perform a behaviour or a resolve to act in a certain way.
			Attitude towards the behaviour	These interventions promote a change in the individual's evaluation of the behaviour. Changing the cognitive component of the attitudes towards the behaviour promotes a change in the behaviour itself.
			Perceived susceptibility/ vulnerability	Such interventions also operate through change in perceptions of the likelihood that one is vulnerable to a threat.
	5.2. Salience of consequences	'*the trained research assistant highlighted how sleep curtailment affected their appearances* (e.g., *hanging eyelids and droopy mouth), and how that could be perceived by others* (e.g., *as less attractive)'*	Beliefs about consequences	These interventions probably also work by altering the perceptions about what will be attained and/or lost by undertaking a behaviour, as well as the probability that a behaviour will lead to a specific result.
			Perceived susceptibility/ vulnerability	Such interventions also operate through change in perceptions of the likelihood that one is vulnerable to a threat.
	5.3. Information about social and environmental consequences	'*The trained research assistant highlighted how sleep curtailment affected their appearances* (e.g., *hanging eyelids and droopy mouth), and how that could be perceived by others* (e.g., *as less attractive)'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
		'*Reminded of the costs many incur for physical attractiveness* (e.g., *paying a gym*	Beliefs about consequences	They probably also work by altering the perceptions about what will be attained and/or lost by undertaking a behaviour, as well as the probability that a behaviour will lead to a specific result.

(Continues)

TABLE 2 (Continued)

Study	BCT	Excerpts	MoA	Explanation
		membership for $100/month), relative to the benefits accrued from extending sleep duration'	Attitude towards the behaviour	They also promote a change in the individual's evaluation of the behaviour. Changing the cognitive component of the attitudes towards the behaviour promotes a change in the behaviour itself.
	13.4. Valued self-identity	*'Participants scrolled through the website in a self-paced manner and were asked (…) to adjust the scale to select their most attractive self'*	(No conclusive evidence)	–
Hurdiel et al. (2017)	4.1. Instruction on how to perform the behaviour 8.1. Behavioural practise/rehearsal 6.1. Demonstration of the behaviour	*'For 12 weeks, the group practised moderate-intensity physical activities together for one and a half hour, twice a week, at 6 p.m. (…) Physical activities were led by the second author (a researcher and sports educator)'*	Knowledge Skills Beliefs about capabilities (8.1 and 6.1 are also skills and beliefs) ----------(6.1) Social learning/imitation	Interventions that include this BCT are trying to promote the awareness that something exists. They support the ability or proficiency acquired through practise. They probably also operate by enhancing the beliefs about one's ability to successfully carry out a behaviour. ---------- These interventions are thought to work by allowing a process to unfold by which thoughts, feelings, and motivational states observed in others can be adopted and replicated without conscious awareness.
Chang et al. (2021)	12.3. Avoidance/reducing exposure to cues for the behaviour	*'Asked to limit the use of bed to sleep or sexual activity, if they awaken during the night and are unable to return to sleep within 20 min or get out of bed if it takes more than 20 min to fall asleep'*	Environmental context and resources	Interventions that include this BCT are probably making people act upon their environmental and contextual and resources, i.e., promoting changes in people's surroundings that disfavour or favour the targeted behaviour.
	4.1. Instruction on how to perform the behaviour	*'Participants will be asked to spend no more than average total sleep time plus 30 min in bed per night. They will also be asked to maintain a consistent bedtime and wake time and limit naps to less than 60 min'*	Behavioural cueing ---------- Knowledge Skills Beliefs about capabilities	This BCT may also work in a less deliberate way, using prompts from the external environment, from other behaviour, or from automatic thoughts. ---------- This BCT is trying to promote the awareness that something exists. It also supports the ability or proficiency acquired through practise. It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
	4.1. Instruction on how to perform the behaviour	*'Asked to avoid heavy meals, alcohol, caffeine, and exercise 2–3 h before bedtime'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
	5. Remove aversive stimulus		Skills	It also supports the ability or proficiency acquired through practise.

TABLE 2 (Continued)

Study	BCT	Excerpts	MoA	Explanation
				It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
			Beliefs about capabilities ----------	----------
			Environmental context and resources	Interventions that include this BCT are probably making people act upon their environmental and contextual and resources, i.e., promoting changes in people's surroundings that disfavour or favour the targeted behaviour.
	12.1. Restructuring the physical environment	*'Asked to create a sleep environment that is dark, quiet, and comfortable'*	Environmental context and resources	Interventions that include this BCT are probably making people act upon their environmental and contextual and resources, i.e., promoting changes in people's surroundings that disfavour or favour the targeted behaviour.
			Behavioural cueing	This BCT may also work in a less deliberate way, using prompts from the external environment, from other behaviour, or from automatic thoughts.
	4.1. Instruction on how to perform the behaviour	*'Instructed on how to develop a prebedtime routine to help them wind down and prepare for sleep'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
			Skills	It also supports the ability or proficiency acquired through practise.
			Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
	12.6. Body changes	*'Asked to practise deep breathing, guided imagery, and to listen to relaxing music before bedtime'*	(no conclusive evidence)	–
	13.2. Framing/ reframing	*'Asked about sleep beliefs and attitudes, will challenge these thoughts, and turn them from dysfunctional to more adaptive thoughts'*	Attitude towards the behaviour	Interventions that include this BCT are thought to work by promoting a change in the individual's evaluation of the behaviour. Changing the cognitive component of the attitudes towards the behaviour promotes a change in the behaviour itself.
	1.2. Problem solving	*'Relapse prevention'*.	Beliefs about capabilities	These interventions probably work by enhancing the beliefs about one's ability to successfully carry out a behaviour.
			Behavioural regulation	They also act by promoting behavioural, cognitive and/or emotional skills for managing or changing behaviour.
	4.1. Instruction on how to perform the behaviour	*'Listen to it for 45 minutes every night at bedtime for three consecutive weeks'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
		'Participants were asked to listen to their CD before going to bed'	Skills	It also supports the ability or proficiency acquired through practise.
			Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.

(Continues)

TABLE 2 (Continued)

Study	BCT	Excerpts	MoA	Explanation
	4.1. Instruction on how to perform the behaviour	*'(…) and to avoid physical activities during and after the music'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
			Skills	It also supports the ability or proficiency acquired through practise.
	7.5. Remove aversive stimulus		Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
			----------	----------
			Environmental context and resources	Interventions that include this BCT are probably making people act upon their environmental and contextual and resources, i.e., promoting changes in people's surroundings that disfavour or favour the targeted behaviour.
Bruehlman-Senecal et al. (2020)	13.2. Framing/ reframing	*'Reflections were short in-app exercises designed to scaffold cognitive restructuring of negative social experiences and savouring of positive social experiences'* *'Were accompanied by brief written testimonials* (i.e., *short recommendations of specific in-app social challenges written by college students), which were selected to bolster the belief that forming satisfying social connections takes time and effort'*	Attitude towards the behaviour	Interventions that include this BCT are thought to work by promoting a change in the individual's evaluation of the behaviour. Changing the cognitive component of the attitudes towards the behaviour promotes a change in the behaviour itself.
	4.1. Instruction on how to perform the behaviour	*'Get someone a snack from the dining hall,"* and *"When you get the urge to bail on a conversation, ask a couple more questions than you normally would, and really listen to the answer'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
			Skills	It also supports the ability or proficiency acquired through practise.
			Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
	5.4. Monitoring of emotional consequences	*'After completing app-based social challenges, participants were directed to use an interactive mood-rating tool to indicate how they felt about their social experience'*	(No conclusive evidence)	–
	7.1. Prompts/cues	*'Were able to opt to receive intermittent push notification messages that encouraged*	Memory, attention and decision processes	These interventions try to enhance the ability to retain information, focus on aspects of the environment and choose between two or more alternatives.

TABLE 2 (Continued)

Study	BCT	Excerpts	MoA	Explanation
		participants to try new challenges and reflections, to set deadlines for completing challenges, and reminders to come back to the app to mark challenges as completed'	Environmental context and resources	They try to promote changes in people's surroundings that disfavour or favour the targeted behaviour.
			Behavioural cueing	This is probably in a indeliberate way, using prompts from the external environment, from other behaviour, or from automatic thoughts.
Li et al. (2015)	6.1. Demonstration of the behaviour	*'Two qualified coaches who have engaged in physical education over 5 years will teach the participants the correct Baduanjin postures during the whole intervention period'*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.
			Skills	It also supports the ability or proficiency acquired through practise.
	4.1. Instruction on how to perform the behaviour		Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
			(6.1 is also skills and beliefs)	----------
			(6.1) Social learning/imitation	These interventions are thought to work by allowing a process to unfold by which thoughts, feelings, and motivational states observed in others can be adopted and replicated without conscious awareness.
	8.1. Behavioural practise/rehearsal	*'The intervention period in this trial will last 12 weeks. Participants in the Baduanjin exercise group will undergo the regular Baduanjin exercise training at a frequency of 5 days a week with 1 h per day'*	Skills	This BCT works by supporting the ability or proficiency acquired through practise.
			Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
	2.3. Self-monitoring of the behaviour	*'All participants will be required to record their daily activity or sport information during the intervention period'* *'All participants were required to fill in the daily activity log during the intervention period, in which the type, frequency and duration of participants activity in a whole day was recorded and classified as low, moderate or high'*	Behavioural regulation	Interventions that include this BCT supposedly work by promoting behavioural, cognitive and/or emotional skills for managing or changing behaviour.
			Feedback processes	This BCT may also work through a feedback process, by comparing current against a particular standard.
Dvorakova (2017)	4.1. Instruction on how to perform the behaviour	*'Provided with home practise cards (a simple practise*	Knowledge	Interventions that include this BCT are trying to promote the awareness that something exists.

(Continues)

TABLE 2 (Continued)

Study	BCT	Excerpts	MoA	Explanation
	8.1 Behavioural practise/rehearsal	*associated with the core theme)'*	Skills	It also supports the ability or proficiency acquired through practise.
		'Provided with a link to access an audio recording of guided meditations (e.g., body scan, loving-kindness practise) led by the lead facilitators'	Beliefs about capabilities	It probably also acts by enhancing the beliefs about one's ability to successfully carry out a behaviour.
			(8.1 is also skills and beliefs)	
	7.1. Prompts/cues	*'Stickers that reminded them to use mindfulness techniques in response to stress (e.g., three mindful breaths)'*	Memory, attention and decision processes	These interventions try to enhance the ability to retain information, focus on aspects of the environment and choose between two or more alternatives.
		'Advised to place the handout materials in a visible place that would remind them of their participation in the L2B program and their intention to practise mindfulness skills in daily life'	Environmental context and resources	They try to promote changes in people's surroundings that disfavour or favour the targeted behaviour.
			Behavioural cueing	This is probably in a indeliberate way, using prompts from the external environment, from other behaviour, or from automatic thoughts.
	11.2. Reduce negative emotions	*'Introducing simple mindfulness techniques so that students may better manage stressful situations'*	Emotion	Interventions that include this BCT are trying to work by managing complex reaction pattern involving experiential, behavioural, and physiological elements.
	12.6. Body changes	*'Enhancing students' emotion regulation skills, introducing simple mindfulness techniques so that students may better manage stressful situations'*	Behavioural regulation (no conclusive evidence for body changes)	They also act by promoting behavioural, cognitive and/or emotional skills for managing or changing behaviour.
	3.1. Social support (unspecified)	*'Facilitating the learning process in a supportive, group environment'*	Social influences	Interventions that include this BCT target the interpersonal processes that can cause change in one's thoughts, feelings, or behaviours.

interventions (physical activity) ($g = -1.08$, Ezati et al., 2020; $g = -1.51$, Hurdiel et al., 2017) and *Psychological interventions* (*CBT-i*) (Chang et al., 2021; Taylor et al., 2014) had the greatest effect sizes. *Mindfulness interventions* only impacted sleep slightly but showed greater success in improving measures of mental health, such as anxiety and depression, which is not surprising as it's central aims are usually to improve well-being. *Broad health interventions* also reported small but significant effects in sleep indicators, which may have occurred because these interventions targeted multiple health issues that may be interrelated, by increasing physical activity or learning to manage negative emotions, sleep may ultimately be aided. *Psychoeducational interventions* seemed to be the least successful, with only one (Tsai & Li, 2004) reporting some improvements in sleep quality. Hedges' g was not presented for all studies because some lacked important information for its computation (e.g., the number of participants per condition or using a different sleep measure).

4.2 | Meta-analysis results

Half the studies presented a high risk of bias, and none had a low risk of bias (see semaphore in Figure 2). Besides excluding all the studies that presented a high risk of bias, two studies were also excluded (Harmat et al., 2008; Weis et al., 2021) because although they had a moderate risk, they lacked quantitative data to compute Hedges' g. Thus, the meta-analysis included eight studies (see Forest plot in

Figure 3). The estimation of the random effects model showed studies had a small effect in the sleep quality of the participants in the experimental group ($g = -0.26$; 95% CI −0.42 to −0.09), with low levels of heterogeneity ($I^2 = 21\%$) and a small 95% prediction interval (−0.59 to 0.08). The subgroup analysis did not reveal any significant moderators of the effect.

By examining the Funnel plot (Figure 4), it was clear there was some degree of publication bias. The distribution of studies through the areas of significance and non-significance was highly imbalanced, with only one study figuring in the non-significance area. There was also one outlier (Hurdiel et al., 2017) with a large effect but also plenty of standard error associated. Due to the small sample size, it was not possible to run the sensitivity analysis using the Vevea and Hedges weight-function model for publication bias *Shiny app*.

4.3 | Qualitative results

This analysis included the eight studies from the meta-analysis because these cumulatively had the best quality (risk of bias) and quantitative indicators of effect (effect sizes). The coding of these studies led to the identification of 19 different BCTs (from 11 different categories of BCTs). Interventions varied in the number of BCTs employed (minimum of two in Koenig et al., 2013; maximum of seven in Chang et al., 2021), and the most frequent BCT was *'Instruction on how to perform the behaviour'* (n = six). Most BCTs were only reported once or twice (Table S3 in Appendix S1 supplementary file).

The links between BCTs and MoAs are presented in Table 2. The MoAs connected to the most frequently reported BCTs *'Instruction on how to perform the behaviour'* were *'Knowledge'*, *'Skills'*, and *'Beliefs about capabilities'*, meaning that almost all interventions (the least and the most effective ones) were trying to promote an awareness of sleep impairing (or promoting) behaviours, while also supporting one's ability to execute them through practise.

The number of BCTs did not show any relationship to the efficacy of the interventions, as reported above. By looking at the BCTs in Koenig et al., 2013 and Dvorakova, 2017, for instance, it is possible to observe that both studies had small effects, but the first employed two BCTs while the later employed six BCTs. Also, one of the interventions that had the greatest effect sizes (Hurdiel et al., 2017) only employed three BCTs.

5 | DISCUSSION

The literature increasingly points to the fact that college students are poor sleepers, which has implications for their physical health, well-being, and academic performance. As the sleep needs and patterns of young adults who enter the workforce may be different from those who pursue a college education, there will still be some similarities that exist between them, such as progressively reduced parental supervision and increased autonomy and responsibilities (Hirshkowitz et al., 2015), we focused on youth entering adulthood. These factors may put them at risk of developing sleep problems, which can be properly addressed by sleep promoting initiatives. The study of interventions that promote sleep-friendly behaviours in this life phase has been growing, but the key to their success is far from clear. As such, this study proposed to analyse the effects of including behaviour theory in the design of sleep interventions with emerging adults.

The search strategy we employed resulted in the inclusion of 20 studies, depicting six different types of behaviour-change interventions: lifestyle change (physical exercise), psychological (CBT-i), psychoeducational, mindfulness, music therapy, and broad health interventions. All studies used college students as participants and occurred not only in the USA, but also in other parts of the world. The interventions were of varying lengths, employed different delivery modes, used numerous self-report instruments to assess sleep outcomes, and had different methodological features (e.g., active or passive control groups; RCT or non-RCT). Only six studies were based on behaviour-change theories, of which only two could be included in the meta-analysis. This small number of theory-based studies made it impractical to compare them quantitatively on this characteristic.

Due to the high risk of bias present in most studies, only eight were included in the meta-analysis. The studies showed a small effect favouring the intervention condition in the post-intervention period, thus indicating that in the short-term these interventions had an impact, albeit slight, on the sleep quality of emerging adults. The interventions with the greatest effect sizes fall into the categories of *lifestyle change interventions (physical activity)* and *psychological (CBT-i) interventions*. Although the effect sizes were small, they were robust, as our analysis showed low heterogeneity levels. It was not possible to investigate the medium-term effects of these interventions, as there were no sufficient studies with follow up measures.

Contrary to our findings, previous studies, Friedrich & Schlarb, 2018 and Saruhanjan et al., 2021, have found moderate-to-large effect sizes for sleep interventions with young adults, but substantial differences between those studies and the present one need to be considered. First, both those studies employed different inclusion criteria. For example, searches included interventions with college students in general, whereas the present study focused on a specific age range, so some studies with college students outside the age range of emerging adulthood (aged 18–29 years) were excluded. In Saruhanjan et al., 2021, the authors were interested in examining only interventions of a psychological nature, whereas the present study sought for all sorts of behaviour-change interventions. Although we tried to identify studies included in previous systematic reviews that matched our inclusion criteria, only one study (Harmat et al., 2008) was retrieved in this search (from Friedrich & Schlarb, 2018), which also reflects how the scopes and aims of these reviews were different from ours. As such, different pools of included studies, screened for unique inclusion criteria, certainly lead to different results. To compute the meta-analysis, Saruhanjan et al., 2021 used combined effect sizes for each study (i.e., effects of different sleep-related outcomes), while in our study only the PSQI global scores, as a unique effect size, for each study were used. We opted for using the PSQI because it is the most-used instrument among the

studies included and also because using only one type of measurement is often seen as a more conservative approach in meta-analyses concerning the heterogeneity that may result from the combination of results from trials that use different instruments (Puhan et al., 2006). There were also significant divergences regarding the assessment of the quality of the studies, as different guidelines and methods were used for this end in our study and in Saruhanjan et al., 2021. Studies with a high risk of bias were included in the meta-analysis in Saruhanjan et al., 2021, while in our study they were excluded, some of which had the largest effect sizes. Although Saruhanjan et al., 2021 did a subgroup analysis and concluded the risk of bias did not impact the overall effect size, they did not report its change, so there is no way of knowing how much this decision affected their results.

It was not possible to investigate any moderators of the overall effect (e.g., type of intervention, number, and type of BCTs), due to the small sample size. But by looking at the varying number of BCTs used and the effect sizes of each study, it is viable to hypothesise that there may not be a direct link between the quantity of BCTs used and the success of the intervention. A more complex analysis of the characteristics of the interventions, such as the type or number of BCTs used per study, or even elements pertaining to the quality of the implementation of the interventions, may be required to fully understand their variable levels of efficacy.

We may speculate that the interventions that were more successful were probably well designed, following simple and specific instructions – *lifestyle-change interventions (physical activity)*, or had a structure anchored in a behaviour-change theoretical framework that has already been widely tested – *psychological interventions (CBT-i)*. Previous meta-analyses (e.g., Banno et al., 2018; Youngstedt et al., 1997) concluded that exercise may result in some improvements in several sleep outcomes, which is in line with our present findings. A recent meta-analysis on CBT-i interventions for insomnia (van Straten et al., 2018) had already found these types of interventions to be successful, so it is not a surprise they have some effect in the present study too. Also, tailoring sleep education interventions to participants' needs and characteristics is of paramount importance (Dietrich et al., 2016). Psychoeducational interventions tend to be generic in content, which means that participants may have varying needs at baseline that cannot be fulfilled by such an approach. For instance, this may have happened in the only psychoeducational intervention included in our meta-analysis, Perucho et al., 2019, as the BCTs employed in this case aimed particularly to give participants general information about (health and social) consequences that are likely to occur to poor sleepers. If people do not find this information useful to apply to themselves, merely emphasising the relevance of sleep and the consequences of sleep deprivation may not be enough to provoke change – it can even backfire, as participants may feel bored or burdened by irrelevant information (Mead & Irish, 2020). As such, interventions should be co-constructed with input from the participants to better address their beliefs and use their own language, as these aspects may vary from population to population (Fishbein & Cappella, 2006).

Taking a closer look at the most-reported BCT – *'instruction on how to perform the behaviour'* – and its MoA (*Knowledge*, *Skills*, and *Beliefs about capabilities*), it may be supposed that having clear instructions to follow and opportunities to develop abilities related to sleep-friendly behaviours will enhance participants' self-efficacy beliefs, increasing their likelihood of performing those behaviours. A meta-analysis on the Health Action Process Approach in several health domains (Zhang et al., 2019) highlights the role of self-efficacy in predicting health behaviours, showing its value as an underlying construct in health interventions. Both the most and the least successful interventions used this BCT, which suggests that it probably means different things in the context of each intervention. Giving instructions to perform a single behaviour (e.g., in physical activity interventions) is probably different than giving instructions to perform a series of sleep-friendly behaviours (such as in psychoeducational interventions), likely leading to different results. We may also speculate that the combination of various BCTs to target distinct behaviours that boost sleep might also play a role. For instance, in psychological interventions the opportunity to get knowledge about sleep-friendly behaviours, combined with the promotion of behavioural, cognitive, and/or emotional skills for managing those behaviours, is likely to lead to a change in the evaluation of the behaviours (i.e., attitudes). And changing the cognitive component of the attitudes towards the behaviour might promote a change in sleep. But this type of intervention does not solely revolve around individual variables; it also targets contextual variables. By making people act upon the environmental or contextual resources that may disturb sleep (with the use of the BCT *'restructuring of the physical environment'*), there is a chance that sleep will be improved.

The present study has several limitations. All the studies included in this review address interventions that targeted college students specifically, for the simple reason that we were not able to find any study that included emerging adults in a non-college setting. As such, our findings cannot be generalised universally for emerging adults, as some of the features of these interventions may be specific to challenges faced by college students. The overall quality of the studies was questionable, as most did not report enough details to allow for a clear understanding of what was done and how. This led to a meta-analysis that comprised less than half of the studies included in the review, which may have weakened the overall effect size. This lack of detail also applies to the analysis of the BCTs, as it was carried out using the scanty descriptions of the interventions depicted in these studies. If more comprehensive accounts had been provided, more BCTs would probably have been identified, leading to a more profound analysis of the underlying MoAs and the possible rationale behind the effects of the interventions.

We followed rigorous methods in defining our search protocol, and we were especially careful in exactly describing our target population, emerging adults. However, we do acknowledge that the literature concerning people aged 18–29 years is abundant in concepts and definitions that sometimes overlap in age range but follow different theoretical views about this population. As such, some terms that can be applicable to this development phase may have been left out of our searches simply because there may be too many different terms (and their related synonyms) used by different authors with diverse

theoretical views on young adult development. Only with a clear definition of theoretical concepts in the field of young adult development would it be possible to account for all the hypothetical keywords that may be applicable in studies with this population.

Another limitation concerns the fact that only one researcher extracted the data, contrary to the recommendation that two researchers should do data extraction independently. To try to reduce this bias, a second researcher reviewed the extracted data immediately after reading each study, which resulted in very helpful discussions between the two researchers, leading to a more solid data collection process at the end.

The effects of interventions that seek to prevent the development of problems and the promotion of competences in health-related domains are thought to depend upon aspects that are intimately related to the quality of implementation (Berkel et al., 2011), such as participant responsiveness (number of sessions attended, active participation, homework completion) and facilitator implementation (fidelity to programme integrity, quality of delivery, adaptation to the population). Future studies should seek to analyse the contribution of these indicators to sleep interventions effects. However, as already stated, in published literature on sleep interventions specific details about the specificities of the interventions tend to be scarce. Future studies should strive to include as much detail as possible, if not in the published literature, at least in the protocol registration of the trials, to allow for a more complete assessment of interventions.

Less than half the studies included in the meta-analysis had follow-up measures, which prevented us from addressing one of our research goals, which was to evaluate the effects of the interventions beyond the post-intervention period. Future studies should include follow-up measures, to provide a better understanding on the stability of change across time.

This study only investigated sleep quality as an outcome because of the widespread use of PSQI as a sleep quality instrument. It would be interesting to investigate other sleep outcomes in future interventions and reviews, especially objective outcomes, as it is easier nowadays to collect numerous health measures through wearable devices.

We sought to investigate the role of theory in sleep behaviour-change interventions, but the scarcity of studies using explicitly a behaviour-change theoretical background prevented us from reaching definitive conclusions on this matter. We therefore encourage future studies to be more explicit about their theoretical frameworks and to include more details about the interventions in published documents (e.g., registered protocols), to facilitate the process of trying to understand the key 'ingredients' that make interventions work.

AUTHOR CONTRIBUTIONS

All authors contributed to the study design; Ana Pegado and Maria-João Alvarez performed the initial studies' screening; Ana Pegado worked on data extraction and synthesis, with input from Joana Duarte; Ana Pegado and Magda Sofia Roberto conducted risk-of-bias assessments and quantitative data analysis; Ana Pegado, Joana Duarte and Maria-João Alvarez performed qualitative data analysis; Ana Pegado wrote the first draft, and Maria-João Alvarez and Magda Sofia Roberto contributed with considerable input; all authors contributed to the interpretation of results, to a critical revision, and read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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