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Behavioral interventions as treatment for insomnia – A scoping review of randomized controlled trials

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ABSTRACT

Objective: To map behavioral interventions evaluated as a potential treatment for insomnia in previous randomized controlled trials (RCTs) through a scoping review.
Methods: A bibliographic search was performed to gather RCTs evaluating behavioral interventions for insomnia, either diagnosed according to standardized criteria or limited to moderate to severe symptoms. Behavioral interventions included should be: 1. Focused on modifying behaviors that affect sleep, 2. Self-implementable, 3. Suitable for home implementation, and 4. Not depending on or using cognitive/emotional processes. Behavioral interventions were categorized as "increasing/engaging", "reducing/avoiding", and "adjusting/modifying" behaviors.
Results: Forty-nine RCTs were included, with an average of 1.8 RCTs per year and peak publication record in 2015 and 2023 (k = 6 each). Adjusting/modifying behavior interventions were the most frequent (k = 32, 65.3 %), followed by increasing/engaging behaviors (k = 18, 36.7 %). Among individual interventions, multicomponent behavioral therapy with sleep restriction was the most common (k = 17, 34.7 %), followed by sleep restriction alone (k = 9, 18.4 %), yoga and tai chi (k = 6, 12.2 %) and physical exercise (k = 6, 12.2 %). Another nine interventions were listed, with one to four RCTs each.
Conclusion: Despite the ubiquity of advice to practice good sleep hygiene to improve sleep quality, these findings highlight the need for high-quality randomised trials examining which behavioural interventions lead to improved sleep, as many currently being recommended do not have an adequate evidence base.

1. Introduction

Cognitive-behavioral therapy for insomnia (CBT-I) has been established and recognized as the gold-standard treatment for insomnia [1–4]. This psychotherapeutic approach is based on conventional cognitive-behavioral therapy, contextualized, and adapted to treat chronic insomnia. Chronic insomnia is usually caused by maladaptive or dysfunctional cognitive and behavioral factors related to sleep. CBT-I's main aim is to allow individuals to recognize and modify thoughts, habits, and behaviors that trigger, perpetuate, or are otherwise associated with insomnia [2,5].

Although the efficacy of standard multi-component CBT-I is attested by multiple meta-analyses [6–14] and guidelines [1,3,4,15], some practical drawbacks reduce its wide implementation, including the lack of board-certified professionals and the high costs of treatments. Single-component or specific cognitive-behavioral therapeutics might be an alternative, for which evidence has grown recently [16]. Among those, behavioral single-component interventions might be easier to

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implement than cognitive approaches, as they require fewer resources, and are self-applicable, easily understood by patients, and easier to monitor. Some single-component behavioral interventions that are part of CBT-I programs have already been evaluated and found to be effective, including sleep restriction therapy, stimulus control, and relaxation therapy [1].

Behavioral interventions for insomnia are not restricted to those already included in regular CBT-I programs. Behavioral factors are an important aspect of the perpetuation of insomnia symptoms (as per the 3P hypothesis [17]), as clinical insomnia usually involves the establishment of an association with maladaptive sleep habits such as prolonged wake time in bed, daytime napping, and screen exposure close to bedtime. Therefore, any interventions that aim to change habits that might be considered behavioral interventions. Likewise, most of what is generally understood as "sleep hygiene" involves behavioral changes. This scoping review considers behavioral interventions for insomnia as any intervention that aims at either changing habits that might interfere with or worsen sleep or adjusting sleep-related environmental factors possibly interfering with sleep. These interventions might be directed to behaviors that occur either close to bedtime (e.g., avoiding physical exercise or screen exposure close to bedtime) or in other periods during the day (e.g., avoiding daytime napping or engaging in physical exercise). It also encompasses interventions directed at one's own behavior (e.g., sleep timing, physical exercise, and caffeine intake) or at adjusting environmental factors related to sleep (e.g., noise, light, and temperature). This definition is important to differentiate behavioral from cognitive interventions. Rather than changing sleep-related behaviors, cognitive interventions (or cognitive therapies) focus more on changing one's beliefs, concepts, and perceptions of sleep, such as identifying and modifying misconceptions about sleep, maladaptive beliefs, and negative thinking over one's sleep pattern.

Considering this broad definition of behavioral interventions, the number of possible alternatives is immense and varied, making it almost impossible to establish a general conclusion about their effectiveness. While the efficacy of some behavioral interventions, such as sleep restriction and stimulus control, have already demonstrated empirical backings, others have been contraindicated for single-component interventions (such as sleep hygiene) [1]. Exercise has a reasonable foundation of research, however the implementation varies considerably [18–20] In many instances, evidence is too low to endorse some commonly listed sleep hygiene practices [21,22]. Therefore, a literature overview is essential to evaluate which behavioral interventions have been tested and assessed in properly performed randomized controlled trials (RCTs).

This scoping review was performed to investigate and map behavioral interventions that have been evaluated as a potential treatment for insomnia in previously published RCTs, evaluating the temporal progression, research trends, and bibliometric aspects related to each listed behavioral intervention.

2. Methods

2.1. Scoping review

A scoping review is a type of systematic review used to map and analyze a field of research from a broader perspective [23–25]. It is usually used to provide a qualitative overall assessment of the research output on a field, describing its main characteristics and publication trends, rather than to test a hypothesis (as in systematic reviews followed by meta-analyses). This report was prepared according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA [26]) and its extension to scoping reviews (PRISMA-ScR [25]) The protocol was made available at Open Science Framework (OSF - https://osf.io/8ahxg/).

2.2. Behavioral interventions

The central aspect of this scoping review was to map and analyze studies that have evaluated behavioral interventions in individuals with insomnia. To be considered as a behavioral intervention according to the aims of this scoping review, the intervention complied with the following criteria:

- The intervention should have focused on modifying one specific behavior (or a specific set of behaviors) that might interfere or worsen sleep, including environmental factors. However, they do not necessarily have to be primarily associated with sleep (e.g. avoiding physical exercise close to bedtime).
- The intervention should be self-directed and suitable to be performed without healthcare professionals or other individuals' assistance. It is possible that healthcare professionals explain and set the conditions in which a given behavioral change intervention is set (e.g., sleep restriction), but the research participant should be able to implement it autonomously.
- The intervention should be suitable for implementation at home, without needing a healthcare setting.
- The behavioral interventions do not (or very little) depend on or use cognitive or emotional processes.

The behavior change interventions were categorized into three main domains, as disclosed below, and a non-exhaustive list of possible behavioral change interventions is presented in Table 1.

- *Increasing/engaging behaviors*: interventions in which the performance of a behavior should be increased or in which participants should engage in a behavior not performed before.
- *Reducing/avoiding behaviors*: interventions in which the performance of a behavior should be reduced or in which participants should avoid a behavior usually performed previously.
- *Adjusting/modifying behaviors*: interventions in which a particular behavior should be modified or adjusted instead of simply increasing or reducing it.

2.3. Search strategy

The literature search was performed in three databases (PubMed, Web of Science, and Scopus) on August 8th, 2023. The search strings were initially developed for PubMed and then adapted to the other databases' syntax and search engines. The search strategy was composed by combining two components: insomnia (as both population and outcome) and RCTs (as research design). To increase search sensitivity,

Table 1
List of behavioral interventions for insomnia.

Increasing/engaging behaviors	Reducing/avoiding behaviors	Adjusting/modifying behaviors
Doing physical activity	Reducing caffeine intake	Sleep restriction therapy
Bright light therapy	Reducing nicotine use	Sleep timing adjustment
Using blue filter devices	Reducing alcohol consumption	Temperature adjustment of bedroom
Relaxation/ mindfulness	Avoiding screen exposure close to bedtime	
Mind-body exercise (e.g., yoga)	Avoiding physical exercise close to bedtime	
Listening to music before sleep	Reducing bedroom noise and/or light exposure	
Listening to white noise before sleep	Avoiding daytime napping	

This list contains examples of behavioral interventions in each category and should not be interpreted as a complete list. Other interventions might also be included, provided that they fall into the classification criteria for behavioral interventions used in the current study.

no specific search strategy was composed for each behavioral intervention due to the breadth of possibilities. Instead, the behavioral interventions were screened and selected according to the inclusion and exclusion criteria in the eligibility analysis.

A combination of MeSH terms and free terms was used for each of the search components. The search string for insomnia consisted of the search filter proposed by Pires et al. [27]. The search string for RCTs consisted of Cochrane's RCT filter – precision maximizing version [28]. Grey literature or secondary data sources have not been screened. The PubMed search filter can be found below, and the complete search strategy for all databases from a supplementary file.

((“Sleep Initiation and Maintenance Disorders” [mh] OR insomnia [tiab] OR Insomni*[tiab] OR “sleep-onset association disorder”) NOT “fatal familial”) AND ((“randomized controlled trial” [pt] OR “controlled clinical trial” [pt] OR randomized[tiab] OR placebo[tiab] OR “clinical trials as no topic"[mesh:noexp] OR randomly[tiab] OR trial [ti]) NOT (animals [mh] NOT humans [mh]))

2.4. Inclusion and exclusion

Only RCTs evaluating behavioral interventions for insomnia were considered eligible. The restriction to only RCTs is justified by the subjective nature of insomnia and its response to treatment. By excluding observational studies, the possible effect of co-variants, confounders, and methodological biases is reduced. There were no inclusion or exclusion criteria for the outcomes, as any possible outcomes were considered eligible. Only articles in English were included, and there were no exclusion criteria related to publication date. The eligibility analysis was based on the following criteria.

- *Type of article:*
  - o *Inclusion*: Original articles published in peer-reviewed journals, including meta-analyses.
  - o *Exclusion*: Any theoretical article (e.g., editorials, narrative reviews, and letters to the editor), systematic reviews (except meta-analyses), or non-peer-reviewed data (e.g., congress posters and book chapters).
- *Research design:*
  - o *Inclusion:* RCTs.
  - o *Exclusion:* Either of the following items.
    - Any other study design, including case reports, case series, observational studies, non-randomized controlled trials, and cross-over studies. Although cross-over trials can be considered randomized, they were excluded due to the possible biases created by uncertainties related to disease remission or insufficient wash-out period between interventions.
    - Full text was unavailable (only in the second step of data screening).
- *Population:*
  - o *Inclusion:* Either of the following items.
    - Adults with a diagnosis of insomnia disorder according to standardized clinical diagnostic criteria (including but not limited to the Diagnostic and Statistical Manual 5th edition – DSM-V, the International Classification of Diseases 10th revision – ICD10, the International Classification of Sleep Disorders, 3rd edition – ICSD-3, and their previous versions).
    - Adults with moderate to severe insomnia symptoms measured by validated questionnaires (including but not limited to the Insomnia Severity Index – ISI and the Athens Insomnia Scale – AIS). Studies for which the population includes individuals with mild insomnia symptoms were considered eligible if it was possible to extract a group of individuals with moderate to severe symptoms.
  - o *Exclusion:* Any of the following items:
    - Individuals with sleep disorders and complaints other than insomnia.
    - Insomnia was evaluated via self-report or unstandardized diagnostic criteria.
    - Individuals with mild or no insomnia symptoms. Studies for which the populations include multiple insomnia severity levels and for which it was not possible to separate a specific group with moderate to severe insomnia symptoms were considered ineligible.
    - Studies conducted in animals.
- *Intervention*
  - o *Inclusion:* Any intervention primarily composed of behavioral interventions, considering the definitions of behavioral interventions disclosed above. Studies investigating multiple concurrent interventions were deemed eligible if none were considered primarily cognitive. Structured interventions (e.g., brief behavioral therapy) were considered eligible if they did not encompass a significant sleep-related cognitive aspect. Mind-body interventions (yoga, meditation, and mindfulness) were considered eligible if they were not followed or associated with sleep-related cognitive aspects.
  - o *Exclusion:* Either of the items listed below.
    - Behavioral interventions as part of CBT-I interventions of any format (in-person, telemedicine, digital, group, etc.) or other cognitive-oriented therapies, in which the effect of the behavioral components cannot be detached from the cognitive aspects of the therapy.
    - Any cognitive intervention for insomnia (even if concurrent with one of the above behavioral interventions).
- *Comparator/control*
  - o *Inclusion:* Both parallel positive and negative control groups were eligible if they were not subjected to concurrent behavioral change interventions. The following options were eligible comparators: No treatment, placebo, minimal treatment (such as sleep hygiene booklets or lectures), pharmacological treatment, or CBT-I (including in-person, telemedicine, in group, or digital). CBT-I was included as a comparator, as it represents the gold-standard, therapist-delivered treatment for insomnia, allowing behavioral-only interventions to be contextualized against this benchmark.
  - o *Exclusion:* No control group, before-after control group, or group subjected to concurrent behavioral interventions.

2.5. Data screening and evaluation

The records retrieved from the literature search in the three databases were exported into Covidence, where de-duplication and eligibility analyses were performed. Duplicated records were excluded automatically. Two out of three independent reviewers (BH, LS, ER) evaluated each non-duplicated article using a two-step process: initially, titles and abstracts were reviewed, followed by a full-text analysis. An article was only considered eligible in each step if there was consensus regarding the analysis of two reviewers. A fourth reviewer (GNP) solved disagreements between the reviewers. A calibration round was performed at the beginning of the eligibility analysis process to analyze the agreement rates between reviewers. Reviewers evaluated the first 100 records, reaching an overall agreement rate of 87.5 $\pm$ 15.9 % and a Fleiss's kappa index of 0.465, considered as moderate agreement. Once the final sample of eligible studies was reached, data extraction was performed using Covidence by three independent reviewers (BH, LS, ER) and checked by a senior reviewer (GNP). Missing items were filled as “non-available/not applicable” (N/A).

2.6. Data extraction

The following data were extracted.

- *Article metadata*: first author, publication year, source title, and full reference string.

- *Source country*: defined as the country where the participants were enrolled. When this information could not be determined, the source country was determined as the country of the first affiliation of the first author.
- *Sample size*: overall number of individuals in the study and sample size per group.
- *Sex/gender*: male, female, both, other, or N/A.
- *Age*: The age range for inclusion and the mean ± standard deviation (SD) for the whole sample and both groups.
- *Insomnia diagnosis*: Diagnostic criteria and tools used to diagnose insomnia and to enroll participants. It includes the DSM, ICD, and ICSD in all its versions, the ISI, and the AIS.
- *Type of intervention*: Classification of eligible interventions as increasing/engaging behaviors, reducing/avoiding behaviors, and adjusting/modifying behaviors.
- *Intervention:* Any possible behavior change interventions were extracted if they were in accordance with the definition of behavioral interventions used in this study (including but not limited to the options listed in Table 1).
- *Intervention length:* Duration of the intervention protocol.
- *Intervention delivery/usage:* In session only – single session, in session only – recurrent sessions, single/few training + at-home activities, fully autonomous activities (minimal instructions).
- *Primary outcomes:* The main outcomes included a set of variables that might be useful in evaluating insomnia symptoms and response to treatment in individuals with insomnia. It contains only continuous variables acquired from objective (i.e., actigraphy and polysomnography (PSG)) and subjective (sleep logs, questionnaires, and scales) assessment tools.
  - o Insomnia symptoms score (ISI or AIS).
  - o Daytime sleepiness score – overall (Epworth Sleepiness Scale (ESS)).
  - o Daytime sleepiness score – moment (Stanford Sleepiness Scale (SSS) or Karolinska Sleepiness Scale (KSS)).
  - o Sleep quality (Pittsburgh Sleep Quality Index (PSQI)).
  - o Sleep latency (self-reported, actigraphy, or PSG).
  - o Total sleep time (self-reported, actigraphy, or PSG).
  - o Sleep efficiency (calculated from self-reported data, actigraphy, or PSG).
  - o Wake after sleep onset (calculated from self-reported data, actigraphy, or PSG).
  - o Sleep staging (acquired through PSG)
- *Secondary outcomes*: Other outcomes were categorized according to the outcome taxonomy proposed by the Core Outcome Measures in Effectiveness Trials (COMET) [29]. Additionally, sleep-related outcomes were further specified and extracted in two domains:
  - o *Other objective sleep variables*: These included other PSG and actigraphy variables not listed in the primary outcomes and outcomes measured by other objective sleep assessment tools.
  - o *Other subjective sleep variables*: These included outcomes measured by sleep questionnaires and scales not listed in the primary outcomes list.
- *Control group characteristics:* The control groups were categorized as either passive/negative (including no treatment/waiting list, placebo or minimal treatment – sleep hygiene, lifestyle counselling, lectures, etc.) or active/positive (including pharmacological treatment, CBT-I in different presentations, and cognitive therapies, among others).
- *Results:* Results were rated and categorized as “mostly positive”, “mostly neutral”, or “mostly negative".

2.7. Data synthesis and presentation

Results were restricted to a descriptive presentation of data to explore its quantitative and qualitative aspects (known as “charting analysis”). Charts and tables were prepared to explore the behavioral interventions used in previously published RCTs, allowing 1) to evaluate the types of behavioral interventions assessed according to the number of articles published, 2) to analyze the temporal progression of the publication output, and 3) explore the association of the publication output with other variables, such as insomnia diagnostic criteria, outcome types, among others. For descriptive purposes, study outcomes were categorized as ‘mostly positive’, ‘mostly neutral’, or ‘mostly negative’ depending on whether the majority of reported sleep-related outcomes within each study showed statistically significant improvement, no significant change or deterioration respectively.

3. Results

The bibliographic search resulted in 23,592 records. After deduplication, 13,161 non-duplicated records were screened. Forty-nine RCTs were considered eligible after full-text screening, composing our final sample [30–50] [51–78]; (Fig. 1). Details of each included article are available in Table 2, a sample description in Table 3, and a summary of RCT characteristics per behavioral intervention in Table 4.

3.1. Overall sample description

Most of the included RCTs were based on samples from the United States (k = 23, 46.9 %), followed by five from the United Kingdom (k = 5, 10.2 %). The remaining 21 RCTs (42.9 %) were distributed among 14 countries, each with no more than three RCTs (Fig. 2). The timespan under analysis was reasonably short, considering that the first study was published in 1998. The number of RCTs per year was also limited, with an average of 1.8 per year and a bimodal distribution with a maximum publication output of six articles in 2015 and 2023. A time trend was observable, denoting an increase in the number of RCTs in recent years, with a surge after 2012 (Fig. 3) and 71 % of the studies published in the last 10 years (Table 2), although following an erratic growth pattern due to the limited sample.

The population in the eligible RCTs consisted of 26.5 % older adults (>55 years) and the remaining 73.5 % younger adults. Most studies included both men and women (79.6 %), while eight (16.3 %) were restricted to women and two (4.1 %) to men. In most studies (k = 28, 57.1 %), insomnia was evaluated in populations with specific concomitant conditions or characteristics, the most common of them being older adults (k = 13, 26.5 %), followed by postmenopausal women (k = 4, 8.2 %), cancer patients (k = 3, 6.1 %), and military veterans (k = 3, 6.1 %).

Regarding insomnia diagnosis, most studies applied the DSM criteria, covering editions three to five (k = 38, 77.6 %), while 14 used the ICSD criteria, covering editions one to three (k = 14, 28.6 %). Only one study was included based on ISI criteria (restricted to ISI score >7). Of note, many RCTs were excluded due to using ISI-related inclusion criteria encompassing mild (or subthreshold) insomnia symptoms.

Primary outcome measures were mainly subjective sleep assessment methods. Self-reported sleep data (including sleep logs/diaries) were reported by 25 RCTs (51.0 %). Among questionnaires, the ISI was the most common (k = 23, 46.9 %). PSG and actigraphy were used as outcome measures only by 12 RCTs each (24.5 %).

3.2. Behavioral interventions

Adjusting/modifying behavior interventions were the most frequent (k = 32, 65.3 %). This category includes the most elaborate interventions, such as structured behavioral therapy programs, mindfulness-based therapies, sleep restriction, and stimulus control. More straightforward interventions were more likely to be categorized as increasing/engaging or reducing/avoiding behaviors.

Increasing/engaging behaviors were used in 18 RCTs (36.7 %) and encompassed mainly physical activity-related activities. On the other hand, reducing/avoiding behaviors were only used by a single article (2.0 %), evaluating blocking/avoiding light exposure at night (Figs. 3

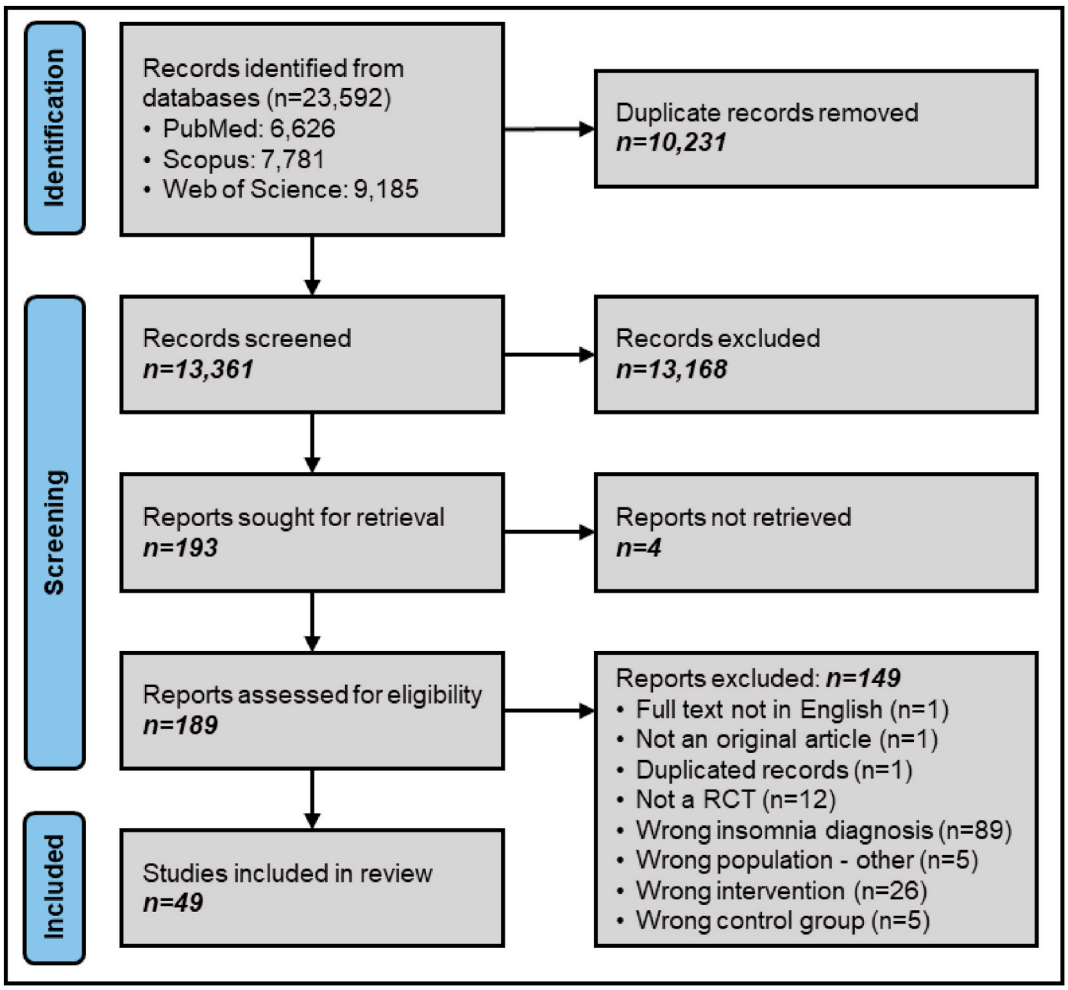

Fig. 1. Flowchart of article selection.

and 4). Among the types of interventions, multi-component behavioral therapy with sleep restriction was the most common (k = 17, 34.7 %), followed by sleep restriction alone (k = 9, 18.4 %), yoga and tai chi (k = 6, 12.2 %), and physical exercise (k = 6, 12.2 %). Another nine interventions were listed, with one to four RCTs each (Fig. 4). Most behavioral interventions for insomnia anticipated in the protocol (Table 1) were not evaluated in any RCTs and therefore were not included in this review. This includes habits usually associated with insomnia and often listed in sleep hygiene lists, such as reducing or avoiding caffeine intake, nicotine use, alcohol consumption, screen exposure close to bedtime, and avoiding daytime napping.

The duration of the interventions varied considerably, with the majority lasting one to four weeks (k = 19, 38.8 %). Longer intervention durations and follow-ups were less frequently reported, with three RCTs reporting interventions of 13–24 weeks (6.1 %) and three with interventions for more than 24 weeks (6.1 %).

The results of the interventions were considered "mostly positive" for the vast majority of the RCTs (k = 46, 93.9 %). The results of three studies were considered "mostly neutral" (6.1 %), and none were considered "mostly negative".

4. Discussion

This scoping review sought to assess the availability of experimental research examining the efficacy of individual behavioral interventions for treating insomnia. By mapping and ranking interventions based on publication frequency and analyzing trends and bibliometric characteristics, this review aimed to identify research gaps and provide insights into the field's evolution.

Despite the ubiquity of advice to practice good sleep hygiene to improve sleep quality [21], our results demonstrate that many behavioral recommendations for insomnia have not been empirically tested using RCTs. While forty-nine RCTs were included in our study, which might seem a reasonable sample, these forty-nine studies represent twelve different intervention types (Table 4). When taking each possible behavioral intervention independently, the only two that have resulted in a significant number of RCTs are multi-component behavioral therapy with sleep restriction and sleep restriction therapy alone. No other interventions (including lifestyle, complementary, and common sleep hygiene recommendations) have resulted in more than six RCTs each.

While there is most certainly a strong logic for the importance of sleep hygiene, this review highlights a significant lack of research examining whether changing behaviors associated with sleep hygiene is likely to lead to an improvement in sleep quality for people experiencing insomnia. Furthermore, the experimental evidence available to support particular behavioral interventions is thinly spread across demographics, behavior type, and how the behavior is experimentally implemented. This further dilutes the relevance of research for future implementation, making meta-analyses or other evidence-synthesis approaches for behavioral interventions less likely.

Our rigorous inclusion criteria likely explain the low number of included studies. In particular, the restriction to RCTs and the requirement for insomnia diagnoses based on well-defined criteria (either by standardized diagnostic criteria or limited to moderate to severe

Table 2
Characteristics of the studies included in this scoping review.

Study	Country	Age range	Sex/ gender	Concurrent populational criteria	Insomnia diagnosis criteria	Intervention	Intervention duration	Intervention delivery	Mode of delivery	Primary outcomes	Other sleep outcomes	Control procedures	Perception of results
[30]	France	18–64	Female		DSM-5	Physical exercise	12 weeks	In-session only - recurrent sessions	In-person/ Under supervision	Actigraphy; Self-reported sleep data		No treatment/ waiting list	Mostly positive
[31]	Israel	ND	Both	PTSD	DSM-IV	Listening to music; Relaxation techniques/ exercises	3 weeks	Single/few training sessions + at-home activities	Digital intervention	Actigraphy	MSQ; Technion sleep questionnaire	No treatment/ waiting list	Mostly positive
[32]	USA	≥18	Both		DSM-5	Multi-component behavioral therapy with sleep restriction	5 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Digital intervention	ISI; ESS; PSQI; Self-reported sleep data		CBT-I - in person	Mostly positive
[33]	USA	ND	Both	Older adults	DSM-IV; ICSD 2	Multi-component behavioral therapy with sleep restriction	4 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision; Digital intervention	ESS; PSQI; Actigraphy; PSG; Self-reported sleep data		Minimal treatment	Mostly positive
[34]	USA	≥55	Both	Older adults	DSM-IV; ICSD 2	Yoga/Tai Chi	16 weeks	In-session only - single-session	In-person/ Under supervision	PSQI	Rate of insomnia remission	Minimal treatment; Cognitive therapy (apart from a full CBT-I program)	Mostly positive
[35]	USA	ND	Both	Older adults	DSM-5	Multi-component behavioral therapy with sleep restriction	4 weeks	In-session only - recurrent sessions	In-person/ Under supervision	Self-reported sleep data; Actigraphy		Minimal treatment	Mostly positive
[36]	USA	≥18	Female	Postmenopausal women	DSM-5	Sleep restriction/ compression alone	6 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision; Digital intervention	PSG: Self-reported sleep data	MSLT	Minimal treatment; CBT-I - in person	Mostly positive
[37]	USA	≥18	Female	Postmenopausal women	DSM-5	Sleep restriction/ compression alone	6 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Digital intervention	ISI; Self-reported sleep data		Minimal treatment; CBT-I - in person	Mostly positive
[38]	Canada	≥25	Both		DSM-IV	Multi-component behavioral therapy with sleep restriction	8 weeks	In-session only - recurrent sessions	In-person/ Under supervision	ISI; Self-reported sleep data	DBAS	Cognitive therapy (apart from a full CBT-I program)	Mostly positive
[39]	New Zealand	16–75	Both		ICSD 2	Sleep restriction/ compression alone	4 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ISI; ESS; PSQI; Self-reported sleep data; Actigraphy		Minimal treatment	Mostly positive
[40]	USA	≥55	Both	Older adults	ICSD 2	Bright light therapy	12 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ESS; Self-reported sleep data; Actigraphy; PSG	Spielman Insomnia Symptom Questionnaire, Sleep Hygiene Questionnaire, MEQ	Minimal treatment	Mostly neutral

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Table 2 (*continued*)

Study	Country	Age range	Sex/ gender	Concurrent populational criteria	Insomnia diagnosis criteria	Intervention	Intervention duration	Intervention delivery	Mode of delivery	Primary outcomes	Other sleep outcomes	Control procedures	Perception of results
[41]	Brazil	50–65	Female	Postmenopausal women	DSM-5	Relaxation techniques/ exercises; Mindfulness-based interventions	8 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ISI; PSQI		Minimal treatment	Mostly positive
[42]	Canada	≥18	Both	Cancer patients	DSM-IV	Yoga/Tai Chi; Mindfulness-based interventions	8 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ISI	DBAS	CBT-I - in person	Mostly positive
[43]	USA	≥60	Both	Older adults; Treatment-resistant depression	DSM-5	Multi-component behavioral therapy with sleep restriction	8 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision	ISI; Self-reported sleep data		No treatment/ waiting list	Mostly positive
[44]	USA	≥60	Both	Older adults	DSM-IV	Multi-component behavioral therapy with sleep restriction	4 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	PSQI; Self-reported sleep data		Minimal treatment	Mostly positive
[45]	USA	18–60	Both	Military veterans	ICSD 2	Multi-component behavioral therapy with sleep restriction	4 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ISI; PSQI; PSG		Minimal treatment	Mostly positive
[46]	USA	25–65	Both		ICSD 2	Multi-component behavioral therapy with sleep restriction; Mindfulness-based interventions	8 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ISI		Minimal treatment	Mostly positive
[47]	South Africa	20–60	Male	Alcohol abuse disorder	DSM-III	Relaxation techniques/ exercises	2 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	Self-reported sleep data		No treatment/ waiting list	Mostly positive
[48]	UK	≥40	Both	Physically inactive individuals	ICSD 2	Physical exercise	24 weeks	Fully autonomous (minimal instructions)	Autonomous activities	ISI; ESS; Actigraphy		No treatment/ waiting list	Mostly positive
[49]	USA	≥25	Both		DSM-IV; ICSD 2	Multi-component behavioral therapy with sleep restriction	8 weeks	In-session only - recurrent sessions	In-person/ Under supervision	ISI; Self-reported sleep data; PSG		CBT-I - in person; Cognitive therapy (apart from a full CBT-I program)	Mostly positive
[50]	USA	≥25	Both		DSM-IV	Multi-component behavioral therapy with sleep restriction	8 weeks	In-session only - recurrent sessions	In-person/ Under supervision	ISI; Self-reported sleep data	Sleep Behavior Rating Scale (SBRS)	CBT-I - in person; Cognitive therapy (apart from a full CBT-I program)	Mostly positive
[51]	Taiwan	ND	Female	Female hospital nurses on rotating shifts	Insomnia severity index	Bright light therapy; Blocking/	2 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision;	ISI		Minimal treatment	Mostly positive

(*continued on next page*)

Table 2 (*continued*)

Study	Country	Age range	Sex/ gender	Concurrent populational criteria	Insomnia diagnosis criteria	Intervention	Intervention duration	Intervention delivery	Mode of delivery	Primary outcomes	Other sleep outcomes	Control procedures	Perception of results
						avoiding light exposure at night			Autonomous activities				
[52]	USA	42–83	Female	Breast cancer survivors	DSM-IV	Yoga/Tai Chi	12 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision	ESS; PSQI		CBT-I - in person	Mostly positive
[53]	Denmark	18–65	Both		DSM-5	Listening to music	3 weeks	Fully autonomous (minimal instructions)	Digital intervention	ISI; PSQI; Actigraphy; PSG		No treatment/ waiting list; Other (audiobook)	Mostly positive
[54]	Switzerland	≥18	Both		ICSD 3	Sleep restriction/ compression alone	8 weeks	Fully autonomous (minimal instructions)	Digital intervention; Autonomous activities	ISI; PSQI; Self-reported sleep data	DBAS	No treatment/ waiting list	Mostly positive
[55]	UK	≥18	Both		DSM-5	Sleep restriction/ compression alone	48 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision	ISI		Minimal treatment	Mostly positive
[56]	China	ND	Both		ICSD 3	Physical exercise	12 weeks	Fully autonomous (minimal instructions)	Autonomous activities	ISI; ESS; PSQI		Pharmacological treatment	Mostly positive
[57]	USA	≥59	Both	Older adults	ICSD 1	Sleep restriction/ compression alone; Relaxation techniques/ exercises	2 weeks	Fully autonomous (minimal instructions)	In-person/ Under supervision; Autonomous activities	ESS; PSG; Self-reported sleep data	Insomnia impact scale, DBAS	Minimal treatment	Mostly positive
[58]	Brazil	48–65	Female	Postmenopausal women	DSM-5	Aromatherapy	4 weeks	Recurrent sessions + at home activities; Fully autonomous (minimal instructions)	In-person/ Under supervision; Autonomous activities	ESS; Self-reported sleep data		Placebo	Mostly positive
[59]	USA	18–75	Both	Military veterans	DSM-5	Multi-component behavioral therapy without sleep restriction	4 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision; Digital intervention	ISI; ESS; PSQI; Self-reported sleep data	Insomnia quality of life scale	Other (muscle relaxation)	Mostly positive
[60]	UK	≥18	Female	Breast cancer patients	ICSD 2	Bed linen interventions	4 weeks	Fully autonomous (minimal instructions)	Autonomous activities	Self-reported sleep data		Minimal treatment	Mostly positive
[62]	UK	25–55	Both		DSM-5	Sleep restriction/ compression alone	12 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision	ISI; Self-reported sleep data; PSG		Minimal treatment	Mostly positive
[61]	UK	35–55	Both		DSM-5	Sleep restriction/ compression alone	12 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision	ESS; PSG;		Other (Time in bed regularization)	Mostly positive
[63]	USA	≥65	Both	Older adults	DSM-IV	Multi-component behavioral therapy with sleep restriction	2 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision	Self-reported sleep data		Minimal treatment	Mostly positive

(*continued on next page*)

Table 2 (*continued*)

Study	Country	Age range	Sex/ gender	Concurrent populational criteria	Insomnia diagnosis criteria	Intervention	Intervention duration	Intervention delivery	Mode of delivery	Primary outcomes	Other sleep outcomes	Control procedures	Perception of results
[64]	Brazil	30–55	Both		DSM-IV	Physical exercise	1 week	In-session only - recurrent sessions	In-person/ Under supervision	PSG; Self-reported sleep data		No treatment/ waiting list	Mostly positive
[65]	USA	18–75	Both	Military veterans	DSM-5	Multi-component behavioral therapy without sleep restriction	24 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision	ISI; PSQI		Other (muscle relaxation)	Mostly positive
[66]	USA	19–80	Both		ICSD 1	Stimulus control alone	8 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	ESS; Self-reported sleep data		Minimal treatment	Mostly positive
[67]	Sweden	≥18	Both		DSM-5	Sleep restriction/ compression alone	10 weeks	Recurrent sessions + at-home activities	Digital intervention	PSG		Sleep compression	Mostly neutral
[68]	USA	25–49	Both		DSM-IV; ICSD 2	Multi-component behavioral therapy with sleep restriction	48 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision	ISI; Self-reported sleep data		CBT-I - in person	Mostly positive
[69]	Hong Kong	≥60	Both	Older adults	DSM-5	Yoga/Tai Chi; Physical exercise	12 weeks	In-session only - recurrent sessions	In-person/ Under supervision	PSQI; Actigraphy		No treatment/ waiting list	Mostly positive
[71]	Sweden	ND	Both		DSM-5	Multi-component behavioral therapy with sleep restriction	10 weeks	Recurrent sessions + at-home activities	Digital intervention	ISI; Self-reported sleep data		No treatment/ waiting list	Mostly positive
[70]	Sweden	ND	Both		DSM-5	Multi-component behavioral therapy with sleep restriction	10 weeks	Recurrent sessions + at-home activities	Digital intervention	ISI		CBT-I - digital/app	Mostly neutral
[72]	Finland	30–65	Male	Overweight and obese men	DSM-IV	Physical exercise	26 weeks	Single/few training sessions + at-home activities	Autonomous activities	Self-reported sleep data	Beddit sleep monitor	No treatment/ waiting list	Mostly positive
[73]	USA	≥60	Both	Older adults	DSM-IV	Multi-component behavioral therapy with sleep restriction	4 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision; Autonomous activities	PSQI; Actigraphy; PSG;		Minimal treatment	Mostly positive
[74]	USA	ND	Both	Older adults; Nocturia	DSM-IV	Multi-component behavioral therapy with sleep restriction	4 weeks	Single/few training sessions + at-home activities	In-person/ Under supervision; Autonomous activities	PSQI; Self-reported sleep data; Actigraphy		No treatment/ waiting list	Mostly positive
[74]	USA	≥60	Both	Older adults; Nocturia	DSM-IV	Multi-component behavioral therapy with sleep restriction	4 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	PSQI; Actigraphy; Self-reported sleep data		Minimal treatment	Mostly positive
[77]	India	18–45	Both		DSM-5	Yoga/Tai Chi	4 weeks	Single/few training sessions + at-home activities	Autonomous activities	PSQI		No treatment/ waiting list	Mostly positive

(*continued on next page*)

Table 2 (*continued*)

Study	Country	Age range	Sex/ gender	Concurrent populational criteria	Insomnia diagnosis criteria	Intervention	Intervention duration	Intervention delivery	Mode of delivery	Primary outcomes	Other sleep outcomes	Control procedures	Perception of results
[76]	India	18–45	Both		DSM-5	Yoga/Tai Chi	7 weeks	In-session only - recurrent sessions; Fully autonomous (minimal instructions)	In-person/ Under supervision; Autonomous activities	PSQI		Conventional medical treatment	Mostly positive
[78]	China	≥75	Both	Older adults	DSM-IV	Mindfulness-based interventions	8 weeks	Recurrent sessions + at-home activities	In-person/ Under supervision; Autonomous activities	PSQI		No treatment/ waiting list	Mostly positive

Abbreviations: CBT-I: Cognitive-behavioral therapy for insomnia. DBAS: Dysfunctional beliefs and attitudes about sleep scale. DSM: Diagnostic and Statistical Manual of Mental Disorders. ESS: Epworth sleepiness scale. ICSD: International Classification of Sleep Disorders. ISI: Insomnia severity index. MSLT: Multiple sleep latency test. MSQ: Morningness-Eveningness Questionnaire. ND: Not disclosed. PSG: Polysomnography. PSQI: Pittsburgh sleep quality index. UK: United Kingdom USA: United States of America.

insomnia symptoms) contributed to this limitation. Increasing the flexibility of these criteria would undoubtedly lead to a larger sample, as studies evaluating behavioral interventions utilizing observational study designs (mostly cross-sectional and cohort studies) or with samples of milder or poorly characterized insomnia symptoms are numerous. However, doing so would compromise our intention to map clinically meaningful behavioral interventions and decrease the average methodological quality of the sample.

Rigorous and methodologically robust RCTs about pharmacological interventions for insomnia have been available since the 1990s, and a surge in well-performed RCTs about CBT-I (both in-person and digital) has been observed in the last decade [79]. In all these cases, both the number and the quality of these RCTs have been sufficient to allow the performance of meta-analyses, thus generating adequate evidence to safely recommend these interventions for the treatment of insomnia on the most recent guidelines [1,3,4,15].

For this reason, rather than including observational studies and milder insomnia populations in our scoping review, we preferred to focus on rigorously defined insomnia. Therefore, unlike pharmacological and multi-component cognitive interventions, the RCT publication output and the consequent evidence about behavioral interventions are limited. Not surprisingly, isolated behavioral interventions and sleep hygiene, in general, are usually not recommended in the available insomnia treatment guidelines (with exceptions to single-component behavioral restriction therapy).

CBT-I is obviously an important tool for addressing insomnia symptoms and treating insomnia disorders [1,3,4,15], and as the usual CBT-I protocols naturally include structured behavioral modules. Some of these guidelines even recommended single-component behavioral interventions for insomnia, mainly sleep restriction therapy and stimulus control therapy (1, 4). However, it may be noted that these behavioral interventions are complex constructs, for which the proper implementation requires an experienced psychologist to customize behavioral modules to the patient's insomnia profile and needs and are not simply composed of simple behavioral modification advice (such as most of those included in Table 1). For these simple behavioral modifications (usually part of sleep hygiene lists), there remains a significant lack of empirical evidence to determine which, and how much they can contribute to improvements in sleep quality and insomnia symptoms.

As previously argued, behavioral modification interventions (primarily those usually listed in sleep hygiene recommendations) have advantages, including being more straightforward to implement than cognitive approaches, requiring fewer resources, and being self-implementable. However, implementing these interventions seems more based on theoretical reasoning for insomnia physiopathology than solid scientific evidence. Although sleep hygiene can be clinically valuable for the prevention of insomnia and the management of milder insomnia symptoms, its limited evidence does not allow its implementation for the treatment of clinically meaningful insomnia disorder.

While the limited publication output remains our study's main concluding remark, the following subsections further explore some other points raised in this scoping review.

4.1. Intervention characteristics

This review aimed to include a broad range of behavioral interventions for insomnia being tested in RCTs. However, the diversity of behavioral interventions and the number of RCTs analyzing each of them were reduced and smaller than anticipated.

The findings revealed that "adjusting/modifying" behaviors—including structured behavioral therapy, sleep restriction, and stimulus control have dominated research efforts. Of these, multi-component behavioral therapies, often combining several strategies, received the most attention. However, although they demonstrate the effectiveness of combined strategies, they do not show the efficacy of individual behaviors in improving sleep quality. The second most

Table 3
Sample description of the included studies.

	RCTs	%		RCTs	%
Publication year rowhead			**Intervention length**		
1998–1999	2	4.1 %	1–4 weeks	19	38.8 %
2000–2004	1	2.0 %	5–8 weeks	14	28.6 %
2005–2009	3	6.1 %	9–12 weeks	10	20.4 %
2010–2014	9	18.4 %	13–24 weeks	3	6.1 %
2015–2019	16	32.7 %	>24 weeks	3	6.1 %
2020–2023	19	38.8 %	**Intervention delivery/implementation**		
Age ranges rowhead			In-session only - single-session	1	2.0 %
Adults (18–54)	15	30.6 %	In-session only - recurrent sessions	8	16.3 %
Older adults (≥55)	13	26.5 %	Training sessions + at-home activities	11	22.4 %
Adults overall (≥18)	14	28.6 %	Recurrent sessions + at-home activities	23	46.9 %
Sex/Gender rowhead			Fully autonomous (minimal instructions)	8	16.3 %
Female	8	16.3 %	**Mode of delivery**		
Male	2	4.1 %	In-person/Under supervision	38	77.6 %
Both	39	79.6 %	Digital intervention	11	22.4 %
Concurrent populational criteria rowhead			Autonomous activities	23	46.9 %
Older adults	13	26.5 %	**Primary outcome**		
Postmenopausal women	4	8.2 %	Self-reported sleep data	25	51.0 %
Cancer	3	6.1 %	ISI	23	46.9 %
Military veterans	3	6.1 %	PSQI	18	36.7 %
Nocturia	2	4.1 %	ESS	12	24.5 %
Alcohol abuse disorder	1	2.0 %	Actigraphy	12	24.5 %
Nurses	1	2.0 %	PSG	12	24.5 %
Treatment-resistant depression	1	2.0 %	**Control group**		
Overweight and obese individuals	1	2.0 %	Minimal treatment/Placebo	20	40.8 %
Physically inactive individuals	1	2.0 %	No treatment/waiting list	12	24.5 %
PTSD	1	2.0 %	CBT-I - in person	8	16.3 %
Insomnia diagnostic criteria rowhead			Cognitive therapy	4	8.2 %
DSM	38	77.6 %	CBT-I - digital/app	1	2.0 %
ICSD	14	28.6 %	Pharmacological treatment	1	2.0 %
ISI	1	2.0 %	Other	5	10.2 %
Type of behavioral intervention rowhead			**Perception of results**		
Adjusting/modifying behaviors	32	65.3 %	Mostly positive	46	93.9 %
Increasing/engaging behaviors	18	36.7 %	Mostly neutral	3	6.1 %
Reducing/avoiding behaviors	1	2.0 %			

Abbreviations: CBT-I: Cognitive-behavioral therapy for insomnia. DSM: Diagnostic and Statistical Manual of Mental Disorders ESS: Epworth sleepiness scale. ICSD: International Classification of Sleep Disorders. ISI: Insomnia severity index. PSG: Polysomnography. PSQI: Pittsburgh sleep quality index. PTSD: Post-traumatic stress disorder.

popular area of investigation was 'increasing/engaging' type behaviors, focusing on physical exercise and mind-body interventions (such as yoga, tai chi, or other exercise modalities), but still with fewer RCTs for each of these modalities.

There are meta-analyses evaluating the effects of exercise and mind-body interventions on insomnia, usually encompassing samples higher than the one included in our study. That is generally due to using unspecific or loose inclusion criteria for insomnia. For example, in a meta-analysis about the effects of yoga on sleep quality and insomnia in women [80], the inclusion criteria was only the evaluation of sleep by

Table 4
List of behavioral interventions for insomnia with the nature of the cohorts that these interventions have been tested with.

Increasing/engaging behaviors	Number of RCTs	Special Populations
Doing physical activity	6	≥ years old cancer patients, ≥40, ND, 30–55, ≥60, 30–65 overweight males,.
Bright light therapy	2	≥55, female nurses
Using blue filter devices	Nil	
Relaxation/mindfulness	7	PTSD, 50–65 postmenopausal, ≥18 cancer patients, 20–60 male, ≥59, ≥60, ≥75
Mind-body exercise (e.g., yoga)	5	≥55, ≥18 cancer patients, 42–83 breast cancer survivors, 18–45 (k = 2)
Listening to music before sleep	2	PTSD, 18 -65
Listening to white noise before sleep	Nil	
Increase daytime light exposure	Nil	
Reducing/avoiding behaviors		
Reducing caffeine intake	Nil	
Reducing nicotine use	Nil	
Reducing alcohol consumption	Nil	
Avoiding screen exposure close to bedtime	Nil	
Avoiding physical exercise close to bedtime	Nil	
Reducing bedroom noise and/or light exposure	1	Female nurses
Avoiding daytime napping	Nil	
Adjusting/modifying behaviors		
Sleep restriction therapy	8	≥18 post-menopausal (k = 2), 16–75, ≥18 (k = 2), ≥59, 25–55, 35–55, ≥18
Sleep timing adjustment	Nil	
Temperature adjustment of bedroom	Nil	
Multicomponent		
Multicomponent BT with sleep restriction	18	≥18, older adults (k = 2), ≥25, ≥60 (k = 4), 18–60, 25–65, ≥25 (k = 2), 18–75 military veterans, ≥65, 25–49, ND (k = 3)

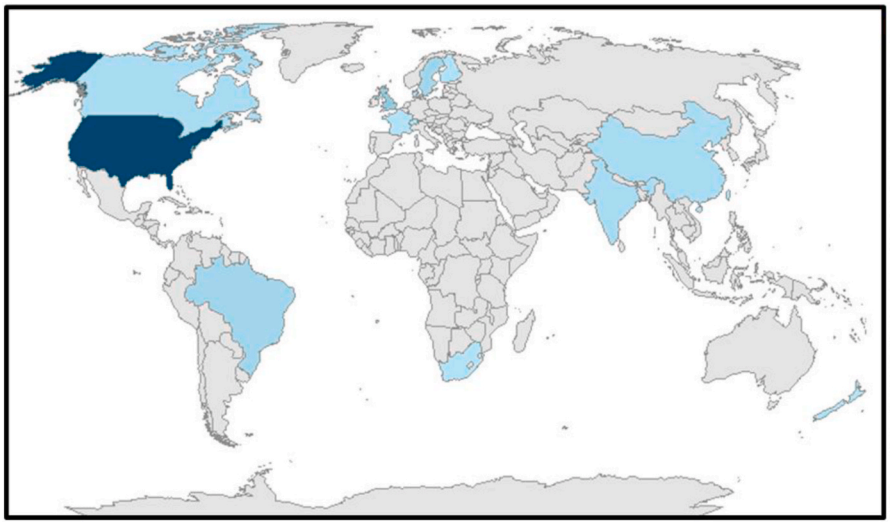
means of PSQI or ISI, regardless of any predefined baseline diagnostic threshold. In addition, out of 19 included studies, only three had ISI results available, all with baseline ISI scores mainly in the subthreshold insomnia range (>15). The yoga intervention did not significantly affect ISI scores in this meta-analysis. Likewise, a recently published meta-analysis intended to evaluate the effects of tai chi on insomnia patients [81]. However, the inclusion criteria considered only the PSQI to screen patients with insomnia. PSQI is a reliable measure of sleep quality but, cannot be taken as a proxy for insomnia diagnosis, as it subjects the sampling to a low specificity and high false positive risk. Therefore, the results of this meta-analysis cannot be considered valid for clinically characterized insomnia.

Interventions such as reducing caffeine, nicotine, alcohol, or screen exposure were conspicuously missing from our sample research despite their frequent promotion in sleep hygiene guidelines. This imbalance in evidence availability underscores a need for further exploration of under-studied interventions. Additionally, while multi-component approaches show promise, it remains unclear which elements within these interventions drive efficacy. The limited number of studies examining singular behavioral interventions makes it difficult to determine whether the behavior itself is new to the individual or if other factors, such as high stress, pain, obesity, or other underlying conditions play a more dominant role than the absence of the intervention being studied. In essence, behavioral interventions should be in response to a noted absence or presence of a particular behavior. This future research (ideally RCTs) should prioritize dismantling studies to isolate and evaluate individual components.

4.2. Research trends

There has been an apparent increase in experimental research on behavioral interventions for insomnia, with over 71 % of studies published in the past decade, although following an erratic growth pattern, possibly due to the small number of RCTs included. However, although there has been a growth in the number of articles published, the absolute publication output is still insufficient compared to other treatment modalities for insomnia. In a recent meta-epidemiological study with equivalent inclusion criteria to ours [79], it was demonstrated that the number of RCTs about both pharmacological and cognitive-behavioral interventions for insomnia is growing, being significantly higher than the RCTs of behavioral interventions. As a matter of comparison, 132 RCTs were included, and the single interventions for insomnia with more RCTs published are digital CBT-I (k = 35), in-person CBT-I (k = 28), and zolpidem (k = 22). Therefore, the number of RCTs about isolated behavioral interventions is smaller than those about pharmacological and cognitive-behavioral interventions.

A significant part of the sample was performed addressing specific populations, such as older adults, postmenopausal women, cancer patients, and military veterans. While these targeted studies provide valuable insights, they raise questions about the findings'



Country	RCTs	%
Brazil	3	6.1%
Canada	2	4.1%
China	2	4.1%
Denmark	1	2.0%
Finland	1	2.0%
France	1	2.0%
Hong Kong	1	2.0%
India	2	4.1%
Israel	1	2.0%
New Zealand	1	2.0%
South Africa	1	2.0%
Sweden	3	6.1%
Switzerland	1	2.0%
Taiwan	1	2.0%
UK	5	10.2%
USA	23	46.9%
Total	49	

Fig. 2. Geographical origin of the included RCTs.

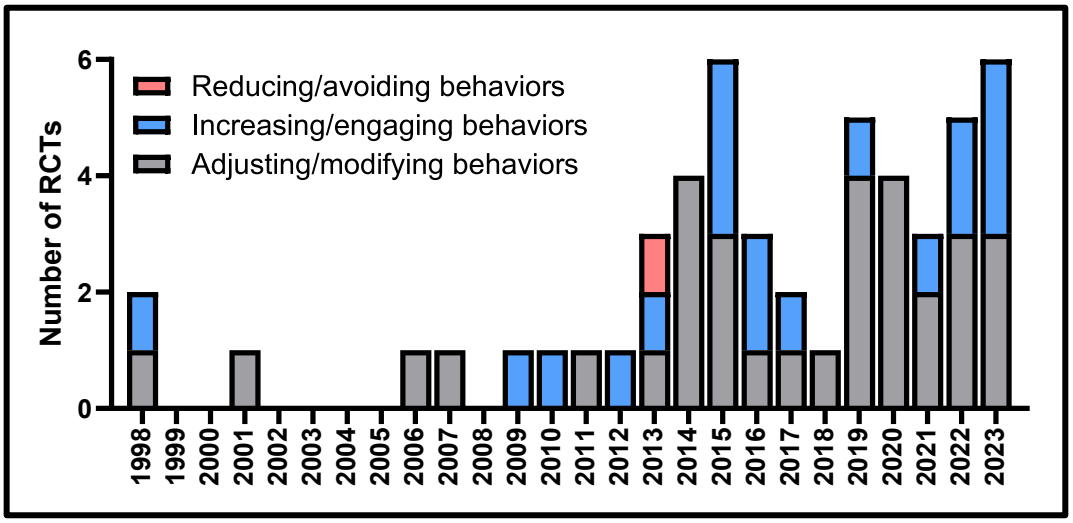


Fig. 3. Publication output over time, stratified by type of behavioral interventions. **Abbreviations:** RCT: Randomized controlled trial.

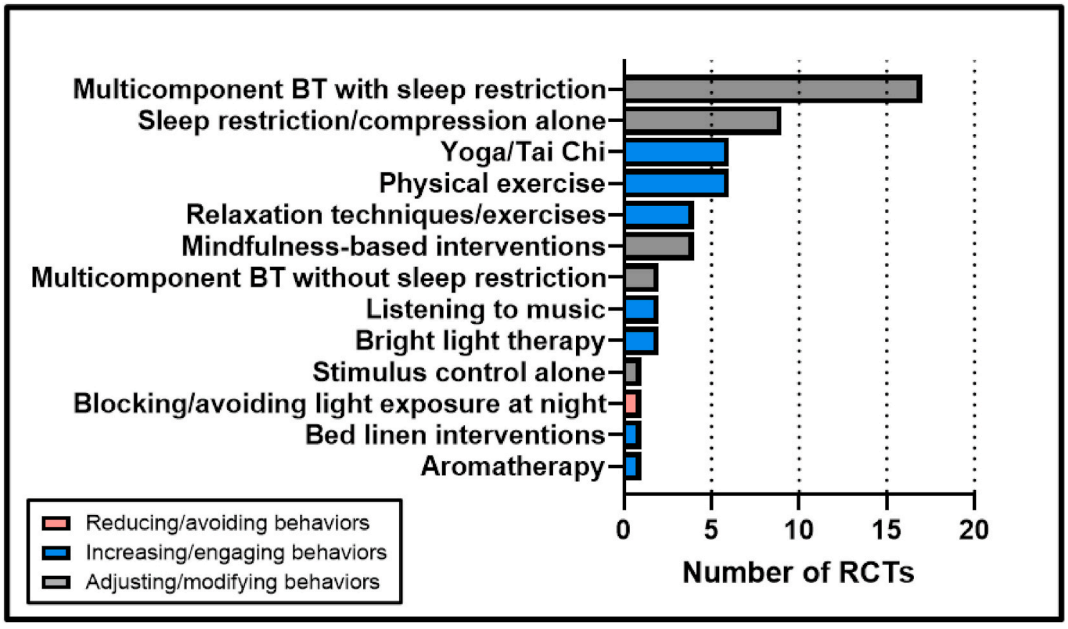


Fig. 4. Number of RCTs per intervention. **Abbreviations:** BT: Behavioral therapy. RCT: Randomized controlled trial.

generalizability and external validity to broader populations. For example, in the case of increasing sunlight exposure, research has only been undertaken with older adults and female nurses (Table 4). More RCTs would be required on samples of insomnia patients regardless of further specification so the reliability of the results could be understood in its general aspects.

Geographically, most research was conducted in the United States, which accounts for almost half of the publication output in this field, while the remaining half is divided among 15 other countries. The reasons for this uneven global distribution of the publication output are unclear. Still, they might reflect the typical leading position of the United States in the number of publications, which has also been demonstrated in other bibliometric analyses regarding obstructive sleep apnea [82], insomnia [83], and sleep-related meta-analyses [84]. Disparities in funding, infrastructure, or research priorities across regions cannot be confirmed, considering the limited sample available. Expanding research efforts internationally would provide more diverse perspectives and enhance the generalizability of findings.

4.3. Outcome measures

Sleep outcomes were predominantly measured through subjective sleep assessment tools. Self-reported sleep data (including sleep diaries) was the most common outcome assessment method, while ISI was the most commonly used sleep questionnaire. Subjective sleep assessment methods are appropriate tools for measuring outcomes related to insomnia in RCTs [85], as they reflect the subjective nature of sleep disorders and the patient's perceptions of their symptoms. However, despite the validity of self-report sleep measures, their use in the context of behavioral interventions may introduce potential biases, as participants cannot be fully blinded to interventions.

Few studies included in our sample employed actigraphy or PSG. RCTs focusing on subjective assessment methods are not necessarily a problem, since insomnia diagnosis does not require any objective sleep assessment. However, the inclusion of objective evaluation of sleep in insomnia-related RCTs has already been recommended by previous studies [85], as it might complement the results obtained by

questionnaires, allowing a more complete description of the effects of each intervention on sleep. Furthermore, individuals with concerns about their sleep quality are increasingly turning to consumer health technology for a more objective assessment of sleep quality. Given the increasing availability and quality of consumer technology for measuring sleep quality, and the obvious limitations of subjective evaluation of sleep, it may be worthwhile for future research to include validated objective measures of sleep as part of their research methodology.

Most interventions evaluated ranged in duration from one to twelve weeks, with limited long-term follow-up. While short-term improvements in sleep quality were common, it is unclear whether these benefits persist or whether participants struggle to maintain the necessary behavioral changes. This highlights a critical gap in understanding the sustainability of these interventions over time. Insomnia usually has a long course (40 % persistence rate over 5 years [86]), and both insomnia relapse and long-term residual effects are common in insomnia patients [87]. Therefore, behavioral interventions might be more effective if sustained over the long term, resembling a lifestyle modification.

4.4. Limitations

Some considerations about the limitations of this study are needed for a proper interpretation of our findings. First, this scoping review was not intended to determine the efficacy of any behavioral intervention for insomnia but rather to map how these interventions have been tested in current literature. Most of the results are focused on the publication output, which cannot be considered as an indicative of the effectiveness of an intervention. Proper evidence-synthesis approaches (ideally meta-analyses of RCTs) should be performed to determine the actual effect of each of these interventions, as long as there are sufficient studies to justify it. Second, our scoping review did not encompass methodological quality or risk of bias evaluation. Although we work exclusively with RCTs, which are usually regarded as the best methodological design for evaluating the effects of controlled interventions, it does not mean that all the studies included were correctly performed or were free of methodological biases. This issue shall be accounted for in future meta-analyses evaluating behavioral interventions for insomnia. Third, this scoping review focused explicitly on behavioral interventions, and CBT-I was not included, despite being considered the gold-standard non-pharmacological treatment for insomnia. Some discussion is provided comparing the publication output of behavioral interventions and CBT-I, which arises from indirect comparisons with the results of other meta-epidemiological studies.

Finally, strict inclusion criteria—focusing on RCTs with moderate to severe insomnia—strengthened the internal validity but might have limited the scope of this review. We do not consider it a proper limitation, as prioritizing high-quality evidence ensures that conclusions are robust and reliable. However, these strict criteria and their impact on the study sample size should be considered when interpreting our data. Broadening the criteria to include studies on mild insomnia or self-reported symptoms could have increased the sample size and diversity of findings but may have reduced the generalizability of the findings for clinically diagnosed insomnia.

4.5. Implications and future research

This review underscores the fact that while there is logic in implementing sleep hygiene recommendations, there is little evidence that changing each of these behaviors might improve insomnia symptoms in individuals with clinically characterized insomnia. There is a need to understand better how changing these behaviors might lead to an improvement in sleep quality and whether different patient groups benefit from different interventions. The lack of experimental evidence for interventions like caffeine or screen reduction challenges their widespread promotion as solutions for sleep issues. When considering the number of intervention types and the number of papers examining their efficacy, there are also significant gaps in evidence for the general population or various approaches to implementation. For example, certain exercise types are beneficial, but there is no evidence demonstrating their benefit across demographic characteristics or different implementation strategies (i.e. time of day). Although the promotion of logically sound interventions without RCT evidence might be considered harmless by some, untested sleep hygiene behavior changes may be ineffective in insomnia and could even discourage future behavior change. Given the complex challenge of changing an individual's sleep hygiene behavior, it is important to ensure that the patient's efforts result in improved sleep quality.

CBT remains the recommended first-line therapy for insomnia, however the present review raises questions about why it works. The majority of CBT programs combine several behavioural components, including sleep restriction, stimulus control and relaxation, despite few of these being tested in isolation. As such, it is plausible that the apparent effectiveness of CBT might arise from any number of combinations of behavioural changes. For clinicians, this means that while CBT is clearly the most evidence backed approach, it should not be assumed that the behavioural components are necessarily having uniform impact. Practitioners would do well to consider which strategies the patient is actually benefiting from, rather than assuming that all are relevant. Ultimately, research is required to independently test behavioural interventions, while simultaneously acknowledging that some of these interventions will likely only work for some individuals.

Insomnia is a multi-component sleep disorder, not caused by any single and easily identifiable behavioral characteristic. Although it is reasonable to assume that all recommendations on the sleep hygiene list might improve sleep, there is currently no consensus on a definitive sleep hygiene list [21]. Furthermore, simply avoiding sleep-disruptive behaviors might benefit sleep but would hardly be fully resolutive for clinically relevant insomnia cases. For example, avoiding caffeine in the evening or limiting bedtime screen exposure might benefit sleep but will not be sufficient as a treatment for insomnia as insomnia is not simply caused by caffeine intake or screen exposure. In this sense, the latest European insomnia guidelines [4] highlight the importance of shifting focus from isolated practices to multi-component behavioral therapies, demonstrating stronger efficacy even without cognitive modules. Future research should consider these aspects to adequately address the potential of behavioral interventions.

Finally, insomnia disorder is subjective in its nature, including its diagnosis and patient reports. This subjectivity might increase the risk of methodological biases, thus RCTs should be prioritized over other research designs. Only properly performed RCTs can capture the potential of behavioral modification interventions on sleep. Future research should address the following priorities:

- Encourage the performance of RCTs over observational studies when evaluating the effects of behavioral interventions for insomnia.
- Meta-analyses of RCTs about the effect of each behavioral intervention should be performed whenever sufficient primary studies are available.
- Conduct dismantling studies to identify which elements within multi-component therapies drive outcomes.
- Validate effectiveness and explore under-researched interventions, such as reducing caffeine, nicotine, and screen time.
- Increase the use of objective sleep measures to strengthen the reliability of findings.
- Investigate long-term efficacy and the sustainability of behavioral interventions.
- Expand research efforts geographically to include diverse cultural and contextual factors.

5. Conclusion

This scoping review highlights critical gaps in the experimental research on behavioral interventions for insomnia. While multi-component therapies dominate the literature and show promise, the lack of evidence for widely recommended sleep hygiene practices raises questions about their validity. By addressing these gaps and expanding the scope of research, future studies can enhance our understanding of effective strategies for improving sleep quality in insomnia patients.

CRediT authorship contribution statement

Brad Hodge: Writing – review & editing, Writing – original draft, Project administration, Methodology, Conceptualization. **Elena Richert:** Writing – review & editing, Formal analysis. **Lisa Schmitz:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Anna Sigridur Islind:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Timo Leppänen:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Walter T. McNicholas:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization. **Erna Sif Arnardóttir:** Writing – review & editing, Validation, Methodology, Funding acquisition, Conceptualization. **Gabriel Natan Pires:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2025.108676.

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