BMC Medicine

RESEARCH

Open Access

Effects of non-pharmacological interventions on sleep quality in older adults: a systematic review and network meta-analysis of randomized controlled trials

Jia Song[1,2†], Heng Dong[1,2†], Chunying Wang[1,2], Yanxi Zheng[1,2], Yangzhen Huang[1,2], Yilin Wei[1,2], Kangkang Zhang[1,2], Hua Qing[1,2], Zhongbao Xiong[1,2], Yangyang Pan[1,2], Manwei Chen[1,2], Ruizhe Kang[1,2], Bishwajit Ghose[3], Dongfeng Tang[4], Ruoxi Wang[5], Chengxu Long[6], Yunfei Li[7] and Shangfeng Tang[1,2*]

Abstract

Background Sleep problems are common among older adults and are associated with a wide range of adverse health outcomes. Concerns about pharmacological treatments have increased interest in non-pharmacological interventions; however, evidence comparing their relative effectiveness remains limited.

Methods A systematic search was conducted in PubMed, Scopus, Embase, Web of Science, Cochrane Library, and CINAHL. Randomized controlled trials (RCTs) evaluating non-pharmacological interventions in adults aged ≥ 60 years published between 2000 and 2024 were included. Network meta-analyses were conducted using random-effects models to estimate standardized mean differences (SMDs) with 95% confidence intervals (CIs). *P*-scores were used to rank the efficacy of interventions. The protocol was registered in PROSPERO (CRD42024521492).

Results Thirty-four RCTs involving 3078 participants and 21 interventions were included. Eleven interventions significantly improved sleep quality. Cognitive behavioral therapy for insomnia plus positive mood strategies (CBT-I+) showed the largest effect (*P*-score = 0.99, SMD = − 3.32, 95% CI − 4.59 to − 2.06), followed by cognitive behavioral therapy for insomnia (CBT-I) (*P*-score = 0.92, SMD = − 2.18, 95% CI − 3.04 to − 1.31). Subgroup analyses indicated that music therapy (MUS) was more effective among participants with PSQI < 10 (SMD = − 1.25, 95% CI − 1.85 to − 0.65), whereas CBT-I+ showed greater effects for those with PSQI ≥ 10 (SMD = − 5.48, 95% CI − 6.80 to − 4.16). By intervention setting, traditional Chinese health-promotion exercise (TCHPE) was more effective in home-based settings (SMD = − 1.55, 95% CI − 2.60 to − 0.50), whereas CBT-I+ showed greater effects in non-home settings (SMD = − 3.31, 95% CI − 4.57 to − 2.06).

Conclusions CBT-I+ was associated with the greatest improvements in sleep quality among older adults, particularly those with baseline PSQI ≥ 10 and in non-home settings. MUS showed greater benefits among older adults with baseline PSQI < 10, and TCHPE showed greater benefits in home-based settings. These findings support stratified, context-specific intervention selection. Given the low GRADE certainty, these results should be interpreted with caution.

Keywords Non-pharmacological interventions, Sleep quality, Older adults, Network meta-analysis

[†]Jia Song and Heng Dong contributed equally to this work.

*Correspondence:
Shangfeng Tang
sftang2018@hust.edu.cn
Full list of author information is available at the end of the article

Background

Population aging has become one of the most significant public health challenges of the twenty-first century [1]. Recent projections indicate that by the 2070s, adults aged ≥ 65 will outnumber those under 18 for the first time in history, with the proportion of older adults expected to rise from 6.8% in 2000 to 16.3% by 2050 and potentially exceeding 20% thereafter [2]. Population aging is therefore driving an urgent need to address its health implications [3].

Sleep plays a central role in maintaining physical and mental health across the lifespan by supporting physiological function. In older adults, high-quality sleep is particularly important for preserving physiological function, cognitive performance, and emotional regulation [4, 5]. However, sleep problems are common in later life [6, 7]. Epidemiological studies estimate that 40–70% of older adults experience sleep disturbances, with 20–40% reporting poor sleep quality [8]. Poor sleep quality in later life often persists over time and is associated with increased physiological and psychological vulnerability. It has been associated with impaired immune responses, heightened cardiovascular risk, and neurocognitive decline [9–11]. Psychological consequences, including greater susceptibility to anxiety, depressive symptoms, and accelerated cognitive deterioration, are also frequently reported [12, 13]. Collectively, this body of evidence highlights the need for effective interventions to address poor sleep quality in older populations.

Current interventions to improve sleep quality in older adults include both pharmacological and non-pharmacological interventions [14]. Pharmacological treatments may provide short-term symptom relief but are limited by the risks of dependence, tolerance, and cognitive impairment [15–17]. Although newer Z-drugs were initially regarded as safer alternatives, emerging evidence indicates comparable safety concerns [18, 19]. At the drug-class level, a network meta-analysis reported that hypnotic medications provided only modest improvement in sleep onset and duration, while the overall risk of adverse events among triazolam users was nearly twice that observed with zaleplon [20]. Extending these findings, an earlier meta-analysis showed that, compared with placebo, patients taking sedative-hypnotics were almost five times more likely to experience cognitive adverse events and nearly four times more likely to report daytime fatigue [21]. At the population level, a systematic review found that Z-drug use was associated with an approximately 60% increased risk of fractures and fall-related injuries among older adults [22]. Collectively, evidence indicates that pharmacological sleep treatments offer limited benefits relative to their potential risks, underscoring the importance of prioritizing safe, evidence-based non-pharmacological interventions to promote sleep health in older adults.

In this context, non-pharmacological interventions, particularly cognitive behavioral therapy for insomnia, are increasingly recommended as preferred first-line treatments for chronic insomnia, owing to their favorable safety profiles and demonstrated benefits [23, 24]. In addition, accumulating evidence suggests that exercise [25], light therapy [26], mindfulness [27], and other complementary approaches may improve sleep outcomes while posing lower risks of adverse effects compared with pharmacological treatments.

Among non-pharmacological interventions, understanding their relative effectiveness is essential for informing clinical decision-making and guiding the rational allocation of healthcare resources. Due to the limited availability of studies comparing non-pharmacological interventions with each other and with different control groups, such questions cannot be adequately addressed by conventional pairwise meta-analyses based solely on direct comparisons. In contrast, network meta-analysis (NMA) enables the simultaneous synthesis of direct and indirect evidence, allowing estimation of relative treatment effects even in the absence of head-to-head trials [28]. Accordingly, this study conducted a systematic NMA with three objectives: (1) to quantitatively compare the effectiveness of different non-pharmacological interventions for improving sleep quality among older adults; (2) to establish a hierarchical ranking of their comparative effectiveness; and (3) to generate evidence-based insights to support clinical practice and healthcare resource allocation. This study aims to inform the development of optimized, patient-centered intervention strategies for promoting sleep health in aging populations.

Methods

Search strategy and selection criteria

We performed this systematic review according to a prespecified protocol (PROSPERO CRD42024521492) and reported according to Preferred Reporting Items for Systematic Reviews and Network Meta-Analyses (PRISMA-NMA) guidelines [29] (see Additional file 1: Methods S1). Any deviations from the registered protocol are shown in Additional file 1: Methods S2.

Two reviewers (JS and HD) independently searched PubMed, Scopus, Embase, Web of Science, Cochrane Library, and CINAHL from January 1, 2000 to October 20, 2024. In the literature search, the researchers used the following keywords (sleep OR parasomnia OR insomnia OR "circadian rhythm" OR polysomnog OR "overnight eeg" OR "Pittsburgh sleep quality index") AND (program

OR training OR intervention OR treatment OR therapy OR education OR "non-pharmacological intervention") AND ("randomized controlled trials" OR "quasi-randomized controlled trials" OR "controlled clinical trials" OR "controlled before-and-after trials" OR "non-controlled before-and-after studies"). The complete search strategy is reported in Additional file 1: Methods S3.

Two reviewers (JS and HD) independently performed the literature screening. Discrepancies were resolved through discussion or, when necessary, consultation with a third reviewer. Studies were included if they met all of the following criteria: (1) participants were older adults aged ≥ 60 years, consistent with the United Nations definition and commonly adopted in aging research [30]; (2) the study adopted a randomized controlled trial design; and (3) sleep quality was reported as the primary outcome and assessed using a validated questionnaire or an objective measurement tool. Participants were excluded if they had severe psychiatric disorders (including major depressive disorder, bipolar affective disorder, or schizophrenia), cognitive impairment, or severe systemic diseases, such as cardiac, hepatic, or renal failure, cancer, or other serious medical conditions. Detailed inclusion/exclusion criteria based on the PICOS framework (Population; Interventions; Comparison; Outcomes and Study design) are provided in Additional file 1: Methods S4.

All retrieved records were imported into EndNote 21, and the duplicates were removed. Two researchers (JS and HD) independently screened titles and abstracts to identify potentially relevant studies. The full texts of all potentially eligible articles were then retrieved and independently assessed for eligibility according to the predefined inclusion criteria.

Data extraction

Two researchers (JS and HD) individually extracted data from the included studies using a predesigned data extraction form. The extracted data included study characteristics (e.g., author's name and year of publication), participants' baseline characteristics (e.g., age demographics, percentage of men and women, sample sizes for each group), interventions administered (e.g., types of non-pharmacological interventions), and outcomes reported (e.g., sleep quality). Detailed definitions of intervention and control are provided in Additional file 1: Table S1. Sleep-related outcomes were assessed using validated measurement instruments (see Additional file 1: Table S2). For studies reported in multiple publications, duplicate data were collated and extracted only once. For trials with multiple follow-up periods, the immediate post-intervention outcome was selected for analysis. Means and standard deviations (SDs) at baseline and post-intervention were extracted as the primary data for analysis. When standard deviations were not directly reported, they were estimated from standard errors, 95% confidence intervals (CIs), ranges, or interquartile ranges, as appropriate. The detailed formulas and procedures used for standard deviation estimation are provided in Additional file 1: Methods S5. Disagreements were resolved by consensus.

Risk of bias and certainty of evidence

The risk of bias of each included study and outcome was assessed independently by two reviewers (JS and HD) using the Cochrane Risk of Bias 2.0 tool [31]. The assessment focused on the effect of assignment to intervention (intention-to-treat effect). Methodological quality was evaluated across five domains: (1) randomization; (2) deviations from intended intervention; (3) missing outcome data; (4) measurement of the outcome; and (5) selection of the reported result. Each domain involves a series of signaling questions relevant to the risk of bias, resulting in a proposed judgment of "low risk," "some concerns," or "high risk." Disagreements were discussed with a third reviewer (ST) until consensus was reached. An overall judgment of high risk was made when either multiple domains were assessed as having some concerns or if any domain was judged as having a high risk of bias; if a domain was judged as having some concerns, this led to an overall assessment of some concerns, whereas only a judgment of low risk in all domains yielded in an overall judgment of low risk of bias.

The certainty of evidence was evaluated using the CINeMA (Confidence in Network Meta-Analysis) framework, a GRADE-based approach designed for NMAs [32]. CINeMA evaluates six domains: (1) within-study bias (referring to the impact of risk of bias in the included studies); (2) reporting bias (referring to publication and other reporting bias); (3) indirectness; (4) imprecision; (5) heterogeneity; and (6) incoherence. The final assessment follows the GRADE paradigm: judgments across domains are summarized into four levels of confidence (high, moderate, low, very low). Confidence ratings begin at high and are downgraded by one level for domains with some concerns and by two levels for domains with major concerns [33].

Data synthesis and data analysis

We employed a network meta-analysis framework, which extends conventional pairwise methods by integrating all available evidence to enable the simultaneous comparison and hierarchical ranking of multiple interventions within a unified analytical model [34]. All analyses were performed in R (version 4.3.0, R Foundation for Statistical Computing). A frequentist network meta-analysis was performed using the "netmeta" package. For continuous outcomes, the standardized mean difference (SMD) was calculated with 95% CI to accommodate heterogeneous measurement scales [35]. When interpreting the SMD, 0.2, 0.5, and 0.8 indicate small, moderate, and large effect sizes, respectively [36]. Studies reporting medians and interquartile ranges were converted to means and standard deviations using validated methods. The statistical consistency between direct and indirect evidence was evaluated using node splitting analysis. The I^2 statistic was calculated to indicate heterogeneity between studies, with 25%, 50%, and 75% classified as low, medium, and high heterogeneity, respectively [37]. Intervention rankings were generated using *P*-scores, which range from 0 to 1 and summarize the relative performance of interventions based on the extent to which they are superior to competing alternatives [38, 39]. Rankograms and cumulative ranking probability plots were used to visualize the relative ranking of interventions. Publication bias was assessed using funnel plots and Begg's test. Sensitivity analyses were conducted using a leave-one-out approach [40]. Exploratory subgroup analyses were conducted post hoc to examine potential sources of heterogeneity, including baseline sleep quality (PSQI < 10, PSQI ≥ 10) [41, 42] and intervention setting (home-based, non-home-based). These subgroup analyses were not pre-specified in the protocol and should be interpreted with caution.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Study selection

A total of 4812 studies were identified through database searches, with an additional 23 found through references in previous reviews. After removing duplicates, 3783 entries were screened. Following a review of titles and abstracts, 3681 entries were excluded, leaving 102 papers for full-text analysis. Ultimately, 34 studies [23, 43–75] were included in the network meta-analysis (Fig. 1). All studies were published between 2000 and 2024, and the number of people included totaled 3078, including 1708 in the intervention group and 1370 in the control group. Subjects were all aged 60 years and above. The interventions include cognitive behavioral therapy, behavioral therapy, mindfulness, group reminiscence therapy, exercise, relaxation, education, music, tactile stimulation, visual stimulation, and aromatherapy. The characteristics of the included studies are shown in Table 1, and the reasons for exclusion after full-text review are detailed in Additional file 1: Table S3.

Network meta-analysis

The network plots of included studies are presented in Fig. 2. The results of the network meta-analysis are summarized in Fig. 3. Compared with the control group, CBT-I+, CBT-I, STE, GRT, SCT, REL, MUS, SRT, TCHPE, TS, and AE were associated with significantly improved sleep quality among older adults. Among these interventions, CBT-I+ (*P*-score = 0.99, SMD = −3.32, 95% CI −4.59 to −2.06), CBT-I (*P*-score = 0.92, SMD = −2.18, 95% CI −3.04 to −1.31), STE (*P*-score = 0.76, SMD = −1.52, 95% CI −2.59 to −0.45), GRT (*P*-score = 0.71, SMD = −1.37, 95% CI −2.49 to −0.26), SCT (*P*-score = 0.68, SMD = −1.32, 95% CI −2.41 to −0.23), REL (*P*-score = 0.65, SMD = −1.19, 95% CI −1.98 to −0.40), MUS (*P*-score = 0.64, SMD = −1.14, 95% CI −1.71 to −0.57), SRT (*P*-score = 0.61, SMD = −1.10, 95% CI −2.18 to −0.02), TCHPE (*P*-score = 0.61, SMD = −1.04, 95% CI −1.52 to −0.57), TS (*P*-score = 0.60, SMD = −1.06, 95% CI −1.72 to −0.39), and AE (*P*-score = 0.35, SMD = −0.55, 95% CI −1.08 to −0.01). Detailed pairwise comparisons are presented in the league table (see Additional file 1: Fig. S1), and the cumulative ranking probabilities in the *P*-score plot (see Additional file 1: Fig. S2). The heterogeneity test revealed a high degree of inter-study heterogeneity (I^2 = 80.2%). Therefore, we used the random-effects model for meta-analysis. Subgroup analyses were conducted according to baseline sleep quality and intervention setting.

Risk of bias and certainty of evidence

The risk of bias assessment for the 34 included RCTs is summarized in Figs. 4 and 5. Overall, only 5/34 (14.7%) studies were rated as low risk. Across the five assessment domains, the randomization process had the lowest risk of bias; 29 (85.3%) studies were categorized as low risk, primarily due to adequate sequence generation (e.g., computer-based randomization) and allocation concealment methods (e.g., sealed opaque envelopes). In contrast, measurement of the outcome had the highest risk of bias; 15 studies (44.1%) exhibited high risk, attributable to insufficient blinding of outcome assessors.

The certainty of evidence for all comparisons evaluated using CINeMA was predominantly rated as very low (89.3% of pairwise contrasts), with only three comparisons rated as low confidence. This was mainly attributed to the limited number of studies informing each comparison, which contributed to increased imprecision and heterogeneity (see Additional file 1: Table S4).

Subgroup analyses

Statistical tests for between-subgroup differences are only valid when the subgroup networks share a common structure and reference treatment, so that all parameters

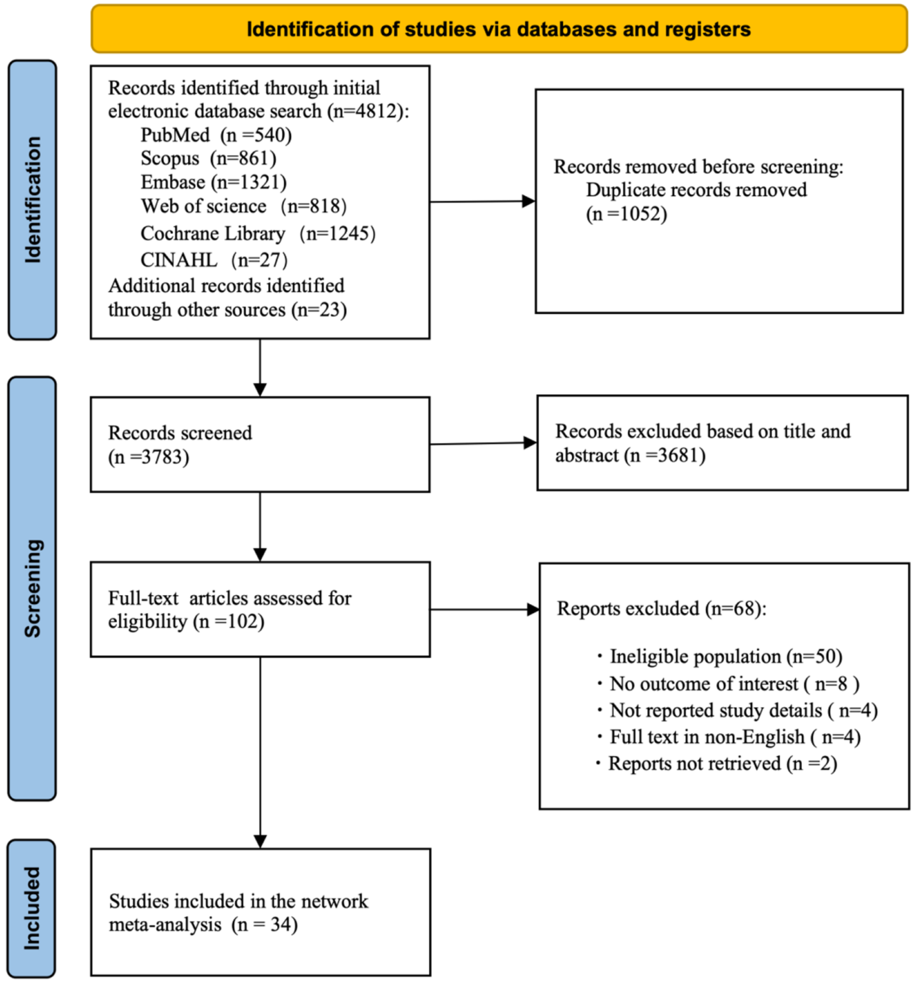

Fig. 1 PRISMA diagram

can be estimated on a comparable scale [76]. In this study, such assumptions were not met; therefore, subgroup results were analyzed descriptively.

Baseline sleep quality

The results are shown in Figs. 6 and 7. For participants with PSQI < 10, the observed effect sizes were comparatively smaller, and only TS (SMD = −1.06, 95% CI −1.54 to −0.59), AT (SMD = −0.97, 95% CI −1.77 to −0.17), TCHPE (SMD = −0.92, 95% CI −1.35 to −0.49), CBT-I (SMD = −0.83, 95% CI −1.52 to −0.15), and MBE (SMD = −0.47, 95% CI −0.81 to −0.13) were associated with statistically significant improvements in sleep quality compared with the control group. Among participants with PSQI ≥ 10 at baseline, CBT-I+ (SMD = −5.48, 95% CI −6.80 to −4.16), CBT-I (SMD = −5.03, 95% CI −6.28 to −3.77), REL (SMD = −1.89, 95% CI −2.60 to −1.77), STE (SMD = −1.52, 95% CI −2.13 to −0.91), GRT (SMD = −1.37, 95% CI −2.07 to −0.68), SCT (SMD = −1.32, 95% CI −1.97 to −0.68), SRT (SMD = −1.10, 95% CI −1.74 to −0.47), MIND (SMD = −1.05, 95% CI −1.76 to −0.34), MCI (SMD = −1.03, 95% CI −1.67 to −0.39), MUS (SMD = −1.03, 95% CI −1.53 to −0.53), AE (SMD = −0.53, 95%CI −0.92 to −0.13), and TCHPE (SMD = −1.10, 95% CI −1.53 to −0.68) were associated with greater improvements in sleep quality compared with the control group. Consistent with the overall results, intervention effects were more pronounced among participants with higher baseline PSQI scores.

Intervention setting

The results are shown in Figs. 8 and 9. Among participants in home-based intervention settings, TCHPE (SMD = −1.55, 95% CI −2.60 to −0.50), STE (SMD = −1.52, 95% CI −2.46 to −0.57), TS (SMD = −1.28, 95% CI −2.00 to −0.56), and MUS (SMD = −1.14, 95% CI −1.65 to −0.63) were associated with greater

Table 1 Study characteristics of the included studies (ordered alphabetically by first author)

Author	Country	Intervention group			Control group			Intervention details				Outcome measures
		Measures	*N* (% male)	Mean age (SD)	Measures	*N* (% male)	Mean age (SD)	Frequency	Duration (minute)	Period (week)	Setting	Subjective outcomes
Aibar-Almazán A (2019) [43]	Spanish	PLT	55 (0)	69.98 (7.83)	BC	52 (0)	66.79 (10.14)	Twice a week	60	12	Community	PSQI
Alessi C (2016) [44]	USA	CBT-I	106 (96.2)	72.2 (7.7)	EDU	53 (98.1)	72.4 (7.3)	The intervention was provided in five 1-h sessions over 6 weeks (with a brief telephone check-in during week 5)		6	Department of Veterans Affairs health-care system	PSQI; ISI
Bağcı H (2020) [45]	Turkey	TT MTT	10* 8*	NR	WLC	7*	NR	Everyday	10	3 days	Nursing home	PSQI-3
Brandão GS (2018) [46]	Brazil	HE	61 (9.2)	69.8 (7.4)	BC	64 (15.6)	69.9 (6.7)	At least three times a week	40	12	Home	PSQI ESS
Chan MF (2010) [47]	China	MUS	21 (42.9)	60–80+②	BC	21 (47.6)	60–80+②	Once a week	45	4	Home	PSQI
Chen MC (2012) [48]	China	BDE	27 (37.04)	70.48 (7.90)	BC	28 (32.14)	72.96 (8.30)	Three times a week	30	12	Home	PSQI
Cheung C (2014) [49]	USA	YG	18 (0)	71.9 (5.23)	WLC	18 (0)	71.9 (6.26)	Once a week	60	8	Yoga studio	PSQI
Choi MJ (2018) [50]	South Korea	FSE	33 (9.1)	77.6 (5.69)	UC	30 (3.3)	78.8 (5.83)	Four times a week	30–40	12	Community	PSQI-K
Corral-Pérez J (2024) [51]	Spain	EDU	109 (22.0)	73.16 (6.13)	BC	88 (31.5)	75.77 (6.91)	In the first month, there had 4 weekly group sessions, each lasting 45–60 min After that, they had 6 personal telephone interviews: 2 in the second month (one every 2 weeks) and 1 per month from the third to the sixth month of the intervention		24	Healthcare centers	PSQI
Curi VS (2018) [52]	Brazil	PLT	31 (0)	64.25 (0.14)	BC	30 (0)	63.75 (0.08)	Twice a week	60	16	NR	PSQI-BR
Epstein DR (2012) [53]	USA	SCT SRT MCI	44 (29.5) 44 (43.2) 41 (34.1)	70.95 (8.33) 68.00 (8.25) 67.22 (6.55)	WLC	50 (36)	69.50 (8.34)	In the first 4 weeks, there was 1 group-based intervention per week In weeks 5 and 6, there was 1 telephone-based intervention per week	The first group session lasted about 2 h The following 3 group sessions lasted about 1 h each The telephone sessions in weeks 5 and 6 lasted about 15 min each	6	Veterans Affairs medical center	ISI

Table 1 (continued)

Author	Country	Intervention group			Control group			Intervention details				Outcome measures
		Measures	*N* (% male)	Mean age (SD)	Measures	*N* (% male)	Mean age (SD)	Frequency	Duration (minute)	Period (week)	Setting	Subjective outcomes
Fan B (2020) [54]	China	BDE	67 (17.9)	70.3 (5.7)	WLC	72 (30.6)	71.8 (6.7)	Five times a week	45	24	Community	PSQI
Genç F (2020) [55]	Turkey	AT	30 (73.3)	74.50 (6.62)	BC	29 (86.2)	72.00 (7.94)	Everyday	The administration was conducted between 22.00 pm and 08.00 am by considering the sleeping hours of the elderly	4	Nursing home	PSQI
Habibollahpour M (2019) [56]	Iran	BR	38 (39.5)	67.95 (5.24)	BC	37 (51.4)	66.89 (4.10)	Twice a day	20	4	Health centers	PSQI
Hariprasad VR (2013) [57]	India	YG	62 (41.9)	75.74 (6.46)	WLC	58 (37.9)	74.78 (7.35)	One time per day	60	24	Elderly homes	PSQI
Jiménez-García JD (2021) [58]	Spain	HIIT MIIT	26 (11.8) 24 (41.2)	68.23 (2.97) 68.75 (5.98)	BC	23 (47.1)	68.52 (6.33)	Two times per week	45	12	NR	PSQI
Karimi S (2016) [23]	Iran	PE	23 (100)	67.49 (4.28)	BC	23 (100)	66.82 (3.84)	Three times a week	30	8	Elderly house	PSQI
Lai HL (2005) [59]	China	MUS	30*	60–83②	BC	30*	60–83②	Everyday	45	3	Home	PSQI; ESS①
Lee EK (2022) [60]	China	mMBSR	105 (17.1)	71.3 (7.0)	WLC	104 (15.4)	71.8 (8.2)	8 times a week	120	8	Home	PSQI
Miyazaki R (2021) [61]	Japan	ATP	34 (20.6)	67.0 (4.8)	BC	15 (13.3)	62.7 (6.6)	Group-based: one time per week Home-based: ≥ 3 days per week	Group-based: 60; home-based: ≥ 20	12	Home	PSQI
Nguyen MH (2012) [62]	Vietnam	TCE	48 (50)	69.23 (5.30)	BC	48 (50)	68.73 (4.95)	Twice a week	60	24	Community	PSQI
Phansuea P (2020) [63]	Thailand	QP	33 (27.3)	69 (6.3)	UC	33 (27.3)	71 (6.9)	Three times a week	60	12	Public health service center	TPSQI
Sadler P (2018) [64]	Australia	CBT-I CBT-I+	24 (37.5) 25 (48.0)	74.7 (7.1) 77.0 (8.4)	EDU	23 (43.5)	72.3 (7.6)	Eight times a week	60–75 75–90	8	Community mental health service	ISI
Sahragard F (2020) [65]	Iran	GRT	36 (33.3)	NR	BC	36 (33.3)	NR	Two times a week	90–120	4	Health care center	ISI

Table 1 (continued)

Author	Country	Intervention group			Control group			Intervention details				Outcome measures
		Measures	*N* (% male)	Mean age (SD)	Measures	*N* (% male)	Mean age (SD)	Frequency	Duration (minute)	Period (week)	Setting	Subjective outcomes
Seyyedrasooli A (2013) [66]	Iran	FB	23 (100)	67.49 (4.28)	BC	23 (100)	66.82 (3.84)	Everyday	20	6	Home	PSQI
Shum A (2014) [67]	Singapore	MUS	28 (42.9)	65.4 (9.2)	BC	32 (25.0)	62.3 (6.3)	Everyday	40	6	Home	PSQI
Siu PM (2021) [68]	China	TCE	105 (20.0)	66.5 (6.4)	UC	110 (20.0)	68.0 (8.2)	Three times a week	60	12	Community	PSQI; ISI
		PE	105 (20.0)	67.3 (5.7)								
Song D (2023) [69]	China	ADP	45 (20.0)	76.71 (5.96)	EDU	44 (30.0)	75.20 (6.63)	Three times a week	60	16	Community	PSQI
Sun J (2013) [70]	China	SReT	37 (29.7)	68.59 (8.45)	EDU	38 (26.7)	70.76 (7.44)	First month: group practice once a week From the second month: at least three times a day at home	Group practice: 90; home practice: 30	48	Home	PSQI; ESS
Vizeshfar F (2021) [71]	Iran	SCTUS	29 (44.4)	70.5 (6.5)	UC	27 (59)	69.1 (15.1)	Everyday	60	3	Home	PSQI
Wang Q (2016) [72]	China	MUS	32 (23.5)	66.94 (4.99)	EDU	32 (14.7)	69.82 (5.61)	Everyday	30–45	12	Home	PSQI
Yoon H (2023) [73]	Korea	AAT	19 (26.3)	74.68 (4.91)	ACUP	22 (27.3)	74.04 (4.99)	Six times a week	NR	3	Senior center	PSQI
Zeng H (2016) [74]	China	ACUP	42 (35.7)	70.07 (7.42)	EDU	40 (22.5)	70.78 (7.26)	One 90-min group session per week for 3 weeks, followed by five group sessions per week and at least two sessions per day at home		48	Home	PSQI
Zhang JX (2015) [75]	China	MBSR	30 (53.3)	78.57 (2.94)	WLC	30 (63.3)	77.63 (3.01)	One 2-h group intervention per week; 45 min of daily practice at home		8	Home	PSQI

Notes: *Studies with unreported sex ratio; *NR*, not reported; *CBT*, cognitive behavioral therapy; *CBT-I*, cognitive behavioral therapy for insomnia; *CBT-I+*, cognitive behavior therapy for insomnia plus positive mood strategies; *BT*, behavioral therapy; *MCI*, multicomponent intervention (composed of stimulus control therapy and sleep restriction therapy); *SCT*, stimulus control therapy; *SRT*, sleep restriction therapy; *MIND*, mindfulness; *MBSR*, mindfulness-based stress reduction; *mMBSR*, modified mindfulness-based stress reduction; *GRT*, group reminiscence therapy; *MBE*, mind–body exercise; *PLT*, Pilates; *YG*, yoga; *FSE*, floor-seated exercise; *TCHPE*, traditional Chinese health-promotion exercise; *BDE*, Baduanjin exercise; *TCE*, tai chi exercise; *QP*, qigong practice; *HIIT*, high-intensity interval suspension training; *MIIT*, moderate-intensity interval suspension training; *STE*, strength training exercise; *HE*, home exercise; *AE*, aerobic exercise; *PE*, physical exercise; *ATP*, aerobic training program; *ADP*, aerobic dancing program; *REL*, relaxation; *BR*, Benson's relaxation; *SReT*, self-relaxation training; *EDU*, education; *MUS*, music therapy; *TS*, tactile stimulation; *AAT*, auricular acupressure therapy; *ACUP*, acupuncture; *TT*, therapeutic touch; *MTT*, mimic therapeutic touch; *VS*, visual stimulation; *SCTUS*, self-care training program using smartphones; *AT*, aromatherapy; *WLC*, wait-list control condition; *BC*, blank control; *UC*, usual care; ① data reported through the tool are not available; ② age range

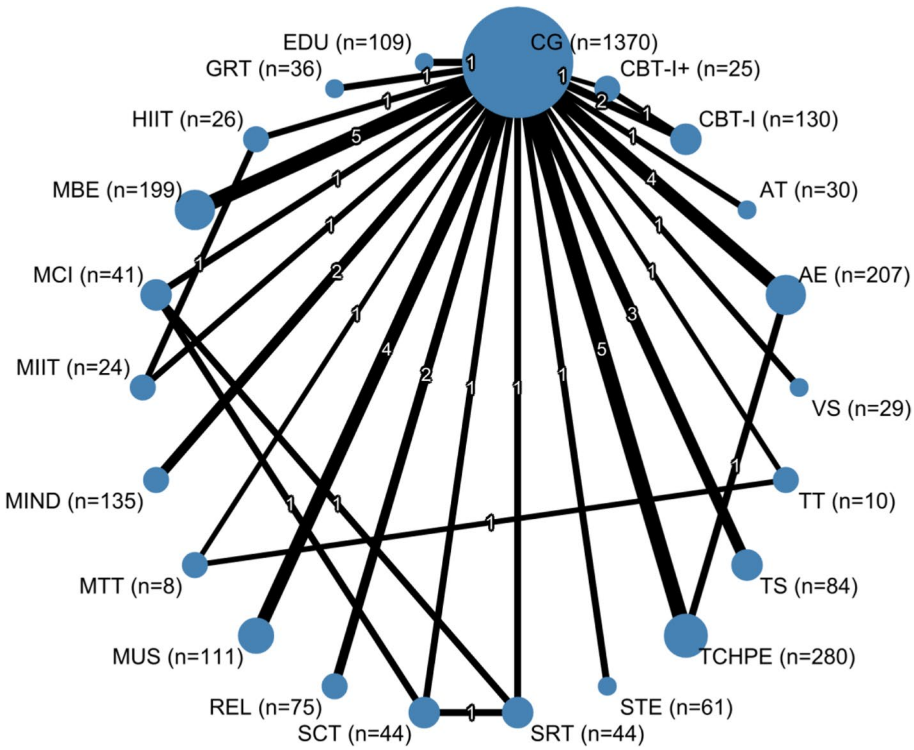

Fig. 2 Network plots of trials included in meta-analysis. Notes: The size of the nodes is proportional to the number of participants (i.e., sample size) involving the specific intervention. The connecting lines represent direct comparisons. Line thickness corresponds to the relative weight of the evidence for each comparison, and the numbers on the lines indicate the studies contributing direct evidence

improvements in sleep quality compared with the control group. For participants in non-home interventions (e.g., nursing homes, communities), CBT-I+ (SMD = −3.31, 95% CI −4.57 to −2.06), CBT-I (SMD = −2.17, 95% CI −3.03 to −1.31), REL (SMD = −1.89, 95% CI −3.01 to −0.76), SCT (SMD = −1.32, 95% CI −2.40 to −0.24), SRT (SMD = −1.10, 95% CI −2.18 to −0.03), TCHPE (SMD = −0.96, 95% CI −1.48 to −0.44), and AE (SMD = −0.64, 95% CI −1.24 to −0.04) were associated with greater improvements in sleep quality compared with the control group.

Additional analysis

The trace and density plots (Additional file 1: Fig. S3) showed no identifiable trends, indicating stable convergence of the model parameters. Results of the global and local inconsistency assessments are provided in Additional file 1: Fig. S4. The comparison-adjusted funnel plot (Additional file 1: Fig. S5) revealed no substantial asymmetry, indicating no significant publication bias. Begg's tests ($p = 0.17$) revealed no significant publication bias (Additional file 1: Table S5). Details of sensitivity analyses are shown in Additional file 1: Fig. S6.

Discussion

To our knowledge, we conducted the most comprehensive network meta-analysis examining non-pharmacological interventions on sleep quality in older adults. In the context of population aging and the growing prevalence of sleep problems among older adults, we systematically synthesized existing evidence and quantitatively compared diverse interventions, thereby providing an evidence-based foundation for the theoretical development and practical improvement of geriatric sleep health interventions. Theoretically, this study demonstrates the contextual variability of non-pharmacological interventions among older adults. Subgroup analyses revealed that intervention effectiveness varied by baseline sleep quality and intervention setting, deepening the theoretical understanding of context-dependent effects in geriatric sleep health. Practically, these findings offer an empirical basis for stratified, context-specific decision-making in sleep management among older adults, providing a valuable reference for the adaptation of intervention strategies across different settings.

Our study revealed that CBT-I and its enhanced version, CBT-I+, were superior to the other interventions. These findings were consistent with previous evidence

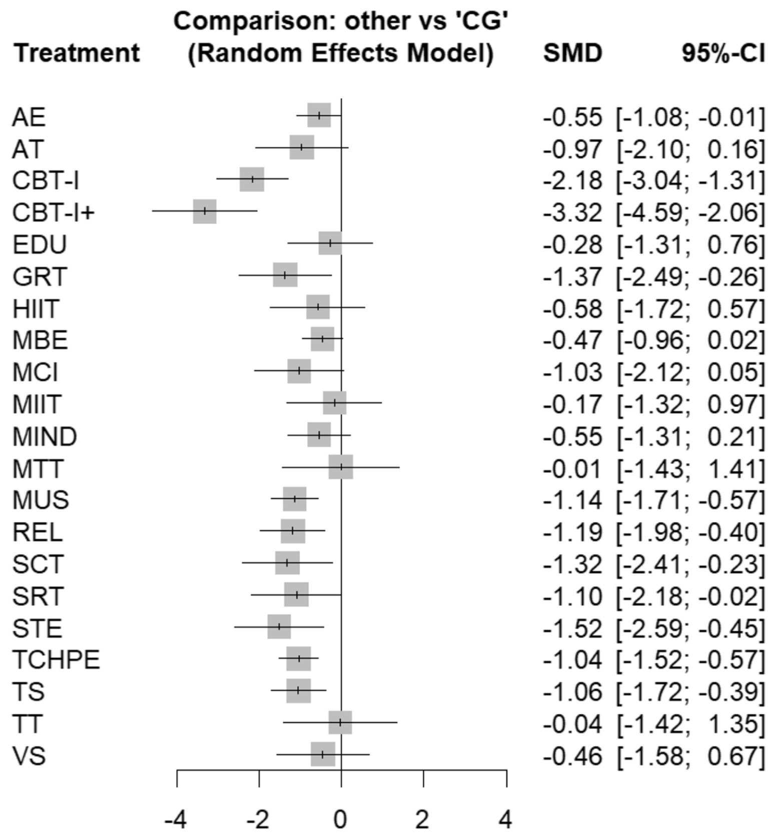

Fig. 3 Forest plot showing the effects of non-pharmacological interventions compared with control on sleep quality in older adults (random-effects model). Notes: Negative SMD values represent better sleep outcomes (improvement), whereas positive SMD values represent worse sleep outcomes

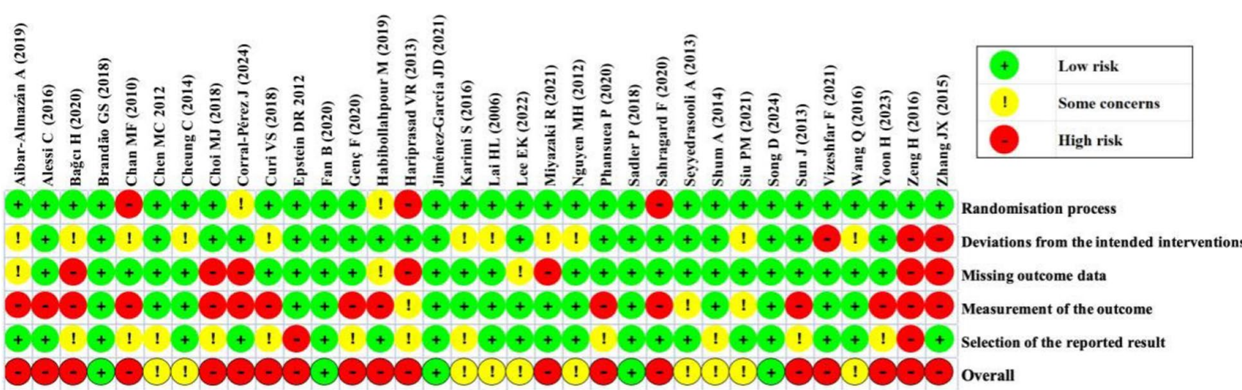

Fig. 4 Risk of bias assessment of articles included in meta-analysis

demonstrating CBT-I's capacity to modify maladaptive sleep-related cognitions and regulate circadian rhythms [77, 78]. Notably, the effect sizes observed here appeared larger than those reported in their meta-analyses. This may be attributed to our study focus on strictly defined geriatric populations (≥60 years) and the incorporation of mindfulness techniques in CBT-I+, which may enhance anxiety management—a common comorbidity in insomnia [79]. However, it has to be recognized that the difference could also be due to the small number of studies included in the analysis. In addition, variations in study quality, measurement instruments, and

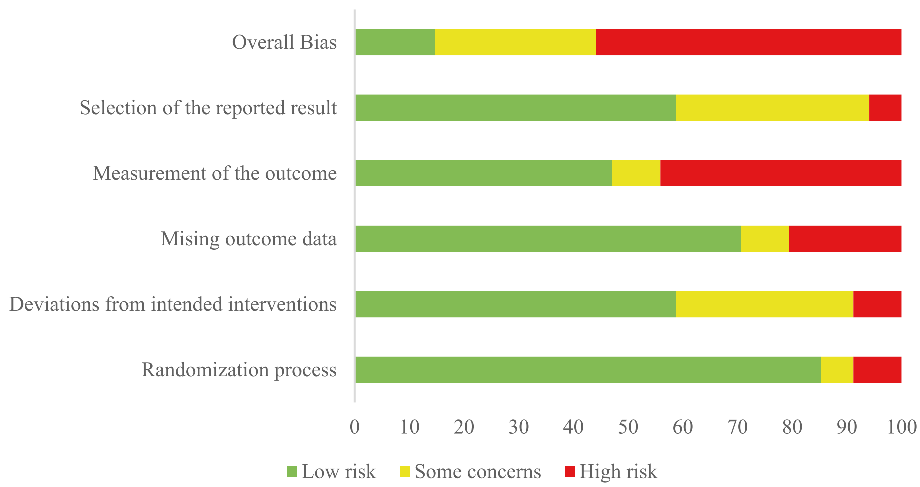

Fig. 5 Risk of bias graph

sample composition may have further contributed to the observed discrepancies. Nevertheless, results from our sensitivity analyses indicated that the exclusion of individual studies did not materially alter the pooled effect estimates or the ranking of interventions, suggesting that the findings are generally robust. Although no significant publication bias was detected, the potential influence of small-study effects or unreported negative findings cannot be completely ruled out.

Compared with previous studies, the effect of aerobic exercise observed in this study appeared to be relatively weaker [80–82]. This discrepancy may reflect variations in exercise intensity, adherence rates among older adults, or reliance on subjective sleep metrics rather than objective measures like actigraphy [83, 84]. Previous evidence suggests that older adults often demonstrate reduced adherence to prescribed exercise regimens due to physical limitations or motivational factors and that studies relying primarily on self-reported sleep outcomes tend to overestimate intervention benefits compared with actigraphy-based assessments [68]. In addition, preserved mobility may enhance activity tolerance but masks sleep-related benefits through ceiling effects that congruent with existing studies showing improved sleep continuity in older adults after exercise [85]. It is notable that our network meta-analysis complements the findings of the previous study, the results revealing that Chinese traditional health promotion programs, such as Taiji and Baduanjin, have a significant advantage over aerobic exercise in improving sleep quality in older adults [86]. This may be partly attributable to their cultural congruence within East Asian populations, which may enhance adherence rates, a key confounding factor that has been insufficiently controlled for in previous cross-cultural studies.

Interventions such as CBT-I+, MUS, and TCHPE showed greater efficacy in individuals with moderate-to-severe sleep dysfunction, aligning with studies emphasizing targeted therapy for high-risk subgroups [87–89]. In addition, the superiority of MUS, TS, and TCHPE in home-based settings underscores the importance of adaptability and minimal resource requirements for community-dwelling older adults. The sustained benefits of home-based interventions may be attributed to their seamless integration with daily routines, where environmental cues reinforce habit formation while eliminating logistical barriers [88, 90]. In contrast, CBT-I leverages structured professional guidance to ensure fidelity in implementing cognitive restructuring techniques, making it indispensable for addressing complex maladaptive beliefs resistant to self-guided interventions [91].

The effect size of CBT-I+ in the baseline PSQI $\geq$ 10 subgroup was significantly higher than its pooled effect in the whole population, suggesting that the intervention has a specific reinforcing effect on patients with severe sleep disorders, which may be related to a neuroplasticity threshold effect. Enhanced therapeutic efficacy of CBT-I+ in moderate-to-severe insomnia (PSQI $\geq$ 10) may be mediated through neuroplastic adaptations in the dorsolateral prefrontal cortex (DLPFC). Neuroimaging studies demonstrate that CBT-I-induced gray matter volume increases in this prefrontal region show a significant correlation with PSQI improvement scores in severe insomnia cohorts [92]. This neuroanatomical remodeling suggests top-down cognitive control mechanisms underlying insomnia remediation. From a clinical perspective, these findings may indicate the potential value of prioritizing CBT-I+ for patients with more severe insomnia, suggesting

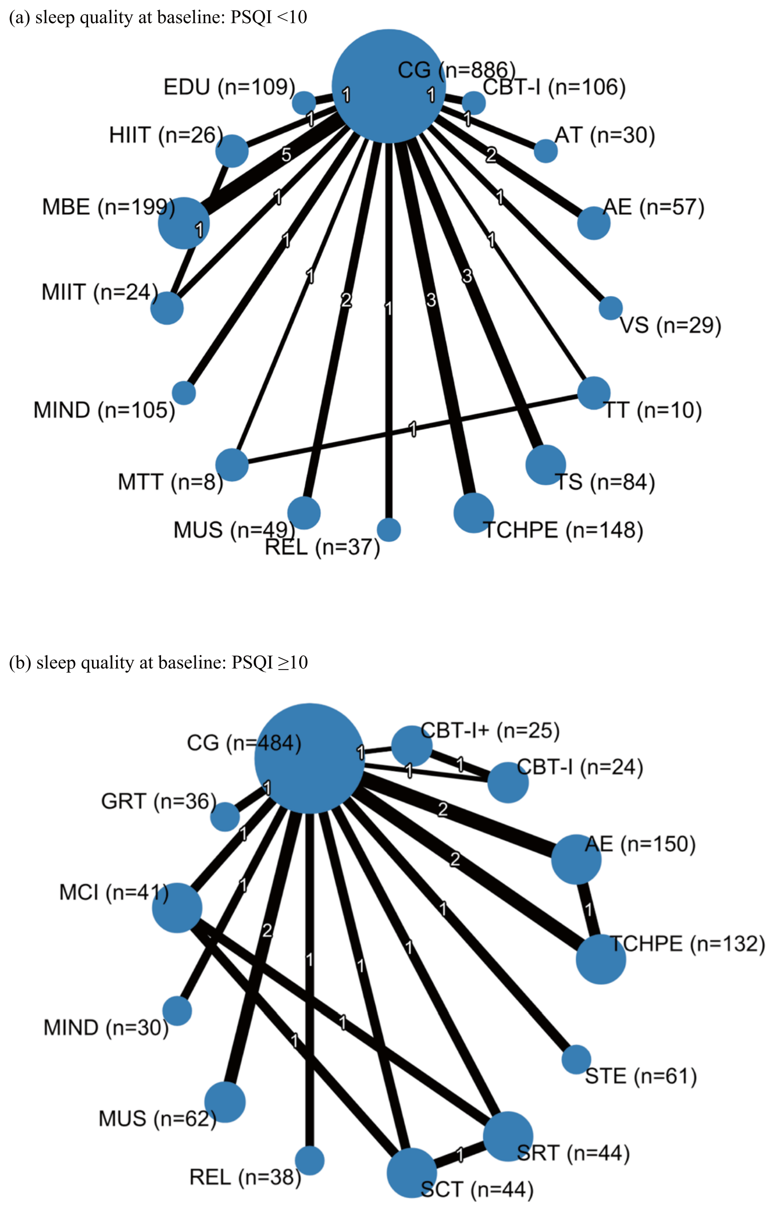

Fig. 6 Network plots of subgroup analysis by baseline sleep quality (PSQI < 10 vs PSQI ≥ 10). Notes: The size of the nodes is proportional to the number of participants (i.e., sample size) involving the specific intervention. The connecting lines represent direct comparisons. Line thickness corresponds to the relative weight of the evidence for each comparison, and the numbers on the lines indicate the studies contributing direct evidence

that intervention protocols may be optimized through symptom-based stratification and differential allocation of therapeutic design. Prior research on personalized CBT has indicated that tailoring therapy features to baseline severity may enhance responsiveness [93]. In addition, remote or telephone-delivered adaptations of CBT-I have demonstrated durable effects in older adults, underscoring that CBT protocols can be flexibly designed to suit varying patient needs [94]. Such an approach may help enhance treatment efficiency and resource utilization in geriatric sleep management. Future studies may further examine whether tailoring CBT-I+ design according to baseline sleep quality can improve long-term effectiveness in older adults.

Based on the present findings, several directions for future research and practice may be considered. Although non-pharmacological interventions are increasingly recognized as safer and more sustainable

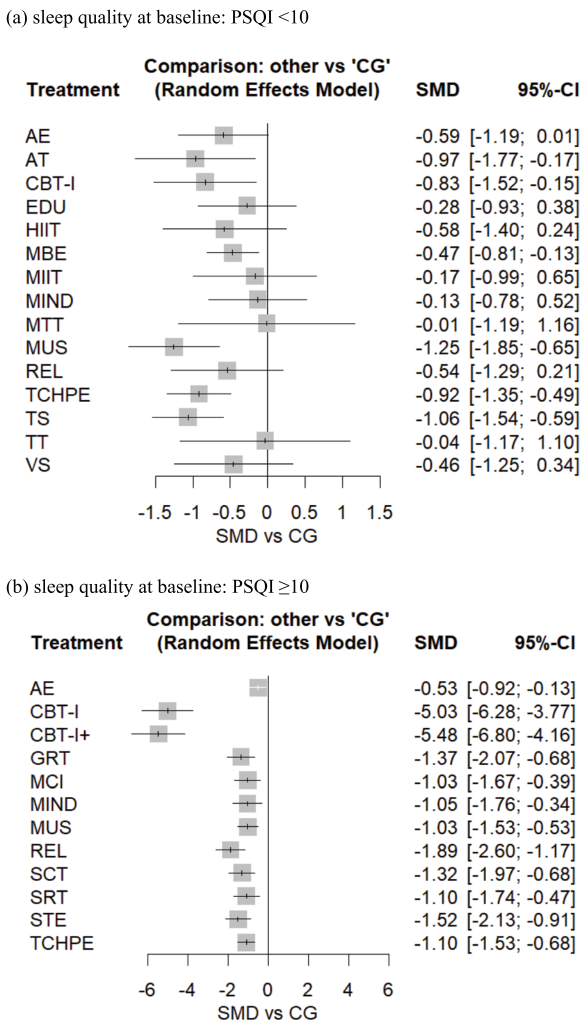

Fig. 7 Forest plot showing the effects of non-pharmacological interventions on sleep quality among older adults, stratified by baseline sleep quality (random-effects model). Notes: Negative SMD values represent better sleep outcomes (improvement), whereas positive SMD values represent worse sleep outcomes

approaches, high-quality randomized controlled trials in older populations remain limited. Future studies should continue to enhance methodological rigor and examine intervention effectiveness across diverse, real-world contexts. In this study, most non-pharmacological interventions showed effectiveness among participants with poorer baseline sleep quality, suggesting that greater baseline impairment may have a larger scope for improvement, and this association warrants further empirical validation in future research. What is more, further research should strengthen the evidence base for understudied interventions to optimize sleep management strategies and health promotion in the aging population.

Although available evidence consistently supports non-pharmacologic interventions for improving sleep quality in older adults, limited guidance exists on which non-pharmacologic interventions to recommend. Our study provides a comprehensive synthesis of evidence on non-pharmacological interventions for improving sleep quality among older adults, offering comparative insights across a broad range of intervention types. Eleven interventions were identified as being associated with significant improvements in sleep quality compared with the control group. While these findings enhance current understanding of non-pharmacological sleep interventions, several methodological factors warrant consideration when interpreting the results. The observed variability in pooled effects likely reflects between-study methodological heterogeneity, including differences in intervention implementation, management of intervention and control groups, feasibility of participant blinding, and potential expectancy- or behavior-related influences among participants. Variability in intervention fidelity, adherence, and outcome measurement tools may also have contributed to heterogeneity across studies. These factors collectively introduce complexity into the interpretation of aggregated findings. Despite this, the use of a random-effects model and confirmation of parameter convergence (via trace and density plots) enhance confidence in the stability of pooled estimates; clinicians should interpret these results cautiously, as heterogeneity may obscure intervention-specific nuances.

This study also has some limitations: (1) Although we searched for all available studies targeting sleep quality in older adults, the number of RCTs remains limited, suggesting that additional rigorous trials are required. (2) Some interventions showed a considerable level of heterogeneity, and thus should be interpreted with caution. (3) Non-pharmacological therapies such as light therapy that may affect sleep quality in older adults were not explored in this study due to the lack of data related to sleep quality. (4) Given the nature and implementation modalities of non-pharmacological interventions, it is challenging to employ allocation concealment and blinding in such studies, thereby potentially introducing biases in implementation and measurement. (5) Furthermore, given the inherent limitations of network meta-analysis and the paucity of literature on certain interventions, the findings should be interpreted with caution.

Conclusions

This study conducted a comprehensive search across 6 databases and conducted a network meta-analysis of 34 randomized controlled trials (involving 3078

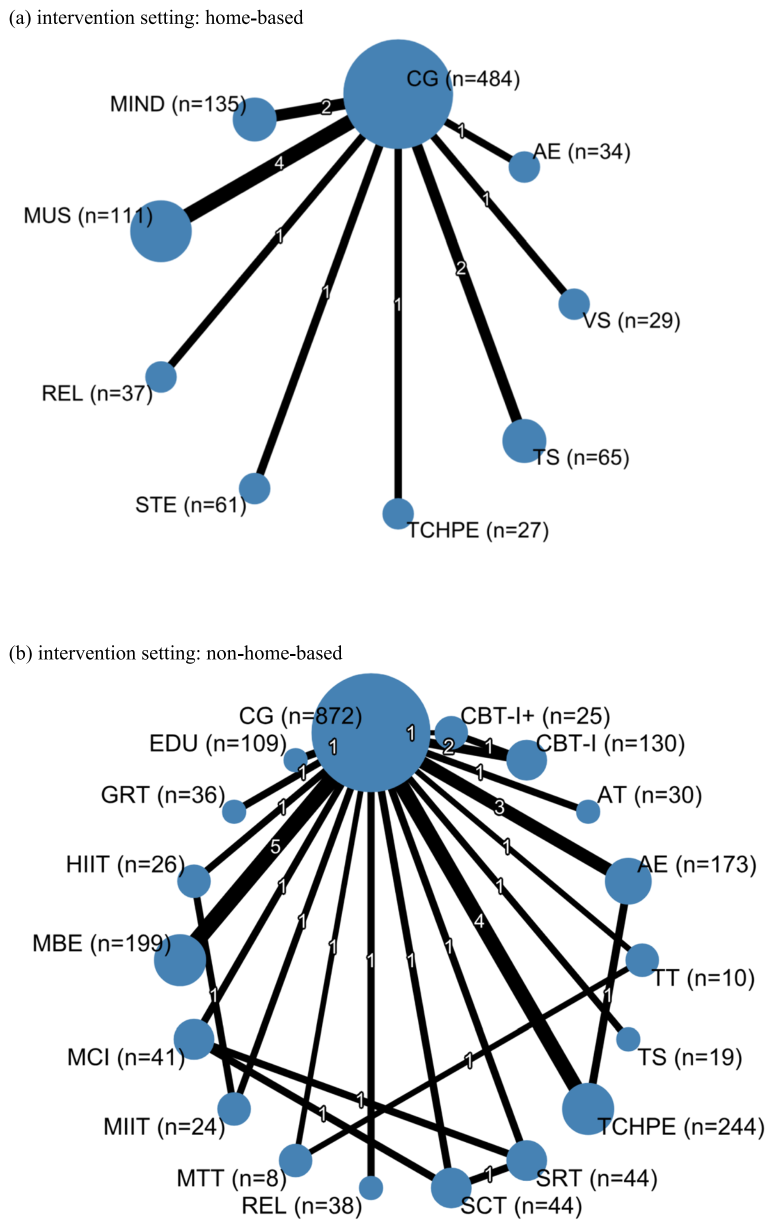

Fig. 8 Network plots of subgroup analysis by intervention setting (home-based vs non-home-based). Notes: The size of the nodes is proportional to the number of participants (i.e., sample size) involving the specific intervention. The connecting lines represent direct comparisons. Line thickness corresponds to the relative weight of the evidence for each comparison, and the numbers on the lines indicate the studies contributing direct evidence

participants) to compare the effects among which cognitive behavioral therapy for insomnia plus positive mood strategies (CBT-I+) showed the greatest overall effectiveness in improving sleep quality among older adults. Subgroup analyses indicated that the relative effectiveness of interventions varied according to baseline sleep quality and intervention setting. Specifically, CBT-I+ showed greater effects among older adults with poorer baseline sleep quality (PSQI ≥ 10) and those receiving interventions in non-home settings. In contrast, music therapy showed greater benefits among individuals with relatively better baseline sleep quality (PSQI < 10), whereas traditional Chinese health-promotion exercises (e.g., Taiji, Baduanjin) were more effective in home-based settings. These findings suggest that stratifying non-pharmacological interventions according to baseline sleep quality and intervention settings may inform future intervention

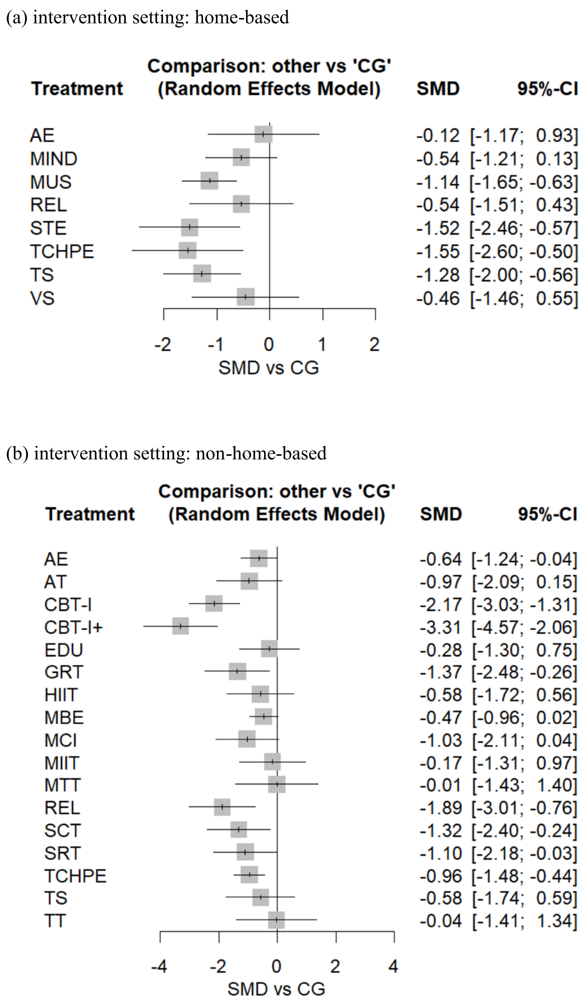

Fig. 9 Forest plot showing the effects of non-pharmacological interventions on sleep quality among older adults, stratified by intervention setting (random-effects model). Notes: Negative SMD values represent better sleep outcomes (improvement), whereas positive SMD values represent worse sleep outcomes

design. Structured interventions such as CBT-I+ may be more appropriate for older adults with poorer baseline sleep quality, whereas self-directed approaches may be better suited to individuals with relatively better sleep quality and to home-based intervention contexts. Together, these findings contribute to refining evidence-based strategies for improving sleep health in aging populations.

Abbreviations

RCT	Randomized controlled trial
SMD	Standardized mean difference
CI	Confidence interval
PSQI	Pittsburgh Sleep Quality Index
GRADE	Grading of Recommendations Assessment, Development and Evaluation
NMA	Network meta-analysis
PRISMA-NMA	Preferred Reporting Items for Systematic Reviews and Network Meta-Analyses
SD	Standard deviation
CINeMA	Confidence in Network Meta-Analysis
AAT	Auricular acupressure therapy
ACUP	Acupuncture
ADP	Aerobic dancing program
AE	Aerobic exercise
AT	Aromatherapy
ATP	Aerobic training program
BC	Blank control
BDE	Baduanjin exercise
BR	Benson's relaxation
BT	Behavioral therapy
CBT	Cognitive behavioral therapy
CBT-I	Cognitive behavioral therapy for insomnia
CBT-I+	Cognitive behavioral therapy for insomnia plus positive mood strategies
EDU	Education
FSE	Floor-seated exercise
GRT	Group reminiscence therapy
HE	Home exercise
HIIT	High-intensity interval suspension training
MBE	Mind-body exercise
MBSR	Mindfulness-based stress reduction
MCI	Multicomponent intervention
MIIT	Moderate-intensity interval suspension training
MIND	Mindfulness
mMBSR	Modified mindfulness-based stress reduction
MTT	Mimic therapeutic touch
MUS	Music therapy
PE	Physical exercise
PLT	Pilates
QP	Qigong practice
REL	Relaxation
SCT	Stimulus control therapy
SCTUS	Self-care training program using smartphones
SRT	Sleep restriction therapy
SReT	Self-relaxation training
STE	Strength training exercise
TCE	Tai chi exercise
TCHPE	Traditional Chinese health-promotion exercise
TS	Tactile stimulation
TT	Therapeutic touch
UC	Usual care
VS	Visual stimulation
WLC	Wait-list control
YG	Yoga

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-026-04682-6.

Additional file 1: Methods S1 PRISMA for Network Meta-Analyses (PRISMA-NMA). Methods S2 Deviations from the registered protocol. Methods S3 Database search strategy. Methods S4 Eligibility criteria based on the PICOS framework. Methods S5 Conversion formula for standard deviation (SD). Table S1 Definitions of interventions and controls. Table S2 Measurement instruments used in included studies. Table S3 Excluded studies and reasons. Table S4 Grading of Recommendations Assessment, Development and Evaluation (GRADE) assessment. Table S5 Results of inconsistency test. Table S6 Results of the Begg test. Fig. S1 League table. Fig. S2 Cumulative probability plot (*P*-score gram and *P*-score line plot). Fig. S3 Trace and density plots. Fig. S4 Comparison-adjusted funnel plot. Fig. S5 Sensitivity analysis.

Acknowledgements

Not applicable.

Authors' contributions
JS, HD, and ST were responsible for conceptualization, data curation, formal analysis, methodology, supervision, validation, verification of the underlying data, writing-original draft, and writing-review and editing. CW, YZ, YH, YW, KZ, HQ, ZX, YP, MC, and RK performed the initial search. BG, DT, RW, CL, and YL were responsible for reviewing and editing the manuscript. All the authors confirm that they had full access to all the data in the study and accept responsibility for the decision to submit for publication. All authors read and approved the final manuscript.

Funding
The study was supported by a grant from the National Key Research and Development Program of China (2023YFC3606400), the National Natural Science Foundation of China (72374079), and the Natural Science Foundation of Hubei Province (JCZRYB202500352).

Data availability
All datasets used in this study can be found in the full-text publications included in the systematic review and network meta-analysis.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]School of Medicine and Health Management, Huazhong University of Science and Technology, Wuhan 430030, Hubei, China. [2]Research Center for Rural Health Service, Key Research Institute of Humanities & Social Sciences of Hubei Provincial Department of Education, Wuhan 430030, Hubei, China. [3]Interdisciplinary School of Health Sciences, Univ Ottawa, Ottawa, ON K1N 6N5, Canada. [4]School of Life Course and Population Sciences, King's College London, London, UK. [5]Institute for Better Health, Trillium Health Partners, Mississauga, Canada. [6]Department of Global Health and Social Medicine, King's College London, London, UK. [7]Department of Neurobiology, Care Sciences and Society, Karolinska Institutet, Stockholm, Sweden.

Received: 5 July 2025 Accepted: 2 February 2026
Published online: 25 February 2026

References

1. Chen C, Ding S, Wang J. Digital health for aging populations. Nat Med. 2023;29:1623–30. https://doi.org/10.1038/s41591-023-02391-8.
2. World population prospects. https://population.un.org/wpp/. Accessed 21 Jan 2026.
3. Chang AY, Bolongaita S, Cao B, Castro MC, Karlsson O, Mao W, et al. Epidemiological and demographic trends and projections in global health from 1970 to 2050: a descriptive analysis from the third Lancet Commission on Investing in Health, Global Health 2050. Lancet. 2025;406:940–9. https://doi.org/10.1016/S0140-6736(25)00902-X.
4. Kerner N, Goldberg TE, Cohen HR, Phillips JG, Cohen DE, Andrews H, et al. Sleep-wake behavior, perceived fatigability, and cognitive reserve in older adults. Alzheimers Dement. 2024;20:4020–31. https://doi.org/10.1002/alz.13802.
5. Tang D, Long C, Wei Y, Tang S. The longitudinal relationship between night-time sleep duration, midday napping, and frailty among middle-aged and older people in China: a prospective analysis. J Glob Health. 2025;15:04059. https://doi.org/10.7189/jogh.15.04059.
6. Li Y, Zhou H, Xu D, Wang H, Zhao Y, Jiang H. Independent and joint associations of physical activity and a body shape index with sleep disorders in older adults with cardiometabolic multimorbidity: a cross-sectional study. BMC Geriatr. 2025;25:519. https://doi.org/10.1186/s12877-025-06170-7.
7. Leroy V, Ayers E, Adhikari D, Verghese J. Association of sleep disturbances with prevalent and incident motoric cognitive risk syndrome in community-residing older adults. Neurology. 2024;103:e210054. https://doi.org/10.1212/WNL.0000000000210054.
8. Praharaj SK, Gupta R, Gaur N. Clinical practice guideline on management of sleep disorders in the elderly. Indian J Psychiatry. 2018;60(3):S383–96. https://doi.org/10.4103/0019-5545.224477.
9. Huang B-H, Del Pozo Cruz B, Teixeira-Pinto A, Cistulli PA, Stamatakis E. Influence of poor sleep on cardiovascular disease-free life expectancy: a multi-resource-based population cohort study. BMC Med. 2023;21:75–86. https://doi.org/10.1186/s12916-023-02732-x.
10. Sagayadevan V, Abdin E, Binte Shafie S, Jeyagurunathan A, Sambasivam R, Zhang Y, et al. Prevalence and correlates of sleep problems among elderly Singaporeans. Psychogeriatrics. 2017;17:43–51. https://doi.org/10.1111/psyg.12190.
11. Lim DC, Najafi A, Afifi L, Bassetti CL, Buysse DJ, Han F, et al. The need to promote sleep health in public health agendas across the globe. Lancet Public Health. 2023;8:e820–6. https://doi.org/10.1016/S2468-2667(23)00182-2.
12. Liu Z, Zhang L, Bai L, Guo Z, Gao J, Lin Y, et al. Repetitive transcranial magnetic stimulation and tai chi chuan for older adults with sleep disorders and mild cognitive impairment: a randomized clinical trial. JAMA Netw Open. 2025;8:e2454307. https://doi.org/10.1001/jamanetworkopen.2024.54307.
13. Himali JJ, Baril A-A, Cavuoto MG, Yiallourou S, Wiedner CD, Himali D, et al. Association between slow-wave sleep loss and incident dementia. JAMA Neurol. 2023;80:1326–33. https://doi.org/10.1001/jamaneurol.2023.3889.
14. Silva D, Martins R, Polido F, Cruz MDC. Elderly: coping with sleep disorders. Eur Psychiatry. 2021;64(1):S556. https://doi.org/10.1192/j.eurpsy.2021.1484.
15. Basu A, Joshi T, Pal A, Gupta R. Management of chronic insomnia using hypnotics: a friend or a foe? Sleep Biol Rhythms. 2022;20:39–46. https://doi.org/10.1007/s41105-021-00363-4.
16. Maeda T, Babazono A, Nishi T, Yasui M. Quantification of adverse effects of regular use of triazolam on clinical outcomes for older people with insomnia: a retrospective cohort study. Int J Geriatr Psychiatry. 2016;31:186–94. https://doi.org/10.1002/gps.4310.
17. Hshieh TT, DuMontier C, Jaung T, Bahl NE, Hawley CE, Mozessohn L, et al. Association of polypharmacy and potentially inappropriate medications with frailty among older adults with blood cancers. J Natl Compr Canc Netw. 2022;20:915-923.e5. https://doi.org/10.6004/jnccn.2022.7033.
18. Yang H-Y, Ren Q-W, Cai A-P, Huang J-Y, Guo R, Gu W-L, et al. Z-drugs are associated with cardiovascular outcomes among patients with heart failure: a population-based cohort study in Hong Kong. Eur J Prev Cardiol. 2025;:zwaf128. https://doi.org/10.1093/eurjpc/zwaf128.
19. Wang L, Pan Y, Ye C, Guo L, Luo S, Dai S, et al. A network meta-analysis of the long- and short-term efficacy of sleep medicines in adults and older adults. Neurosci Biobehav Rev. 2021;131:489–96. https://doi.org/10.1016/j.neubiorev.2021.09.035.
20. Chiu H-Y, Lee H-C, Liu J-W, Hua S-J, Chen P-Y, Tsai P-S, et al. Comparative efficacy and safety of hypnotics for insomnia in older adults: a systematic review and network meta-analysis. Sleep. 2021;44:zsaa260. https://doi.org/10.1093/sleep/zsaa260.
21. Glass J, Lanctôt KL, Herrmann N, Sproule BA, Busto UE. Sedative hypnotics in older people with insomnia: meta-analysis of risks and benefits. BMJ. 2005;331:1169. https://doi.org/10.1136/bmj.38623.768588.47.
22. Treves N, Perlman A, Kolenberg Geron L, Asaly A, Matok I. Z-drugs and risk for falls and fractures in older adults-a systematic review and meta-analysis. Age Ageing. 2018;47:201–8. https://doi.org/10.1093/ageing/afx167.
23. Karimi S, Soroush A, Towhidi F, Makhsosi BR, Karimi M, Jamehshorani S, et al. Surveying the effects of an exercise program on the sleep quality of elderly males. Clin Interv Aging. 2016;11:997–1002. https://doi.org/10.2147/CIA.S106808.
24. Mitchell LJ, Bisdounis L, Ballesio A, Omlin X, Kyle SD. The impact of cognitive behavioural therapy for insomnia on objective sleep parameters: a

meta-analysis and systematic review. Sleep Med Rev. 2019;47:90–102. https://doi.org/10.1016/j.smrv.2019.06.002.

25. Hasan F, Tu Y-K, Lin C-M, Chuang L-P, Jeng C, Yuliana LT, et al. Comparative efficacy of exercise regimens on sleep quality in older adults: a systematic review and network meta-analysis. Sleep Med Rev. 2022;65:101673. https://doi.org/10.1016/j.smrv.2022.101673.
26. Zhang M, Wang Q, Pu L, Tang H, Chen M, Wang X, et al. Light therapy to improve sleep quality in older adults living in residential long-term care: a systematic review. J Am Med Dir Assoc. 2023;24:65-74.e1. https://doi.org/10.1016/j.jamda.2022.10.008.
27. Hmwe NTT, Chan CM, Shayamalie TGN. Older people's experiences of participation in mindfulness-based intervention programmes: a qualitative systematic review. Int J Ment Health Nurs. 2024;33:1272–88. https://doi.org/10.1111/inm.13350.
28. Shen M, Ding X-D, Fu L, He H-X, Chen S-B, Hu Y-C, et al. Comparative effectiveness of multi-sensory interventions for reducing pain among premature infants: a systematic review and network meta-analysis. Int J Nurs Stud. 2025;161:104947. https://doi.org/10.1016/j.ijnurstu.2024.104947.
29. Hutton B, Salanti G, Caldwell DM, Chaimani A, Schmid CH, Cameron C, et al. The PRISMA extension statement for reporting of systematic reviews incorporating network meta-analyses of health care interventions: checklist and explanations. Ann Intern Med. 2015;162:777–84. https://doi.org/10.7326/M14-2385.
30. World population ageing, 2019: highlights. 2019.
31. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898. https://doi.org/10.1136/bmj.l4898.
32. Puhan MA, Schünemann HJ, Murad MH, Li T, Brignardello-Petersen R, Singh JA, et al. A GRADE working group approach for rating the quality of treatment effect estimates from network meta-analysis. BMJ. 2014;349:g5630. https://doi.org/10.1136/bmj.g5630.
33. Nikolakopoulou A, Higgins JPT, Papakonstantinou T, Chaimani A, Del Giovane C, Egger M, et al. CINeMA: an approach for assessing confidence in the results of a network meta-analysis. PLoS Med. 2020;17:e1003082. https://doi.org/10.1371/journal.pmed.1003082.
34. Nikolakopoulou A, Mavridis D, Furukawa TA, Cipriani A, Tricco AC, Straus SE, et al. Living network meta-analysis compared with pairwise meta-analysis in comparative effectiveness research: empirical study. 2018;:0–10. https://doi.org/10.1136/bmj.k585.
35. Hedges L, Olkin I. Statistical methods in meta-analysis. In: Stat med. 1985. https://doi.org/10.2307/1164953.
36. Cohen J. Statistical power analysis for the behavioral sciences. 2. ed., reprint. New York, NY: Psychology Press; 2009.
37. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327:557–60. https://doi.org/10.1136/bmj.327.7414.557.
38. Rücker G, Schwarzer G. Ranking treatments in frequentist network meta-analysis works without resampling methods. BMC Med Res Methodol. 2015;15:58–67. https://doi.org/10.1186/s12874-015-0060-8.
39. Bednárik DS, Földvári-Nagy KC, Simon V, Rancz A, Gede N, Veres DS, et al. Comparative effectiveness of different therapies for *Clostridioides difficile* infection in adults: a systematic review and network meta-analysis of randomized controlled trials. The Lancet Regional Health - Europe. 2025;49:101151. https://doi.org/10.1016/j.lanepe.2024.101151.
40. Noma H, Gosho M, Ishii R, Oba K, Furukawa TA. Outlier detection and influence diagnostics in network meta-analysis. Res Synth Methods. 2020;11:891–902. https://doi.org/10.1002/jrsm.1455.
41. Gallegos AM, Moynihan J, Pigeon WR. A secondary analysis of sleep quality changes in older adults from a randomized trial of an MBSR program. J Appl Gerontol. 2018;37:1327–43. https://doi.org/10.1177/0733464816663553.
42. Allen N, Crock L, Chun T, Reinhard MJ. Investigating a clinically informed sleep disturbance threshold for physical and mental health among gulf war illness veterans. Sleep Adv. 2024;5:zpae018. https://doi.org/10.1093/sleepadvances/zpae018.
43. Aibar-Almazán A, Hita-Contreras F, Cruz-Díaz D, de la Torre-Cruz M, Jiménez-García JD, Martínez-Amat A. Effects of Pilates training on sleep quality, anxiety, depression and fatigue in postmenopausal women: a randomized controlled trial. Maturitas. 2019;124:62–7. https://doi.org/10.1016/j.maturitas.2019.03.019.
44. Alessi C, Martin JL, Fiorentino L, Fung CH, Dzierzewski JM, Rodriguez Tapia JC, et al. Cognitive behavioral therapy for insomnia in older veterans using nonclinician sleep coaches: randomized controlled trial. J Am Geriatr Soc. 2016;64:1830–8. https://doi.org/10.1111/jgs.14304.
45. Bağcı H, Çınar Yücel Ş. Effect of therapeutic touch on sleep quality in elders living at nursing homes. J Relig Health. 2020;59:1304–18. https://doi.org/10.1007/s10943-019-00831-9.
46. Brandão GS, Gomes GSBF, Brandão GS, Callou Sampaio AA, Donner CF, Oliveira LVF, et al. Home exercise improves the quality of sleep and daytime sleepiness of elderlies: a randomized controlled trial. Multidiscip Respir Med. 2018;13:2–11. https://doi.org/10.1186/s40248-017-0114-3.
47. Chan MF, Chan EA, Mok E. Effects of music on depression and sleep quality in elderly people: a randomised controlled trial. Complement Ther Med. 2010;18:150–9. https://doi.org/10.1016/j.ctim.2010.02.004.
48. Chen M-C, Liu H-E, Huang H-Y, Chiou A-F. The effect of a simple traditional exercise programme (baduanjin exercise) on sleep quality of older adults: a randomized controlled trial. Int J Nurs Stud. 2012;49:265–73. https://doi.org/10.1016/j.ijnurstu.2011.09.009.
49. Cheung C, Wyman JF, Resnick B, Savik K. Yoga for managing knee osteoarthritis in older women: a pilot randomized controlled trial. BMC Complement Altern Med. 2014;14:160–71. https://doi.org/10.1186/1472-6882-14-160.
50. Choi M-J, Sohng K-Y. The effects of floor-seated exercise program on physical fitness, depression, and sleep in older adults: a cluster randomized controlled trial. Int J Gerontol. 2018;12:116–21. https://doi.org/10.1016/j.ijge.2017.06.003.
51. Corral-Pérez J, Vázquez-Sánchez MÁ, Casals-Sánchez JL, Contreras-García FJ, Costilla M, Casals C. A 6-month educational program improves sleep behaviour in community-dwelling frail older adults: a randomised controlled trial. Sleep Med. 2024;121:196–202. https://doi.org/10.1016/j.sleep.2024.07.011.
52. Curi VS, Vilaça J, Haas AN, Fernandes HM. Effects of 16-weeks of Pilates on health perception and sleep quality among elderly women. Arch Gerontol Geriatr. 2018;74:118–22. https://doi.org/10.1016/j.archger.2017.10.012.
53. Epstein DR, Sidani S, Bootzin RR, Belyea MJ. Dismantling multicomponent behavioral treatment for insomnia in older adults: a randomized controlled trial. Sleep. 2012;35:797–805. https://doi.org/10.5665/sleep.1878.
54. Fan B, Song W, Zhang J, Er Y, Xie B, Zhang H, et al. The efficacy of mind-body (baduanjin) exercise on self-reported sleep quality and quality of life in elderly subjects with sleep disturbances: a randomized controlled trial. Sleep Breath. 2020;24:695–701. https://doi.org/10.1007/s11325-019-01999-w.
55. Genç F, Karadağ S, Kılıç Akça N, Tan M, Cerit D. The effect of aromatherapy on sleep quality and fatigue level of the elderly: a randomized controlled study. Holist Nurs Pract. 2020;34:155–62. https://doi.org/10.1097/HNP.0000000000000385.
56. Habibollahpour M, Ranjkesh F, Motalebi SA, Mohammadi F. The impact of Benson's relaxation technique on the quality of sleep in the elderly. Top Geriatr Rehabil. 2019;35:88. https://doi.org/10.1097/TGR.0000000000000204.
57. Hariprasad VR, Sivakumar PT, Koparde V, Varambally S, Thirthalli J, Varghese M, et al. Effects of yoga intervention on sleep and quality-of-life in elderly: a randomized controlled trial. Indian J Psychiatry. 2013;55(Suppl 3):S364-368. https://doi.org/10.4103/0019-5545.116310.
58. Jiménez-García JD, Hita-Contreras F, de la Torre-Cruz MJ, Aibar-Almazán A, Achalandabaso-Ochoa A, Fábrega-Cuadros R, et al. Effects of HIIT and MIIT suspension training programs on sleep quality and fatigue in older adults: randomized controlled clinical trial. Int J Environ Res Public Health. 2021;18:1211. https://doi.org/10.3390/ijerph18031211.
59. Lai H-L, Good M. Music improves sleep quality in older adults. J Adv Nurs. 2005;49:234–44. https://doi.org/10.1111/j.1365-2648.2004.03281.x.
60. Lee EK-P, Wong B, Chan PHS, Zhang DD, Sun W, Chan DC-C, et al. Effectiveness of a mindfulness intervention for older adults to improve emotional well-being and cognitive function in a Chinese population: a randomized waitlist-controlled trial. Int J Geriatr Psychiatry. 2022;37. https://doi.org/10.1002/gps.5616.

61. Miyazaki R, Ayabe M, Kumahara H, Morimura K, Inukai Y. Effects of light-to-moderate intensity aerobic exercise on objectively measured sleep parameters among community-dwelling older people. Arch Gerontol Geriatr. 2021;94:104336. https://doi.org/10.1016/j.archger.2020.104336.
62. Nguyen MH, Kruse A. A randomized controlled trial of tai chi for balance, sleep quality and cognitive performance in elderly Vietnamese. Clin Interv Aging. 2012;7:185–90. https://doi.org/10.2147/CIA.S32600.
63. Phansuea P, Tangwongchai S, Rattananupong T, Lohsoonthorn V, Lertmaharit S. Effectiveness of a qigong program on sleep quality among community-dwelling older adults with mild to moderate depression: a randomized controlled trial. J Health Res. 2020;34:305–15. https://doi.org/10.1108/JHR-04-2019-0091.
64. Sadler P, McLaren S, Klein B, Harvey J, Jenkins M. Cognitive behavior therapy for older adults with insomnia and depression: a randomized controlled trial in community mental health services. Sleep. 2018;41. https://doi.org/10.1093/sleep/zsy104.
65. Sahragard F, Rezaei M, Izadi-Avanji FS, Atoof F, Ahmadi Shad M. The effect of group reminiscence therapy on insomnia in older adults: a randomized controlled clinical trial. J Res Dev Nurs Midw J. 2020;17:52–66. https://doi.org/10.29252/JGBFNM.17.1.94.
66. Seyyedrasooli A, Valizadeh L, Zamanzadeh V, Nasiri K, Kalantri H. The effect of footbath on sleep quality of the elderly: a blinded randomized clinical trial. J Caring Sci. 2013;2:305–11. https://doi.org/10.5681/jcs.2013.036.
67. Shum A, Taylor BJ, Thayala J, Chan MF. The effects of sedative music on sleep quality of older community-dwelling adults in Singapore. Complement Ther Med. 2014;22:49–56. https://doi.org/10.1016/j.ctim.2013.11.003.
68. Siu PM, Yu AP, Tam BT, Chin EC, Yu DS, Chung K-F, et al. Effects of tai chi or exercise on sleep in older adults with insomnia: a randomized clinical trial. JAMA Netw Open. 2021;4:e2037199. https://doi.org/10.1001/jamanetworkopen.2020.37199.
69. Song D, Yu D, Liu T, Wang J. Effect of an aerobic dancing program on sleep quality for older adults with mild cognitive impairment and poor sleep: a randomized controlled trial. J Am Med Dir Assoc. 2023;S1525–8610(23):00827–37. https://doi.org/10.1016/j.jamda.2023.09.020.
70. Sun J, Kang J, Wang P, Zeng H. Self-relaxation training can improve sleep quality and cognitive functions in the older: a one-year randomised controlled trial. J Clin Nurs. 2013;22:1270–80. https://doi.org/10.1111/jocn.12096.
71. Vizeshfar F, Ghelbash Z. Effect of a self-care training program using smartphones on general health, nutrition status, and sleep quality in the elderly. Psychogeriatr Off J Jpn Psychogeriatr Soc. 2021;21:910–9. https://doi.org/10.1111/psyg.12766.
72. Wang Q, Chair SY, Wong EML, Li X. The effects of music intervention on sleep quality in community-dwelling elderly. J Altern Complement Med. 2016;22:576–84. https://doi.org/10.1089/acm.2015.0304.
73. Yoon H. Effects of auricular acupressure therapy on psychological factors, sleep quality, and salivary cortisol levels in South Korean older adults in the community: a single-blind, randomized controlled trial. J Korean Acad Fundam Nurs. 2023;30:509–18. https://doi.org/10.7739/jkafn.2023.30.4.509.
74. Zeng H, Liu M, Wang P, Kang J, Lu F, Pan L. The effects of acupressure training on sleep quality and cognitive function of older adults: a 1-year randomized controlled trial. Res Nurs Health. 2016;39:328–36. https://doi.org/10.1002/nur.21738.
75. Zhang J-X, Liu X-H, Xie X-H, Zhao D, Shan M-S, Zhang X-L, et al. Mindfulness-based stress reduction for chronic insomnia in adults older than 75 years: a randomized, controlled, single-blind clinical trial. EXPLORE. 2015;11:180–5. https://doi.org/10.1016/j.explore.2015.02.005.
76. Dias S, Sutton AJ, Ades AE, Welton NJ. Evidence synthesis for decision making 2. Med Decis Making. 2013;33:607–17. https://doi.org/10.1177/0272989X12458724.
77. Enomoto K, Adachi T, Fujino H, Kugo M, Tatsumi S, Sasaki J. Comparison of the effectiveness of cognitive behavioral therapy for insomnia, cognitive behavioral therapy for pain, and hybrid cognitive behavioral therapy for insomnia and pain in individuals with comorbid insomnia and chronic pain: a systematic review and network meta-analysis. Sleep Med Rev. 2022;66:101693. https://doi.org/10.1016/j.smrv.2022.101693.
78. Chang JR, Cheung YK, Sharma S, Li SX, Tao RR, Lee JLC, et al. Comparative effectiveness of non-pharmacological interventions on sleep in individuals with chronic musculoskeletal pain: a systematic review with network meta-analysis. Sleep Med Rev. 2024;73:101867. https://doi.org/10.1016/j.smrv.2023.101867.
79. Wu JQ, Appleman ER, Salazar RD, Ong JC. Cognitive behavioral therapy for insomnia comorbid with psychiatric and medical conditions: a meta-analysis. JAMA Intern Med. 2015;175:1461–72. https://doi.org/10.1001/jamainternmed.2015.3006.
80. Yang P-Y, Ho K-H, Chen H-C, Chien M-Y. Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review. J Physiother. 2012;58:157–63. https://doi.org/10.1016/S1836-9553(12)70106-6.
81. Erickson ML, Allen JM, Beavers DP, Collins LM, Davidson KW, Erickson KI, et al. Understanding heterogeneity of responses to, and optimizing clinical efficacy of, exercise training in older adults: NIH NIA workshop summary. GeroScience. 2023;45:569–89. https://doi.org/10.1007/s11357-022-00668-3.
82. King AC, Pruitt LA, Woo S, Castro CM, Ahn DK, Vitiello MV, et al. Effects of moderate-intensity exercise on polysomnographic and subjective sleep quality in older adults with mild to moderate sleep complaints. J Gerontol A Biol Sci Med Sci. 2008;63:997–1004. https://doi.org/10.1093/gerona/63.9.997.
83. Jackson CL, Patel SR, Jackson WB, Lutsey PL, Redline S. Agreement between self-reported and objectively measured sleep duration among white, black, Hispanic, and Chinese adults in the United States: multi-ethnic study of atherosclerosis. Sleep. 2018;41:zsy057. https://doi.org/10.1093/sleep/zsy057.
84. Farrance C, Tsofliou F, Clark C. Adherence to community based group exercise interventions for older people: a mixed-methods systematic review. Prev Med. 2016;87:155–66. https://doi.org/10.1016/j.ypmed.2016.02.037.
85. Panagiotou M, Michel S, Meijer JH, Deboer T. The aging brain: sleep, the circadian clock and exercise. Biochem Pharmacol. 2021;191:114563. https://doi.org/10.1016/j.bcp.2021.114563.
86. Wu Y-H-T, He W-B, Gao Y-Y, Han X-M. Effects of traditional Chinese exercises and general aerobic exercises on older adults with sleep disorders: a systematic review and meta-analysis. J Integr Med. 2021;19:493–502. https://doi.org/10.1016/j.joim.2021.09.007.
87. Perini F, Wong KF, Lin J, Hassirim Z, Ong JL, Lo J, et al. Mindfulness-based therapy for insomnia for older adults with sleep difficulties: a randomized clinical trial. Psychol Med. 2023;53:1038–48. https://doi.org/10.1017/S0033291721002476.
88. Deng W, van der M J J Kleij R, Shen H, Wei J, Brakema EA, Guldemond N, et al. eHealth-based psychosocial interventions for adults with insomnia: systematic review and meta-analysis of randomized controlled trials. J Med Internet Res. 2023;25:e39250. https://doi.org/10.2196/39250.
89. McCurry SM, Shortreed SM, Von Korff M, Balderson BH, Baker LD, Rybarczyk BD, et al. Who benefits from CBT for insomnia in primary care? Important patient selection and trial design lessons from longitudinal results of the lifestyles trial. Sleep. 2014;37:299–308. https://doi.org/10.5665/sleep.3402.
90. Espie CA, Henry AL. Disseminating cognitive behavioural therapy (CBT) for insomnia at scale: capitalising on the potential of digital CBT to deliver clinical guideline care. J Sleep Res. 2023;32:e14025. https://doi.org/10.1111/jsr.14025.
91. Perrault AA, Pomares FB, Smith D, Cross NE, Gong K, Maltezos A, et al. Effects of cognitive behavioral therapy for insomnia on subjective and objective measures of sleep and cognition. Sleep Med. 2022;97:13–26. https://doi.org/10.1016/j.sleep.2022.05.010.
92. Cheng J-X, Zhao X, Qiu J, Jiang Y, Ren J, Sun S, et al. Effects of transcranial direct current stimulation on performance and recovery sleep during

acute sleep deprivation: a pilot study. Sleep Med. 2021;79:124–33. https://doi.org/10.1016/j.sleep.2021.01.014.
93. Mijnster T, Boersma GJ, Meijer E, Lancel M. Effectivity of (personalized) cognitive behavioral therapy for insomnia in mental health populations and the elderly: an overview. J Pers Med. 2022;12:1070. https://doi.org/10.3390/jpm12071070.
94. McCurry SM, Zhu W, Von Korff M, Wellman R, Morin CM, Thakral M, et al. Effect of telephone cognitive behavioral therapy for insomnia in older adults with osteoarthritis pain: a randomized clinical trial. JAMA Intern Med. 2021;181:530–8. https://doi.org/10.1001/jamainternmed.2020.9049.

Publisher's Note