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Non-pharmacological interventions targeting sleep quality in older adults: a systematic review and meta-analysis

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REVIEW

Non-pharmacological interventions targeting sleep quality in older adults: a systematic review and meta-analysis

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ABSTRACT

Objectives: This review aimed to examine the available evidence about non-pharmacological interventions (NPIs) aimed at improving sleep quality in older adults without insomnia or dementia.
Methods: Studies on NPIs targeting older adults' sleep were searched in the PsycInfo, PubMed and Scopus databases, with no restriction on publication year up to September 2021. Studies on NPIs for older adults with no diagnosed sleep disorders were included, while those on pharmacological therapies and/or concerning pathological samples were excluded. The risk of bias was assessed using tools based on Joanna Briggs' criteria. The data extracted were meta-analyzed using random effects models for subgroups of NPIs.
Results: Of the 1,893 records identified, 31 studies on NPIs (N = 2,224; range of mean ages: 60-78 years) were analyzed. All NPIs improved self-reported sleep quality, albeit to a different extent (physical activity: d=.97 – 95% CI=.62, 1.32-; psychological/psychoeducational, or NPIs that combined more than one sleep-targeting activity: d range: .21 to .97). Only the NPIs based on physical activity improved objectively-measured sleep, d=.31 (.04, .57). The methodological quality of most studies was limited.
Conclusion: The most often used NPIs targeting sleep rely on physical activity and sensory stimulation with promising results on sleep quality for the former. More data are needed on psychological/psychoeducational NPIs and combined interventions in order to test their effectiveness. The methodological weaknesses of the available studies suggest they their findings should be interpreted with caution.

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Introduction

Sleep is essential to physical and mental health, and quality of life (Buysse, 2014; Sella et al., 2021). As people age, their sleep patterns often change: they sleep for less time, and less efficiently, have more trouble falling asleep, wake more often, and have shorter periods of rapid eye movement (REM) sleep and slow wave sleep (Mander et al., 2017). Combined with physical and physiological changes that accompany aging, all this means that sleep problems increase markedly in older age (e.g. Ancoli-Israel, 2009). Insomnia is one of the most prevalent and chronic sleep disorders in older adults (Neikrug & Ancoli-Israel, 2010), characterized by difficulty falling asleep and staying asleep throughout the night. It is associated with mental and physical stress or impaired daily functioning (Sateia, 2014). Other relevant sleep disorders common in older age include sleep-related breathing disorders like obstructive sleep apnea syndrome, and sleep-related movement disorders restless leg syndrome (Neikrug & Ancoli-Israel, 2010).

Older adults diagnosed with sleep disorders are not the only ones to suffer from self-reported and objectively-recorded negative changes in sleep architecture (Neikrug & Ancoli-Israel, 2010; Spira et al., 2012). Even in autonomous and active older adults (Sella et al., 2021), untreated sleeping problems can raise the risk of poor daytime functioning (Min & Slattum, 2018), poor quality of life (Sella et al., 2021), and psychological disorders (Leblanc et al., 2015). Sleep problems, and age-related negative changes in sleeping patterns and quality are also associated with a higher risk of various poor physical health outcomes, including organic conditions such as cardiovascular disease or diabetes mellitus (Yaggi et al., 2006), immune deficiencies or neurodegenerative disorders like Alzheimer's disease (D'Rozario et al., 2020). Hence the importance of interventions targeting older adults' sleep quality to prevent or delay age-related sleeping difficulties in older adults without any sleep disorders.

Interventions developed to improve sleep in older adults with insomnia focus mostly on pharmacological solutions (Sateia et al., 2017). These treatments produce short-lived improvements (Sateia et al., 2017), but are not recommended for long-term use as their efficacy fades over time, and they can cause dependence and other adverse effects (Qaseem et al., 2016; Riemann et al., 2017). Non-pharmacological interventions (NPIs) targeting sleep are considered safer over the longer term and potentially effective for older adults experiencing sleeping problems (e.g. MacLeod et al., 2018). There is evidence of NPIs improving sleep quality in aging as well, by: promoting regular bedtimes and morning waking times, and discouraging napping during the day (e.g. Schutte-Rodin et al., 2008); extending exposure to light in the morning by placing older individuals in brightly-lit rooms (e.g. Friedman et al., 2009); maximizing daytime exercise, as regular aerobic exercise has proved beneficial to the quantity and perceived quality of sleep (Reid et al., 2010); and diminishing daytime sleepiness in older people (Yang et al., 2012). In general, NPIs aim to: modify maladaptive sleep-related habits (like spending more time in bed); educate people about more appropriate sleep hygiene practices; change dysfunctional beliefs and attitudes about sleep; and reduce somatic and cognitive arousal in people

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suffering from chronic insomnia (e.g. Ebben & Spielman, 2009). NPIs have several advantages over pharmacotherapy: they do not have the potential for side effects, whereas medication can cause dependence and tolerance with long-term use; and the effects of NPIs tend to be more persistent than those of sleeping pills or hypnotic drugs (benzodiazepines) (Riemann et al., 2017). They are, thus, considered much more appropriate for older adults (e.g. MacLeod et al., 2018), not only for those with multiple chronic health conditions and polypharmacy issues, but also for typically-ageing older people facing negative changes in their sleep patterns and quality (Fialová et al., 2019).

The most common NPIs for older adults include: sleep hygiene (behavioral practices based on understanding sleeping difficulties and promoting healthy sleeping habits); physical activity programs; relaxation exercises; and psychological therapies like mindfulness-based stress reduction (MBSR), cognitive behavioral therapy (CBT) or behavioral therapies involving sleep restriction and stimulus control (MacLeod et al., 2018; Montgomery & Dennis, 2004; Petit et al., 2003). Another advantage of NPIs lies in the availability of various approaches based on different methods that have proved effective; novel approaches and short forms of these interventions are also being developed all the time.

Only two reviews to date explored practical NPIs to improving older adults' sleep quality, focusing on people with sleep disorders (Montgomery & Dennis, 2004) or insomnia and chronic diseases (MacLeod et al., 2018). The NPIs involved psychological (CBT or MBSR) or behavioral therapies, or sensory interventions (e.g. bright light exposure). MBSR and CBT proved beneficial, as did NPIs combining sleep restriction or sleep hygiene practices with relaxation training or CBT targeting sleep (MacLeod et al., 2018; Montgomery & Dennis, 2004).

While some effort has gone into investigating NPIs for improving sleep quality in older people with insomnia (MacLeod et al., 2018; Montgomery & Dennis, 2004), the same cannot be said for autonomous, community-dwelling older people with no diagnosed sleep disorders or neurodegenerative conditions. The effectiveness of NPIs targeting sleep in the latter has been less thoroughly examined. Sone studies examined NPIs for sleeping difficulties experienced by older people without sleep disorders, considering physical activity sensory stimulation and psychological/psychoeducational interventions, alone or in various combinations (see Table 1), with promising results. No systematic reviews or meta-analyses on the effectiveness of NPIs for older adults' sleep quality have ever been conducted, however. Hence the present study to summarize the findings and establish the strength of the evidence on the effectiveness of such NPIs for improving sleep quality in community-dwelling people aged 60 years or more with no diagnosed sleep disorders.

Another aspect to clarify is whether NPIs targeting sleep would have different effects on both subjective and objective sleep quality measures (e.g. self-reported questionnaires and actigraphy or polysomnography). As such measures are associated, and can provide different but complementary information on the effect of NPIs on older adults' sleep quality, the present study separately examined both self-reported and objectively-recorded sleep quality.

The main objective here was thus to conduct a first systematic review and meta-analysis on the effectiveness of NPIs targeting sleep quality in autonomous, community-dwelling older adults with or without chronic diseases, who had no diagnosed sleep disorders (sleep apnea or insomnia). In the studies reviewed, we considered: the types of NPI and their characteristics; whether and how they improved self-reported or objectively-recorded sleep quality; the quality of the evidence; and the strengths of the various NPIs. To give a brief account of how NPIs have been used to improve self-reported and objective sleep quality, our meta-analytic models focused on the effect size estimates deriving from comparisons between treated groups (i.e. participants in the NPI group) and control groups. As sleep quality correlates with physical and psychological health, and quality of life in aging (see Sella et al., 2021 for a review), we also aimed to take a comprehensive look at whether there are any (indirect) benefits of NPIs targeting sleep that might be transferred to other aspects of psychological well-being in older adults.

Methods

The present review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher et al., 2009; Page et al., 2020), and preregistered (#CRD42021285076) with PROSPERO (Booth et al., 2012). A systematic literature search was conducted to identify studies using NPIs to improve sleep quality in older adults with no sleep disorders. The inclusion/exclusion criteria were defined beforehand using the PICOS (Population; Interventions; Comparison; Outcomes; Study design) approach, a well-structured method for framing research questions in systematic reviews (Schardt et al., 2007). All the studies identified met the following *a priori* inclusion criteria: i) participants were community-dwelling adults over 60 years old with no diagnosed sleep disorders (e.g. insomnia, obstructive sleep apnea syndrome or other sleep disorders), and no dementia (e.g. Alzheimer's or Parkinson's disease) or other neurological or psychiatric disorders; ii) NPIs designed to improve sleep (e.g. psychological or behavioral intervention, sleep hygiene, physical exercise, light therapy, relaxation training) were conducted at home or in class; iii) control groups could be active or passive, or wait-list controls; iv) study designs could be randomized controlled trials (RCTs) or clinical trials published in regular articles, conference papers, conference abstracts, and official reports published in peer-reviewed journals at any time, in English, Italian or Spanish (see Supplementary Material, Table S1).

Search strategy and data collection

The literature search for relevant peer-reviewed articles in the Scopus, PsycInfo and PubMed databases started in September 2021. There was no limit on the initial date of publication in order to include as many records as possible. The choice of search terms was based on the target intervention (i.e. NPIs), population (i.e. older people with no diagnosed sleep disorders and dementia), and outcomes of interest (primary: sleep quality; and secondary: wellbeing), using an appropriate database-specific indexing syntax. All authors reached a consensus on the keywords. The following search terms were used: ("older adult*" OR "older people" OR "elderly") AND ("sleep" OR "sleep hygiene" OR "sleep quality") AND ("program" OR "training" OR "cognitive training" OR "intervention" OR "metacognitive intervention" OR "cognitive intervention" OR "psychological intervention" OR "psychoeducation" OR "treatment" OR "therapy" OR "behavioral therapy" OR "non-pharmacological intervention") AND ("well-being" OR "quality of life" OR "depression" OR "anxiety") NOT ("dementia") NOT ("disease category") NOT ("drug") NOT ("insomnia") NOT ("sleep disorder*"). The complete search algorithm with the keywords for each database is available from the

Table 1. Characteristics of the studies reviewed.

			Intervention group			Control group							
Author	Study design	Country	Activities	N	Age (mean ± SD)	Activities	N	Age (mean ± SD)	Setting	Duration	Sleep measures	Other measures	Key findings
Adachi et al., 2011	Quasi-experimental (pre-post design)	Japan	Self-help educational program	$N = 106$ *Female:* 76	69.8 ± 6.04	–	–	–	Home-based	2-4 weeks	*Self-reported sleep measure:* PSQI	SF-8	Improvements at post-test in PSQI total scores (fewer sleep disturbances), and on the subscales for "subjective sleep quality", "sleep latency", and "sleep disturbance". Improvements in quality of life on the SF-8 subscales for "physical component summary", "physical functioning", "role physical", "bodily pain", "general health perception", and "role emotion".
Bankar et al., 2012	Cross-sectional	India	Yoga exercises	Yoga group: $N = 35$ *Female:* 35%	63.7 y	No specific activities	No-yoga group: $N = 30$ *Female:* 34%	62.8 y	Yoga center	Daily yoga exercise for at least 2 years	*Self-reported sleep measure:* PSQI	LEIPAD	The yoga group reported lower PSQI total scores, and for "disturbances", "latency", "sleep medication", "efficiency", and "subjective sleep quality" than controls. The yoga group also reported better LEIPAD scores than controls.
Bullock et al., 2020	Quasi-experimental (pre-post design)	Canada	Physical exercise	High-intensity interval training (HIIT) $N = 20$ *Female:* 70% ——— Moderate-intensity continuous training (MICT) $N = 19$ *Female:* 47% ——— Stretching (STRETCH) $N = 19$ *Female:* 68%	HIIT *Age:* 72.4 ± 4.5 ——— MICT *Age:* 72.3 ± 6.2 ——— STRETCH *Age:* 71.1 ± 6.5	–	–	–	Motor-driven treadmill (Life Fitness 95Ti) at the fitness center	3 times a week, for 12 weeks	*Self-reported sleep measure:* PSQI	PSS MoCA VO_2	No significant effect on intervention group's self-reported sleep quality, PSQI total score or any of the 7 subscales. MICT and STRETCH improved sleep efficiency for poor sleepers, whereas HIIT did not. HIIT and MICT yielded significantly greater improvements in peak VO_2 than STRETCH. No other significant changes.
Buman et al., 2011	RCT	USA	Moderate-intensity exercise	$N = 36$ *Female:* 66%	*Age:* 61.86 ± 6.33	Health education classes	$N = 30$ *Female:* 66%	*Age:* 60.90 ± 7.19	Center- and Home-based	*Exercise classes:* 2 days a week for 60 min, for 12 months *Home-based exercise:* 3 days a week for 30 min, for 12 months	*Self-reported sleep measure:* PSQI *Objective sleep measure:* PSG	CHAMPS CES-D STAI VO_2 Arm curl and Chair stands	Physically inactive participants with self-reported poor sleep quality were most likely to experience objective benefits on sleep from moderate-intensity physical activity, compared with the control group.. Participants in the intervention group also reported lower levels of depression, a lower BMI, and greater arm curl after 6 months, while no differences emerged in anxiety trait or chair stands. Participants in the control group reported no significant improvements in objective or self-reported sleep, or any other variables.
Chan & Chen, 2017	Quasi-experimental (pre-post design)	Taiwan	Senior elastic band exercises	$N = 84$	> 60 y	Maintaining daily activities	$N = 85$	> 60 y	Senior-citizen activity centers	3 times a week, 40 min per session, for 6 months	*Self-reported sleep measure:* PSQI	SF-12	The intervention group reported lower PSQI total scores (fewer sleep disturbances) than controls after 3 and 6 months of the intervention. On the PSQI subscales, the intervention group reported lower scores than controls for "sleep duration", "subjective sleep quality", and "habitual sleep efficiency". There were no significant differences for "sleep disturbances, "daytime dysfunction" or use of "sleeping medications". The intervention group reported significant improvements in the physical component summary, but not in the mental component summary of the SF-12, compared with the control group.

(*Continued*)

Table 1. Continued.

			Intervention group			Control group							
Author	Study design	Country	***Activities***	***N***	***Age (mean ± SD)***	***Activities***	***N***	***Age (mean ± SD)***	Setting	Duration	Sleep measures	Other measures	Key findings
Chen et al., 2009	Cluster randomized trial.	Taiwan	Silver yoga exercises	$N = 62$ *Female:* 52	*Age:* 65.77 ± 4.32	Wait-list group maintaining their daily activities	$N = 66$ *Female:* 41	*Age:* 72.42 ± 6.04	Senior activity center	3 times a week, 70 min per session, for 6 months	*Self-reported sleep measure:* PSQI	TDQ SF-12	The yoga group reported a drop in the PSQI total score, and for the daytime dysfunction subscale. The control group reported prolonged sleep latency and increased daytime dysfunction. Both groups had significant differences at 3 months on the PSQI subscales for "subjective sleep quality" and "daytime dysfunction", in favor of the yoga group. After 6 months, the yoga group reported a significantly better sleep quality on the PSQI total score and on all the subscales, compared with the control group. Only the intervention group also reported improvements in the physical component summary, and mental component summary of the SF-12. They also reported fewer depressive symptoms after 3 and 6 months of intervention, compared with the control group.
Chen et al., 2012	RCT	Taiwan	Baduanjin exercises	$N = 27$ *Female:* 19	72.96 ± 8.30	No specific activities	$N = 28$ *Female:* 17	70.48 ± 7.90	Home-based	3 times a week, 30 min sessions, for 12 weeks	*Self-reported sleep measure:* PSQI	–	The baduanjin exercise group reported a significant improvement in sleep quality (PSQI total score and subscales) after 4 weeks, which was maintained throughout the 12 weeks. The control group reported no significant improvement in sleep quality.
Curi et al., 2018	RCT	Portugal	Mat-based Pilates exercises	$N = 31$ *Female:* 31	64.25 ± 0.14	No physical exercises Monthly group meetings in the Catholic community	$N = 30$ *Female:* 30	63.75 ± 0.08	Pilates classes	Twice a week, 60 min sessions, for 16 weeks	*Self-reported sleep measure:* PSQI	GHQ-12	The intervention group reported a drop in PSQI total score, and subscales for "sleep latency" and "use of sleeping medication". The intervention group also reported significant improvements in the GHQ-12 total score, and the depression subscale. The control group reported no significant improvements in these outcome variables.
Sousa et al., 2017	Quasi-experimental (pre-post design)	Brazil	Resistance exercises combined with aerobic exercises	$N = 8$ *Female:* 8	67.0 ± 8.0	–	–	–	Center-based	3 times a week, with 24-hour rest between sessions, for 8 weeks	*Self-reported sleep measure:* PSQI	BMI	Improvements in PSQI total score. No significant improvements in BMI.
Fan et al., 2020	RCT	China	Baduanjin exercises	$N = 67$ *Female:* 12	70.3 ± 5.7	Wait-list group maintaining their daily activities	$N = 72$ *Female:* 22	71.8 ± 6.7	Home-based	45 min a day, 5 times a week, for 24 weeks	*Self-reported sleep measure:* PSQI	SF-36	The intervention group had significantly lower PSQI scores after 12 and 24 weeks. The control group had a modest reduction in PSQI scores after 12 and 24 weeks. The intervention group reported significant improvements in sleep quality after 24 weeks, compared with the control group. Only the intervention group reported better SF-36 scores for mental component summary and physical component summary, compared with the baseline. The control group had no significant reduction in PSQI or SF-36 scores at 12 and 24 weeks, compared with the baseline.
Gallegos et al., 2018	RCT	USA	Mindfulness-based stress reduction	$N = 100$ *Female:* 62%	72 ± 6.82	Wait-list group given no specific activities	$N = 100$ *Female:* 62%	73 ± 6.59	Center-based	8 weeks	*Self-reported sleep measure:* PSQI	–	The intervention groups (with baseline PSQI scores > 5 *or* > 10) reported significant improvements in PSQI total score compared with the baseline and with the control group. The intervention groups also reported significant improvements in sleep quality at follow-up. No significant improvements emerged in the control group.

(*Continued*)

Table 1. Continued.

			Intervention group			Control group							
Author	Study design	Country	**Activities**	**N**	**Age (mean ± SD)**	**Activities**	**N**	**Age (mean ± SD)**	Setting	Duration	Sleep measures	Other measures	Key findings
Goerke et al., 2017	Quasi-experimental (pre-post design)	Germany	Aerobic endurance training or Progressive muscle relaxation training	*Aerobic endurance training (treadmill): N = 11* *Progressive muscle relaxation training: N = 10* *Overall female:* 55%,	*Overall sample*: 68.36 y	–	–	–	Center-based	*Aerobic endurance training (treadmill):* 30 min, 3 times a week, for 12 weeks *Progressive muscle relaxation training:* 45 min, twice a week, for 12 weeks	*Self-reported sleep measure:* PSQI Sleep diary	BMI	The two intervention groups did not differ significantly in the PSQI total score after 12 weeks of intervention. The aerobic endurance training group reported a significant decrease in BMI, while the progressive muscle relaxation group did not.
King et al., 1997	RCT	USA	Moderate-intensity exercises	N = 20 *Female*: 12	*Female*:62.4 ± 6.4 *Male:* 62.3 ± 8.4	Wait-list group given no specific activities	N = 24 *Female:* 17	*Female:* 61.2 ± 7.5 *Male:* 58.8 ± 5.6	Center-based	30- to 40-min endurance training sessions per week, for 16 weeks	*Self-reported measure:* PSQI Sleep diary	–	After 16 weeks, the intervention group reported a significant improvement in PSQI total score, and the subscales for "subjective sleep quality", "sleep latency", and "sleep duration", compared with controls.
King et al., 2008	RCT	USA	Moderate-intensity exercises	N = 36 *Female*: 24	61.86 ± 6.33	Weekly health education classes on various topics other than physical activity (e.g. nutrition)	N = 30 *Female*: 20	60.90 ± 7.19	Center-based	60-min sessions, 2 days a week, plus exercise on their own an additional 3 days a week, for 12 months	*Self-reported measure:* PSQI Sleep diary *Objective sleep measure:* PSG	PAR VO_2 BMI	The intervention group reported improvements after 12 months for the "sleep disturbance" subscale of the PSQI, compared with the control group. In a sleep diary, they also reported a shorter sleep onset latency and feeling more rested in the morning. As for objective sleep parameters, the exercise group spent significantly less time in Stage 1 and Stage 2 of sleep than the control group. They also reported significantly fewer awakenings during the first third of the sleep period than the control group. No statistically significant group differences emerged for other PSG variables at 12 months. The intervention group also reported significant improvements in their PAR scores and cardiorespiratory fitness (VO_2) and had significantly lower BMI than the control group.
Kobayashi et al., 1999	Quasi-experimental (pre-post design)	Japan	Morning bright light exposure	N = 10 *Female*: 10	61.7 ± 2.3	Sitting in front of the lighting device without light	–	–	Home-based	1 h sessions, on 5 consecutive days	*Self-reported sleep measure:* OSA *Objective sleep measure:* PSG	–	The intervention group reported better OSA scores (greater sleep maintenance, less sleepiness). The amount of REM sleep in the first third of the sleep period increased in the intervention group. There were no statistically significant differences between the groups for the PSG variables.
Kudo & Sasaki, 2020	Quasi-experimental (pre-post design)	Japan	Hand massage	N = 28	77.8 ± 6.8	No hand massage or other specific activities	–	–	Home-based	25-min hand massage sessions on 6 consecutive days	*Self-reported sleep measure:* OSA *Objective sleep measure:* Actigraphy	HRT VAS for comfort RE	Participants reported higher OSA scores (sleepiness on rising, initiating and maintaining sleep, frequent dreaming, and refreshing) on intervention days. As for the actigraphic variables, they reported higher SE and lower SOL on intervention days than on control days. No other significant differences emerged. The intervention group also reported a significant decrease in HRT, and scored higher on the VAS and RE scales after the intervention compared with before.
Lai & Good, 2006	RCT	Taiwan	Music at bedtime	N = 30	Overall sample: 67 ± 5	No listening to music at bedtime No other specific activities	N = 30	–	Home-based	45 min a day for 3 weeks	*Self-reported sleep measure:* PSQI	–	The intervention group reported a significant decrease in PSQI total score compared with the control group. The intervention group also improved on the PSQI subscales for "subjective sleep quality", "sleep duration", "sleep efficiency", "sleep latency", "sleep disturbance" and "daytime dysfunction". The control group reported no improvements in any PSQI scores.

(*Continued*)

Table 1. Continued.

Author	Study design	Country	Intervention group: Activities	Intervention group: N	Intervention group: Age (mean ± SD)	Control group: Activities	Control group: N	Control group: Age (mean ± SD)	Setting	Duration	Sleep measures	Other measures	Key findings
Latorre-Romàn et al., 2015	Quasi-experimental (pre-post design)	Spain	Balneotherapy	$N = 52$ *Female*: 29	*Female*: 70.31 ± 6.76 *Male*: 69.74 ± 5.19	–	–	–	San Andrés spa	60 to 80 min a day for 12 days	*Self-reported sleep measure:* OSQ	VAS for pain POMS GDS-15	The intervention group reported greater satisfaction with sleep after 12 days of balneotherapy. They also reported improvements in perceived pain levels (VAS), less depression level (GDS), and better mood (POMS), after intervention.
Lee et al., 2022	RCT	China	Mindfulness-based stress reduction	$N = 104$ *Female*: 87	71.3 ± 7.0	Wait-list group given no specific activities	$N = 104$ *Female*: 88	71.8 ± 8.2	Center- and home-based	1 session a week at the center, and 6 practice sessions a week at home, for 8 weeks	*Self-reported sleep measure:* PSQI	SWEMWBS FFMQ SCS MoCA VFT ISLT GDS SCS POM	The intervention and control groups both reported lower PSQI total scores after 2 months. The intervention group reported significant improvements in verbal fluency, and depression levels. Both groups reported improvements in MoCA scores. Neither group experienced any significant improvements in SCS, ISLT or SWEMWBS. All participants completed the follow-up after post-test.
Li et al., 2020	Quasi-experimental (pre-post design) (pre-post design)	USA	Personalized behavioral intervention	$N = 8$ *Female*: 6	74 ± 5.42	–	–	–	Center- and home-based	4 weeks	*Self-reported sleep measure:* ISI ESS *Objective sleep measure:* Actigraphy	PASE	No significant differences in sleep measures (sleep duration, sleep efficiency, or ISI). Participants' daytime physical activity levels (actigraphy), and self-reported physical activity (PASE) increased significantly at posttest.
Lira et al., 2011	Quasi-experimental (pre-post design)	Brazil	Moderate exercise	$N = 14$ *Female*: 0	70.32 ± 0.72	–	–	–	Center-based intervention	60 min a day, 3 times a week, for 24 weeks	*Objective sleep measure:* PSG	BMI VO_2 Blood	Time awake and REM sleep latency decreased after 3 and 6 months of aerobic training. Participants reported improvements in VO_2, but not in BMI.
Ng & Chan, 2008	Quasi-experimental (pre-post design)	China	Integrated group program (social group work, psycho-education, and nonpharmacological Chinese medicine -acupressure and diet)	$N = 19$ *Female*: 17	72 Age range: 56-82	No specific activities	$N = 9$ *Female*: 8	74 Age range: 57-80	Center- and home-based	60 min sessions, once a week, for 6 weeks	*Self-reported sleep measure:* PSQI	–	PSQI total scores decreased in the intervention group after 6 weeks, with a significant improvement on the subscale for "subjective sleep quality". No significant differences emerged in the control group.
Nguyen & Kruse, 2012	RCT	Germany	Tai chi	$N = 48$ *Female*: 24	69.2 ± 5.3	Maintaining daily activities	$N = 48$ *Female*: 24	68.7 ± 4.9	Center-based	60-minute tai chi sessions, twice a week, for 6 months	*Self-reported sleep measure:* PSQI	FES TMT	The tai chi group reported significantly lower PSQI total scores than controls after 6 months. The intervention group also reported better scores for cognitive function (TMT) and balance (FES) after 6 months, compared with the control group. All participants completed the follow-up after post-test.
Rawtaer et al., 2018	Quasi-experimental (pre-post design)	Singapore	Community program: (tai chi exercises; art therapy; mindfulness, awareness, music, reminiscence therapy)	$N = 189$ *Female*: 145	69.3 ± 5.7	–	–	–	Center-based	1 to 2 h per session, weekly for 10 weeks, then fortnightly for 18 weeks, and monthly for the rest of the year	*Self-reported sleep measure:* PSQI	–	Participants reported a significant improvement on the PSQI subscale for "sleep disturbances" after 1 year. No other significant changes emerged for PSQI total score or other subscales.
Seol et al., 2020	RCT	Japan	Low-intensity stepping exercises	Morning exercise: $N = 30$ *Female*: 22 Evening exercise: $N = 30$ *Female*: 23	Morning exercise: 70.7 ± 4.1 Evening exercise: 71.3 ± 3.8	–	–	–	Center- and home-based	30 min a day at home for 8 weeks	*Self-reported sleep measure:* PSQI *Objective sleep measure:* Actigraphy	–	The evening exercise group reported a shorter SOL after 4 and 8 weeks. After 8 weeks, they reported a significantly greater sleep satisfaction than the morning exercise group. On actigraphy, the evening exercise group had a significantly shorter SOL after 4 and 8 weeks. The morning exercise group reported an increase in total sleep time after 4 and 8 weeks. SE and WASO both improved significantly after 4 and 8 weeks in both groups.

(*Continued*)

Table 1. Continued.

			Intervention group			Control group							
Author	*Study design*	*Country*	***Activities***	***N***	***Age (mean ± SD)***	***Activities***	***N***	***Age (mean ± SD)***	*Setting*	*Duration*	*Sleep measures*	*Other measures*	*Key findings*
Seyyedrasooli et al., 2013	RCT	Iran	Footbath	$N=23$ *Female:* 0	67.49 ± 4.28	No specific activities	$N=23$ *Female:* 0	66.82 ± 3.84	Home-based	20 min a day before sleeping, for 6 weeks	*Self-reported sleep measure:* PSQI	–	The intervention group reported significant improvements in PSQI total score compared with control group. The intervention group also reported improvements on all PSQI subscales except for "sleep efficiency" and "uses of sleep medication". The control group did not report any improvements in their PSQI scores.
Shum et al., 2014	RCT	Singapore	Music	$N=28$ *Female:* 16	62.3 ± 6.3	No specific activities	$N=32$ *Female:* 24	65.4 ± 9.2	Home-based	40 min a day, for 6 weeks	*Self-reported sleep measure:* PSQI	–	The intervention group reported a significant decrease in PSQI total score after 6 weeks. No significant differences emerged in the control group.
Sousa et al., 2017	Quasi-experimental (pre-post design)	Brazil	Resistance exercises combined with aerobic exercises	$N=8$ *Female:* 8	67.0 ± 8.0	–	–	–	Center-based	3 times a week, with 24-hour rest between sessions, for 8 weeks	*Self-reported sleep measure:* PSQI	BMI	Improvements in PSQI total score. No significant improvements in BMI.
Sun et al., 2013	RCT	China	Progressive muscle relaxation and meditation based on sleep hygiene education	$N=40$ *Female:* 26	68.59 ± 8.45	Sleep hygiene education	$N=40$ *Female:* 30	70.76 ± 7.44	Center- and home-based	90 min group relaxation sessions, once a week, for 4 weeks, then 30-min sessions of PMR and meditation at home at least 3 times a day, for 1 year	*Self-reported sleep measure:* PSQI ESS	MMSE WMS-CR	The intervention group reported a significant gradual decrease in PSQI total score after 3, 6 and 12 months. The intervention group also reported less sleepiness (ESS), and better cognitive functioning (measured with the MMSE and WMS-CR). No significant improvements in PSQI or ESS scores, or cognitive functioning, emerged in the control group.
Tanaka et al., 2001	Quasi-experimental (pre-post design)	Japan	Short naps after lunch and moderate-intensity exercise in the evening	$N=6$ *Female:* NA	72.0 ± 5.2	–	–	–	Home-based	30-min nap after lunch and evening exercise, daily for 4 weeks	*Objective sleep measure:* Actigraphy	GHQ	Wake time after sleep onset significantly decreased and sleep efficiency significantly increased after the intervention. No other sleep parameters were reported. Participants also reported better mental health (GHQ).
Tanaka et al., 2002	Quasi-experimental (pre-post design)	Japan	Short naps after lunch and moderate-intensity exercise in the evening	$N=11$ *Female:* NA	73.8 ± 5.4	–	–	–	Home-based	30-min nap after lunch and evening exercise, daily for 4 weeks	*Objective sleep measure:* Actigraphy	GHQ	Sleep efficiency increased significantly after the intervention. No other sleep parameters were reported. Participants also reported better mental health (GHQ).
Zeng et al., 2016	RCT	China	Sleep health education + acupressure training	$N=42$ *Female:* 27	70.07 ± 7.42	Sleep health education	$N=40$ *Female:* 31	70.78 ± 7.26	Home-based	90-minute training sessions once a week for 3 consecutive weeks At least two 30-minute sessions of acupressure exercises at home, daily for 1 year	*Self-reported sleep measure:* PSQI ESS	MMSE WMS-CR	PSQI total scores decreased in the group given acupressure training and practice for 1 year. This group also reported significant improvements in cognitive functioning (MMSE and subscales of the WMS-CR), while the control group did not.

Note. PSQI = Pittsburgh Sleep Quality Index; SF-8= Medical Outcomes Study 8-item Health Survey; SF-12= Medical Outcomes Study 12-item Health Survey; LEIPAD = QOL Leiden-Padua Questionnaire; PSS = Perceived Stress Scale; MoCA = Montreal Cognitive Assessment; CES-D = Center for Epidemiological Studies - Depression Scale; STAI = State–Trait Anxiety Inventory; PSG = polysomnography; TDQ = Taiwanese Depression Questionnaire; GHQ-12= General Health Questionnaire; BMI = body mass index; IPAQ = International Physical Activity Questionnaire; PAR = Stanford 7-day physical activity recall; OSA = Oguri-Shirakawa-Azumi sleep inventory; HRT = heart rate variability; GDS = Geriatric Depression Scale; POMS = Profile of Mood Status; OSQ = Oviedo Sleep Questionnaire; VAS = visual analog scale; RE = Rating Scale of Emotion; GDS-15= Geriatric Depression Scale-15 item; SWEMWBS = Chinese Short Warwick-Edinburgh Mental Well-being Scale; FFMQ = Five Facet Mindfulness Questionnaire Short Form; SCS = Self-Compassion Scale Short Form; VFT = Verbal Fluency Test; ISLT = International Shopping List Test; SCS = Self-Compassion Scale Short Form; POM = Peace Of Mind scale; PASE = Physical Activity Scale for the Elderly; ISI = Insomnia Sleep Index; ESS = Epworth Sleepiness Scale; FES = Falls Efficacy Scale; TMT = Trail Making Test; WMS = Wechsler Memory Scale-Chinese Revised; GHQ = General Health Questionnaire.

authors on request. All potential references were organized and deduplicated using the Zotero software (Roy Rosenzweig Center for History & New Media, 2016). Two reviewers (LC, and ES) independently screened the titles and abstracts of the articles retrieved for eligibility. Any disagreements over which articles to retain were solved by consensus, consulting the third author (EB) if necessary.

Quality assessment of the selected studies (risk of bias)

The methodological quality of each eligible study was assessed using an adaptation of the Joanna Briggs Institute (JBI) Critical Appraisal checklist for RCTs (Munn et al., 2014). The study designs varied considerably, so the following sources of bias potentially affecting internal validity were addressed during the study selection process: presence and type of control group, randomization, blinding, concealment of allocation, baseline differences, intention-to-treat (ITT) analyses, reliability of outcome measurements, and appropriateness of statistical analyses. Each criterion was rated as "1" for yes, "0" for no, and "unclear" if studies lacked sufficient detail. A scoring system was agreed by all authors according to the JBI Reviewer's Manual (Joanna Briggs Institute, 2016). Each study's methodological quality (i.e. risk of bias) was classified as "high" if it scored "1" on less than 49% of the questions, "moderate" if it scored "1" on 50% to 69%, and "low" if it scored "1" on more than 70% (the maximum score was 14). Two authors (ES, LC) rated each study as being at high, moderate or low risk of significant bias for each item. If they disagreed, a third author (ET) also rated the study.

Coding of the effects and meta-analytical strategy

Meta-analyses were computed to estimate the average effects of different types of NPI on subjective and objective sleep outcomes. The effects of interest were standardized mean differences (SMDs), with Hedges' correction for small samples. Effect sizes and their variances were calculated according to the study design, considering: pretest-posttest-controlled designs (randomized or not); pretest-posttest designs without a control group; and controlled designs without a pretest/baseline (i.e. treated vs control groups compared only at posttest). In the first case, Morris's formulas (2008; cf. d_{pcc2}) were used for mean pre-post change in the treated group, corrected for the mean pre-post change in the control group, divided by the pooled pretest SD. In the second and third cases, SMDs for pre-post scores and SMDs for independent samples were calculated, respectively, using the formulas proposed by Borenstein et al. (2009). For SMDs involving repeated measures, variances were estimated assuming pretest-posttest correlations of $r = 0.70$ (as a plausible degree of stability of the scores). Effect sizes for follow-up comparisons were similarly coded.

A dataset in long format was coded, with an effect size in each row, one for each group treated and for any subjective or objective sleep parameter reported in the articles. Descriptive statistics (*N*, *M*, *SD* by group and time point) were extracted from texts, tables and figures, or requested from the corresponding authors if unavailable. As no overall objective sleep index is available, the parameters (i.e. Time in Bed, TIB; Total sleep time, TST; Sleep onset latency, SOL; Sleep efficiency, SE; Wake after sleep onset, WASO; Number of awakenings, NA) measured using objective methods (e.g. actigraphy or polysomnography) were aggregated. For the sake of simplicity, multiple effect sizes available for a given treated group were aggregated using the formulas suggested by Borenstein et al. (2009). A between-effects correlation of $r = 0.70$ was assumed to calculate the variance of the aggregated effects.

Separate meta-analyses were run for self-reported and objective sleep quality, and for different types of NPI (see below for details). As recommended by Borenstein et al. (2009), we used random-effect models to account for any heterogeneity across underlying true effect sizes, which was to be expected because different populations and approaches were involved. All estimated effects are reported along with their 95% confidence intervals (CIs) to express uncertainty. The robustness of the estimated effects was checked using the leave-one-out method (a sensitivity analysis in which the meta-analysis is repeated excluding one study at a time). Some studies examined multiple treated groups, so hierarchical (multilevel) models were implemented in the *metafor* package (Viechtbauer, 2010) of R, with groups nested within studies (and considered together as random effects). The following heterogeneity indexes were computed (Borenstein et al., 2009): I^2 (the fraction of observed variance attributed to underlying heterogeneity); and τ (the estimated SD between the underlying true effect sizes). As multilevel models were used, these indexes are reported as total I^2 and total τ for the sake of simplicity. No moderator analysis was planned because of the expectedly small number of studies in each meta-analysis. Investigating publication bias was challenging for the same reason, but an attempt was made to do so using the *zcurve* package in R. The z-curve, an improved version of the p-curve (Bartoš & Schimmack, 2020), was computed for all available effects rather than for aggregated effects.

Results

The PRISMA diagram shows that 1,596 records remained after removing duplicates. Screening titles and abstracts identified 48 eligible studies, and 31 of them met our inclusion/exclusion criteria (Figure 1).

Participants and study design

Table 1 provides details of the 31 studies included in the review, which concerned 2,224 older adults in all (sample sizes ranged from 6 to 189), with 1,443 participants in the treated groups, and 781 in the control groups. Sixteen studies were RCTs, 14 were quasi-experimental (pre-post design), and 1 was cross-sectional. The studies were conducted in several countries around the world: 19 in Asia, 8 in America, and 4 in Europe.

Characteristics of the non-pharmacological interventions

The NPIs targeting sleep varied considerably and were grouped into main topic categories by two of the authors (ES and EB) (Table S2). The NPIs lasted from 5 consecutive days to 104 weeks (Table 1).

Physical activity

Most of the NPIs to improve sleep quality included some degree of physical activity (18 studies), lasting from 30 to 60 min per

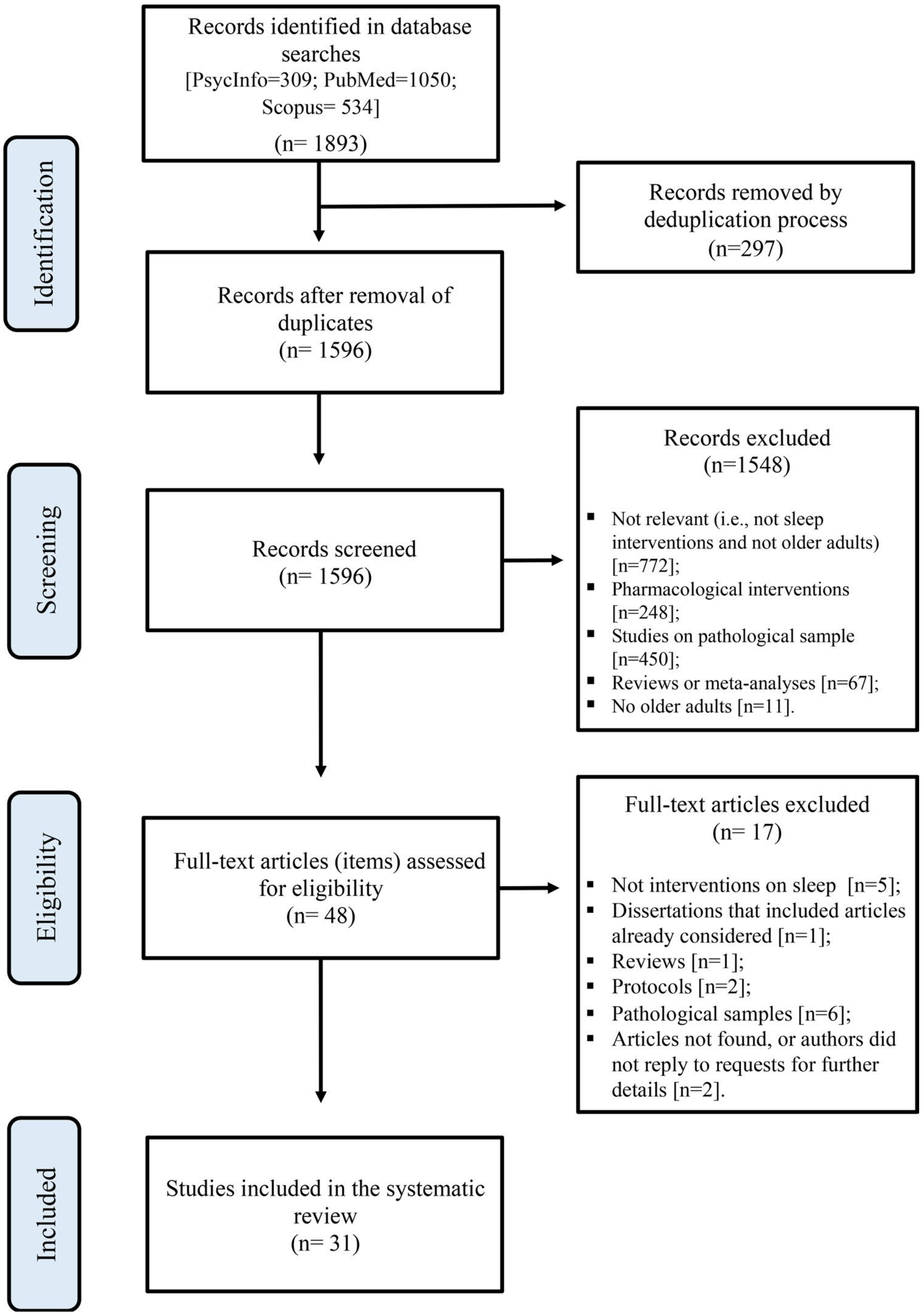

Figure 1. Flow diagram of the study selection procedure.

session, up to 3 times a week, for up to 6 months. Treated groups were trained by instructors who were certified or had been trained by the researchers to manage the NPI or instruct participants to perform the exercises at home. The effectiveness of physical activity on self-reported sleep quality was reported in all the studies reviewed except one by Lira et al. (2011), a pilot study on a small sample. NPIs involving physical activity could include:

i. moderate-intensity exercise including home-based endurance training (e.g., aerobic exercises using stepping platforms, brisk walking, muscle power or elastic bands) (Bullock et al., 2020; Buman et al., 2011; Chan & Chen, 2017; King et al., 1997; 2008; Lira et al., 2011), aerobic endurance training on stationary treadmills (Goerke et al., 2017), stretching and flexibility exercises after a short nap after lunch (Tanaka et al., 2001; 2002), or circuit training using bench presses, leg presses, leg extensions, rowing, and shoulder presses, for instance (Sousa et al., 2017). Personalized behavioral training adapted to participants' baseline level of physical activity was also provided by a certified trainer (Li et al., 2020);
ii. Pilates routines with classical stretching and breathing exercises, plus intermediate-level exercises (e.g., straight leg stretch) (Curi et al., 2018);
iii. tai chi sessions with participants attending classes (Nguyen & Kruse, 2012), baduanjin home-based exercises involving simple, slow, relaxing movements (Chen et al., 2012; Fan et al., 2020), and daily home-based Yoga exercises (Bankar et al., 2013) or

structured Yoga programs including warm-up, gentle stretching, relaxation and guided imagery meditation (Chen et al., Ng and Chan, Ng and Chan, 2008).

Sensory stimulation

The NPIs that involved sensory stimulation (7 studies) were particularly diverse: some focused on touch (acupressure, massage, or balneotherapy); others involved visual or auditory stimulation with light or music. Participants were repeatedly exposed to the sensory stimulation (for periods ranging from 5 consecutive days to 6 consecutive weeks, in sessions lasting from 20 to 90 min per session. Only acupressure was administered 3 times a week for 3 weeks. Given the nature of the interventions, participants were always adequately guided by certified professionals and/or monitored by instructors in the classroom.

The studies on NPIs involving touch focused on hand massage (Kudo & Sasaki, 2020), footbaths (Seyyedrasooli et al., 2013), balneotherapy (Latorre-Romàn et al., 2015), and acupressure (Zeng et al., 2016). The assumption was that massaging and bathing the hands or feet, or applying pressure to certain points on the body can be comforting and relaxing, lower core body temperature, facilitate sleep initiation, and improve sleep quality. Although these methods were effective in before-and-after analyses, only evening footbaths and acupressure were effective in between-group analyses (compared with usual activities in a control condition).

Two RCTs examined the use of music at home: participants chose their favorite relaxing music (Lai & Good, 2006), and the most comfortable place for listening to it (Shum et al., 2014). Both studies reported a significant improvement in subjective sleep quality compared with a control group.

One study tested exposure to bright light (BL, 8000 lux) for an hour using a before-and-after study design. The treated group reported a significant improvement in their sleep quality, but there was no evidence of light exposure improving objectively-measurable sleep parameters.

Psychological/psychoeducational interventions

Three studies examined this type of NPI. Two were RCTs on the effect of MBSR programs on subjective sleep quality (Gallegos et al., 2018; Lee et al., 2022) ; that compared a treated group's baseline, post-treatment, and follow-up data with a wait-list control group. Participants learned the formal practice of MBSR from professional trainers in daily sessions delivered at home (Gallegos et al., 2018), or in weekly classes (Lee et al., 2022). They reported experiencing significant and persistent improvements in their sleep quality.

Another study examined a sleep education program. Participants learned about the impact of life habits (napping, exercise), and environmental factors (noise, light) from textbooks at home. They reported a significantly improved overall subjective sleep quality 2-4 weeks after the intervention (Adachi et al., 2011). This study did not include a control group, however.

Combined interventions

Three studies examined NPIs that combined different approaches to improving sleep quality. One RCT on progressive muscle relaxation combined with education on sleep hygiene found a better overall self-reported sleep quality and less drowsiness during the day compared with the baseline and a control group. Two were pre-post studies (Sun et al., 2013; Rawtaer et al., 2018), while one study was RCT (Sun et al., 2013). These studies analyzed NPIs combining education on sleep hygiene with progressive muscle relaxation and meditation (Sun et al., 2013), group art or music activities (Rawtaer et al., 2018), or interactive group exercises drawn from traditional Chinese medicine (Ng & Chan, 2008). All these studies found improvements in subjective sleep quality, but no other improvements.

Sleep measures and subjective outcome measures

The tools used to assess sleep quality were mainly self-report measures. Few studies used objective methods to assess older adults' sleep patterns (see Table 1 and Supplemental Material-Part 3 for all sleep measures used).

Methodological quality of the studies reviewed (risk of bias)

The overall quality of the studies was poor (see Table S2). Scores obtained with the JBI Critical Appraisal checklist ranged from 0 to 14 (mean 6.06). Sixteen studies were at high risk of bias (mean 2.13), 10 at moderate risk (mean 8.89), and only 5 at low risk (mean 12.20). The most common sources of bias were lack of blinding, low measurement reliability, and high statistical inference bias (see details in Figure S1).

There was a control group in 58% of the studies, but only 16% used active control groups. Most studies showed a high risk of bias in blinding participants, personnel administering the NPIs, and outcome assessors. A proper double-blind procedure was only used in 4 studies (Buman et al., 2011; Curi et al., 2018; Zeng et al., 2016). There were also allocation and randomization biases: participants were randomized in only 52% of the studies, while 45% concealed participants' allocation to intervention groups, and 52% paid adequate attention to individual differences at the baseline. As for other sources of bias, more than half the studies reported ITT analyses: in 77% of cases, participants were analyzed in the groups to which they had been randomized, whether it was the experimental or the control arm. Adequate information on the ITT analysis was reported in 39% of cases, and only 10% (3 studies, see Table 1) included a follow-up beyond the posttest assessment, so nobody knows whether and for how long the effects of the NPIs persisted. In 87% of the studies the outcome measures used are unreliable (partly due to lack of blindness and performance bias), and in 68% the statistical procedure was inadequate (no power analysis or sample size justification, no reported effect sizes or post hoc adjustments for multiple comparison).

Quantitative summary of evidence

Meta-analytical estimates of posttest effects by type of NPI are shown in Figure 2 for subjective sleep quality, and in Figure 3 for objective sleep quality. These estimates ranged from $d = 0.21$ to 0.97, depending on the type of NPI, and 95% confidence intervals (CI) excluded zero for all but one case ("Combined interventions" in Figure 2). Heterogeneity was generally large, with most I^2 indexes around 80%, and most τ estimates around 0.30 to 0.50. The sensitivity analyses using the leave-one-out method nonetheless indicated that no single study had a major

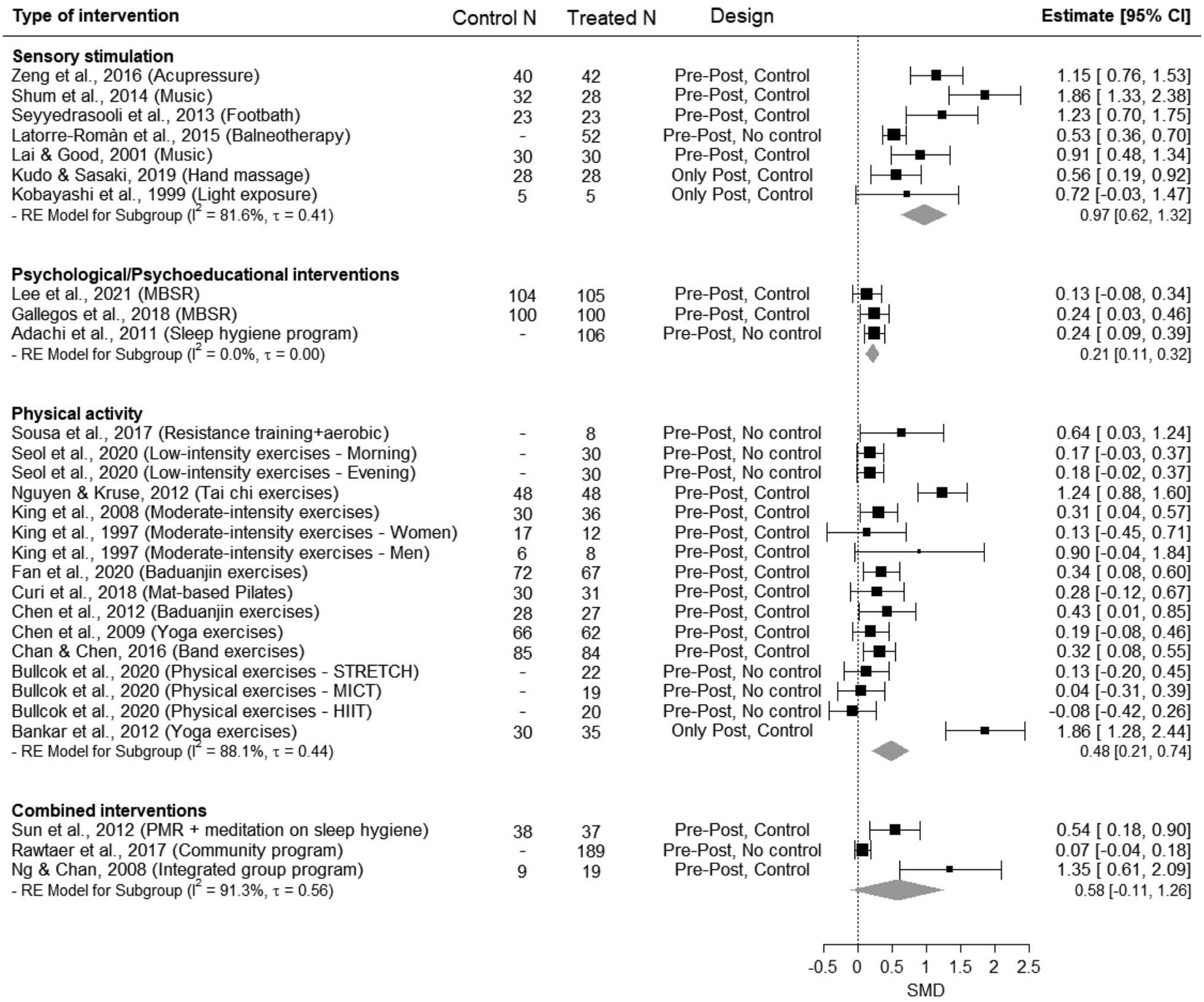

Figure 2. Quantitative evidence obtained with meta-analytical estimates for subjective sleep parameters.

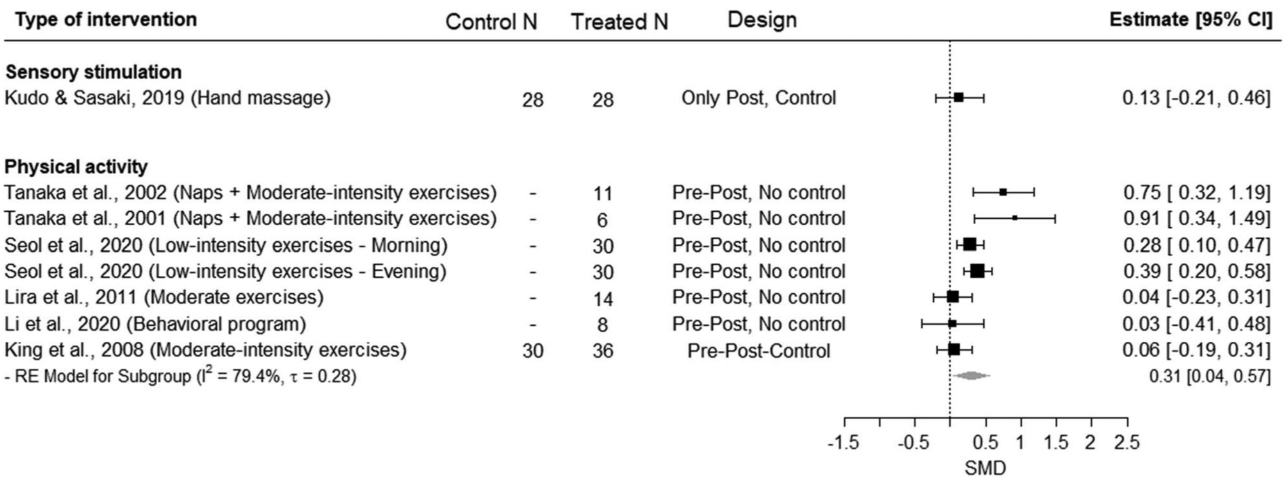

Figure 3. Quantitative evidence with meta-analytical estimates for objective sleep parameters.

impact on any meta-analytically estimated effect, as the overall estimate always fell within the 95% CI (see Supplementary materials–Part 4).

Although Z-curves could not be calculated separately by type of NPI due to the limited number of observations, there was probably a publication bias for the whole set of effects concerning the subjective parameters: the statistically significant effects were 42%, but the expected discovery rate (the estimated power based on the effects distribution) was only 14%, albeit with a very large uncertainty (95%CI: 5%, 93%). For the objective parameters, the statistically significant effects were 43%, while the expected discovery rate was 24% (5%, 57%).

Meta-analytical estimates of follow-up effects could only be computed for "Physical activity": on subjective parameters, the mean estimated effect was $d = 0.46$ (0.23, 0.70), total $I^2 = 77.3\%$, total $\tau = 0.25$, based on 6 studies and 7 treated groups; on objective parameters, $d = 0.32$ (0.14, 0.50), total $I^2 = 41.5\%$, total $\tau = 0.11$, based on 3 studies and 4 treated groups. For the other types of NPI, there was always only one study reporting follow-up measures, and only for subjective parameters, with effects ranging from 0.16 for Psychological/Psychoeducational intervention (MBSR) to 1.03 for Progressive muscle relaxation combined with Meditation, to 1.17 for Sensory Stimulation with music.

Additional analysis

We estimated that future RCTs in this field should plan for sample sizes of between $N = 68$ and $N = 180$ to achieve an adequate statistical power (for assumptions and full details, see Supplemental material–Part 5).

Discussion

This systematic review and meta-analysis newly aimed to summarize findings on the self-reported and objectively-measured efficacy of NPIs targeting sleep in autonomous, community-dwelling older adults with no diagnosed sleep disorders. There is a surprising gap in the literature on this topic, considering that such typically-aging people may report having difficulty sleeping, and sleep quality is important in preventing ill-health, promoting quality of life, and preserving functional skills in older age.

The 31 studies identified regarding NPIs targeting sleep in this population varied considerably, so the types of NPI were grouped into four main categories: physical activity, sensory stimulation, psychological/psychoeducational interventions, and combined approaches. Most of the NPIs included physical exercise (stretching or walking, low- or moderate-intensity aerobic exercises, muscle relaxation, Pilates, tai chi), and were found to improve self-reported sleep quality with a moderate effect size ($d = 0.48$). These results are consistent with previous reviews on older adults with a clinical diagnosis of sleep disorders (MacLeod et al., 2018; Montgomery & Dennis, 2004). This pattern of findings also confirms the well-known benefits of physical exercise for older adults, as it can improve their sleep quality as well as mobility, muscle strength, endurance (Giné-Garriga et al., 2014) and cognitive functioning (Sofi et al., 2011).

NPIs based on sensory stimulation (BL, music at bedtime, hand massage, footbaths, balneotherapy, acupressure) had a large effect size on self-reported sleep quality ($d = 0.97$), as in a previous review concerning older adults with dementia and disrupted sleep-wake cycles (Dimitriou & Tsolaki, 2017; Prins et al., 2020). Here again, the efficacy of NPIs based on sensory stimulation in improving sleep quality can be extended to healthy older adults who have difficulty sleeping.

The psychological interventions using MBSR, or psychoeducational programs about sleep hygiene, also reportedly prompted improvements in sleep quality, but with a small effect size ($d = 0.21$). The extremely limited attention paid to such NPIs (only 3 studies came to light) is rather surprising. More research is clearly needed on the importance of an adequate understanding of sleep health issues (adaptive sleep practices, regular sleeping schedules, appropriate activities before bedtime), the value of mindfulness for managing stress (including the stress relating to sleeping difficulties), and the association between pre-sleep arousal or negative emotional responses and insomnia (Ong et al., 2012), even in older adults with no diagnosed sleep disorders. It also seems strange that none of the studies considered NPIs designed to modify other crucial factors contributing to poor sleep quality, such as lack of control over presleep thoughts, or unhelpful and dysfunctional sleep-related beliefs, which can also exacerbate sleeping difficulties in older adults with no diagnosed sleep disorders (Sella et al., 2019; Sella & Borella, 2021). Future studies should examine NPIs that focus on sleep-related metacognitive knowledge aiming to contain inappropriate sleep-related beliefs, promote functional metacognitive strategies for managing intrusive presleep thoughts, nurture sleep-promoting behaviors, and enhance sleep quality even in older adults without insomnia.

Combinations of NPIs improved self-reported sleep quality, with a medium effect size ($d = 0.58$). These results extend the findings of a previous review on older adults with insomnia (MacLeod et al., 2018) to older adults with no sleep disorders. NPIs that involved participants in a combination of group or individual activities designed to reduce the impact of stress and improve sleep (mindfulness, music, light therapy, acupressure) promoted older people's subjective sleep quality. The evidence is still very limited, however, and more work is needed on the efficacy of such combined NPIs in community-dwelling elderly people.

When objective sleep parameters were investigated, only NPIs involving physical activity and sensory stimulation (hand massage) improved participants' sleep quality, but the former had a small effect size ($d = 0.31$), and for the latter there were not enough data to examine overall efficacy. As age-related changes in sleep architecture emerge not only from self-assessed nighttime sleep quality, but also from objectively measurable changes - in NREM-REM sleep cycles, and sleeping-waking processes, for instance (Mander et al., 2017) - future studies on the efficacy of NPIs targeting sleep quality in older adults should also include objective assessments.

Another aspect worth mentioning is that other subjective/psychological outcomes, such as psychological wellbeing, mood, and cognition, also seemed to benefit from these NPIs, as well as sleep quality (the primary targeted outcome) (Table 1). The well-documented relationship between sleep and measures of wellbeing, and quality of life in aging (i.e. Sella et al., 2021) could account for such an indirect effect of NPIs on older adults' wellbeing and quality of life. Here again, the paucity of studies, and the different outcome measures used prevented us from analyzing this issue more thoroughly and confirming such benefits.

The present review suggests that different NPIs to improve sleep quality can have some effect in older people. Caution is needed, however, given the generally limited effect sizes and very small number of studies on some types of NPI (especially psychological/psychoeducational interventions and combined interventions), the paucity of information on the persistence of any benefits and their impact on other measures, and the marked diversity within the same type of NPI (in the case of physical activity, for instance). The studies reviewed had adopted different procedures for delivering the NPIs, in terms of setting (home- or lab-based), duration (from 5 days to 104 weeks), secondary outcome measures (psychological or physical), and mode of delivery (in groups or individually). Several studies also revealed various methodological weaknesses, a high risk of bias in methodological aspects (no control group, inadequate blinding of participants and personnel delivering the NPI, no follow-up), hindering any estimation of the NPIs' direct effects on sleep quality. Although most of the studies employed valid, widely-used tools (like the Pittsburgh Sleep Quality Index), their sleep outcome measurements were judged largely unreliable (e.g. due to the absence of independent raters or inter-rater reliability), and their study design suboptimal (e.g. sample sizes too small for an adequate statistical power). Future studies should involve rigorous, preferably preregistered RCTs to confirm and extend the findings summarized here. They should also examine whether NPIs targeting sleep quality have long-lasting effects, and how they might positively influence other life domains (e.g. quality of life, cognitive functioning).

It is important to acknowledge some limitations of this review. Formulating inclusion criteria to identify studies on NPIs targeting sleep for community-dwelling older adults with no dementia or sleep disorders proved a significant challenge. Although the sample examined had no severe disabilities (according to each study's inclusion criteria), some participants may have had chronic diseases like arthritis, which could interfere with the potential efficacy of NPIs, masking their effects on sleep quality and thereby biasing the results. Future studies should consider chronic health conditions when investigating the effects of NPIs on elderly people's sleep quality. Our sample was also made up of community-dwelling older people with no diagnosed sleep disorders, but some of them may have had such disorders that had not been recognized as such.

In conclusion, this review and meta-analysis suggests that NPIs have the potential to improve sleep quality in "typically"-aging older adults with no specific sleep disorders. Despite the paucity and methodological weaknesses of studies on this topic, NPIs based on physical exercise and sensory stimulation seemed to show the most promise. Psychological and psychoeducational interventions, and combined interventions deserve further investigation. From applied and clinical perspectives, our findings point to the value of NPIs in alleviating sleep difficulties, promoting a better sleep quality, and a consequently better quality of life, in older adults.

Note

1. References marked with an asterisk indicate studies included in the systematic review and meta-analysis

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