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Systematic review and meta-analysis

An RCT META analysis based on the effect of tai chi exercise therapy on the outcome of elderly patients with moderate-to-severe sleep disorders-A systematic review study

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ABSTRACT

Background: According to statistics, about one-fifth of the world's elderly people suffer from sleep disorders, and the problem of sleep disorders in the elderly is extremely serious, and this problem is one of the important causes of chronic diseases such as hypertension, hyperlipidemia, diabetes mellitus, and coronary heart disease in the elderly. The positive effect of Tai Chi exercise therapy on sleep problems has been confirmed, but at present, the effect of the specific duration of Tai Chi exercise on the improvement of elderly people with moderate to severe sleep disorders varies.
Objective: META analysis was used to investigate and find that long-term Tai Chi exercise therapy has the best effect on improving sleep in elderly patients with moderate to severe sleep disorders.
Methods: META analysis was performed using Revman 5.3 after searching Web of science, Pubmed, Scopus, The Cochroae Library, OVID, CBM, CNKI, VIP, and other databases, and then filtering and extracting.
Results: A total of seven papers were included. Meta-analysis showed that tai chi exercise was more effective in improving sleep problems in elderly patients with sleep disorders compared to the control group, and the difference was significant. This was demonstrated by a decrease in the global Pittsburgh Sleep Quality Index (PSQI) score [SMD = −0.66, 95 % CI (−0.91, −0.41), P < 0.00001], as well as its subdomains of subjective sleep quality [SMD = −0.79, 95 % CI (−1.06, −0.52), P < 0.00001], sleep latency [SMD = −0.80, 95 % CI (−1.21, −0.40), P < 0.00001], sleep duration [SMD = −0.38, 95 % CI (−0.72, −0.04), P = 0.03], habitual sleep efficiency [SMD = −0.58, 95 % CI (−0.84, −0.31), P < 0.0001], sleep disturbance [SMD = −0.51, 95 % CI (−0.78, −0.25), P = 0.00001] and daytime dysfunction [SMD = −0.33, 95 % CI (−0.59, −0.07), P = 0.01]. Improvement was also observed in the Epworth Sleepiness Scale (ESS) and Insomnia Severity Index Scale (ISI). The results showed that the optimal duration and frequency of Tai Chi exercise therapy for improving moderately severe elderly patients with sleep disorders was long-term.

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Conclusion: This study systematically assessed the efficacy of Tai Chi exercise therapy for elderly patients with moderate-to-severe sleep disorders. Through a meta-analysis of relevant randomized controlled trials (RCTs), it aims to determine the effectiveness of Tai Chi exercise in improving sleep quality in elderly patients with moderate-to-severe sleep disorders, as well as to compare its effects with those of traditional treatments; to analyze the safety of Tai Chi exercise for this patient population and assess its feasibility as a non-pharmacological therapy; and to fill the research gaps and provide more comprehensive and systematic evidence support. This study provides a practical approach to reducing the risk of medication side effects in older adults with sleep disorders and offers a potentially effective non-pharmacological treatment option, especially for those who are unable or unwilling to use medication. Tai chi exercise may not only improve sleep, but also improve coordination, muscle strength, balance, and reduce stress and anxiety in older adults. It also helps older adults socialize and enhances their social connections and emotional support. This study suggests that community centers or activity centers for the elderly can organize tai chi classes to promote the participation of older adults, and can be used as a scientific exercise rehabilitation tool in clinical treatment, incorporating tai chi practice into daily life, such as tai chi practice at a fixed time every day or every week, which not only helps to improve the sleep disorders of older adults, but also improves their overall quality of life.

1. Introduction

Insomnia is a prevalent sleep disorder that affects up to 15 % of the world's population and is the second most common mental health problem [1]. Sleep disorders are categorized as Difficulty Falling Asleep (DFA) or Difficulty in Sleeping (DIS), Sleep Continuity Disorder (SCD) or Difficulty in Maintaining Sleep (DMS), Early Morning Awakenings (EMA), Non-Restorative Sleep (NRS), or a combination of all symptoms [2–4]. Across all age groups, women have higher rates of insomnia than men [5], which is associated with poor quality of life and physical and mental health [6]. Humans spend at least one-third of their lives asleep, and we know little about why we need sleep and the mechanisms by which it restores the mind and body. The interaction of circadian rhythm effects, i.e., the usual time of falling asleep and waking up, determines the beginning and end of sleep [7]. Various sleep disorders, such as obstructive sleep apnea and insomnia, have been associated with a variety of health problems and reduced quality of life. Chronic sleep deprivation can lead to conditions such as decreased alertness and responsiveness, slower cognitive processes, depressed mood, and poor concentration [8,9]. Sleep quality and duration affects cellular immunity and cytokine levels, and even mild sleep deprivation can compromise a person's immunity [10,11]. Sleep disorders are also associated with metabolic changes, increased caloric intake, and obesity [12,13]. Short sleep duration can have deleterious health effects such as increased all-cause mortality [14], coronary artery disease, type 2 diabetes [15], obesity, and hypertension [16].

Women are more likely to suffer from sleep disorders compared to men [17]. A study by Phillips BA [18] and Akberzie W [19] showed that females generally have higher PSQI (Pittsburgh Sleep Quality Index) scores, indicating that they have relatively poorer sleep quality. The existence of such gender differences may be closely related to physiological factors. As women experience more fluctuations in physiology and biochemistry, such as the menstrual cycle and conception [20] process. These physiological changes may cause women to be more susceptible to hormone levels, which in turn affects their sleep patterns [21]. During menstruation [22] and menopause [23], fluctuations in women's hormone levels [24] may lead to a decrease in sleep quality and an increased risk of sleep disorders. In addition, studies by Magnusson L [25] and Kang AW [26] have shown that women usually take on more life stresses and social responsibilities, which may cause them to be more susceptible to anxiety and emotional distress, which may interfere with falling asleep and maintaining a good night's sleep [27]. Therefore, the relatively more severe sleep disorders in women may be caused by a complex interaction of physiological and psychological factors. This finding has important implications for the development of gender-specific sleep interventions and individualized treatment approaches.

On the other hand, sleep disorders are very common in the elderly population, with the prevalence increasing with age.2023 A survey found that more than 50 % of people over the age of 60 had insomnia, and the diagnosis of insomnia ranged from 12 % to 20 % [28]. In past studies, sleep disorders in older adults have been studied in a number of areas, ranging from sleep quality to various health-related effects. The Samara MT [29] showed that more than 60 % of older adults reported sleep disorders, including insomnia and sleep disruption. Their study further explored the adverse effects that these disorders may have on the health status of older adults. The Morin CM [30] and others demonstrated sleep patterns in older adults and found that long-term sleep problems were associated with decreased cognitive functioning, mental health problems, and an increased risk of cardiovascular disease. In particular, Liu S [31] et al. demonstrated that long-standing sleep disturbances were found to be associated with accelerated cognitive decline, suggesting an important link between sleep quality and cognitive health. In addition, Fang H [32] et al. study revealed the negative impact of sleep disorders on the mental health of older adults, with poor sleep quality associated with increased symptoms of depression and anxiety. In addition to health effects, Cohen DA [33] et al. study also found that sleep disorders may also have negative effects on daily life functioning in older adults. The Banks S [34] et al. study found that chronic sleep problems were associated with daytime fatigue, poor concentration, and decreased motor coordination, which may threaten the quality and safety of daily life in older adults.

This is because sleep disorders are also associated with metabolic changes, increased caloric intake and obesity [35,36]. Sleep deprivation in the elderly leads to increased prevalence. The factors include a variety of factors such as older age, chronic diseases, depression, and anxiety [37]. Inadequate sleep quality and prolonged naps are strongly associated with a high prevalence of cognitive

decline in older adults [38]. This is critical for physical, cognitive and mental health. However, sleep problems become increasingly prominent with age.

Taken together, these findings demonstrate the multifaceted negative impact of sleep disorders on the health and lives of older adults. These studies demonstrate the urgency that we now need to improve the quality of sleep in older adults to prevent cognitive decline, mental health problems, and impaired daily functioning in order to improve their overall quality of life. While tai chi has many health benefits such as alleviating psychobiological stress response and promoting mental health [39], lowering blood pressure [40], improving flexibility and muscle strength, and delaying the onset of many chronic diseases [41]. It may also serve to calm the mind, promote central nervous system homeostasis and help improve sleep quality [42]. Although exercise has been shown to enhance sleep quality in the elderly, the intensity and load of exercise cannot be determined for the elderly population given their unique characteristics. Therefore, this study will focus on the unique advantages of taijiquan exercise, analyze the safety and effectiveness of different cycles of taijiquan exercise in the elderly population with sleep disorders, and assess its feasibility as a non-pharmacological therapy. The main purpose of this study is to systematically investigate the effects of tai chi on moderate-to-severe elderly patients with sleep disorders, with the aim of providing a scientific basis to support tai chi as a gentle yet effective unique exercise modality that maximizes the promotion of sleep quality in the elderly through appropriate cycles and frequencies, and ultimately reduces the global prevalence of morbidity and mortality in the elderly.

2. Sources and methods

This study is A systematic review study - based on meta-analysis.

This study applied for and has been registered through the PROSPERO platform with registration ID CRD42023363974.

2.1. Literature search

The study strictly followed the process set out in the PRIMSA entry [43], and the search, inclusion, screening, and exclusion criteria of the literature were strictly developed according to the principles of PICOS for evidence-based medicine. Literature was searched in Web of science, Pubmed, Scopus, The Cochroae Library, Embase, OVID, CBM, CNKI, VIP, and WanFang Data databases under the terms (“elderly” or “65 years and older” or “elderly”) and (“Tai Chi” or “taiji” or “taiji exercise therapy”). “Tai Chi exercise therapy”) and (“sleep disorders” or “moderate to severe insomnia” or “insomnia”) and (“randomized controlled trial” or “controlled clinical trial”) as Chinese subject terms for Boolean logic search; (“Aging” or “senior” or “over 65″) and (“Tai-ji” or “Tai Chi” or “taijiqu”) as Chinese subject terms for Boolean logic search; and (“Tai Chi” or “taijiqu”) as Chinese subject terms for Boolean logic search. Chi” or “Tai Chi”) and (“hypersomnia” or “Sleep Disorders” or “wakefullness” or “insomnia”) and (“Randomized controlled trial” or “Controlled Randomized controlled trial” or “Controlled clinical trial” or “Randomized”) as English subject terms for Boolean logic search. The language was limited to Chinese and English, and the search timeframe was from the deadline of the database to January 1, 2023, when the database was built. Literature was also accessed through other means such as tracing the references of related studies.

3. Inclusion criteria

3.1. Literature inclusion criteria

Only randomized controlled trials (RCTs) were included in this study; older adults (including those with moderate to severe sleep disorders or symptoms) who underwent an RCT trial of tai chi exercise interventions for sleep disorders, and papers in which the intervention group interventions were papers that viewed tai chi exercise as a primary intervention for improving sleep were included, Regardless of the style of tai chi, the control group interventions were maintaining regular activities; receiving health education; no regular physical activity; or a CBT-I short course treatment program. The outcome indicator was the PSQI scale (the intervention was considered valid if the difference between the values measured after and before the intervention was less than 0). Specifically for our inclusion, PSQI equivalents greater than 3 and less than 5 were considered mild sleep disorders and were not included in our inclusion criteria, greater than or equal to 5 were considered moderate and greater than 7 were considered severe [44]. Because this study focuses only on older adults with moderate to severe sleep disorders.

3.2. Exclusion criteria

Non-RCT experiments; experimental animal studies; descriptive and investigative literature, review literature, secondary research, academic conference included literature, and repetitively published literature; characteristics such as subjects are other than the elderly or have other clinical conditions; experimental results data are not presented in the form of ($x \pm s$) or the data can not be extracted indicators of the literature; there are interventions during the course of the intervention there are other interventions; The data description was incomplete or could not be converted. In addition, PSQI scores of less than 5 for mild sleep disorders will be excluded from the literature, as will interventions that are not Tai Chi [45].

3.3. Literature screening and data extraction

Two researchers, Li L and Huang Y, introduced the collected literature into NoteExpress 3.0 software according to the research

strategy, excluded duplicates, and then screened them independently according to the title and abstract. Then, they screened again by reading the full text in detail according to the inclusion and exclusion criteria. Thereafter, two people cross-checked the results of their respective screening, and if the checking was consistent, it was included in the study; if the checking was different, the third researcher, Li X, entered into the consultation, and the decision was made jointly after the discussion reached a consensus; finally, the final literature was included in the information extraction process, and the pre-established information extraction form was used to summarize the data of the literature included in the study, as well as the records of the literature risk of bias. Data extraction mainly included: (1) basic information of the included literature (title, first work, year, etc.); (2) subject characteristics and information (sample size, age, etc.); (3) intervention and control details (type, duration, frequency, etc.); (4) sleep disorder score (moderate, severe); (4) quality of the literature; and (5) endpoint indicators and main study results.

3.4. Risk of bias evaluation of the included literature

The risk of bias assessment tool in the Cochrane Handbook for Systematic Evaluation, version 5.1 [46] was used, and two researchers independently carried out the quality evaluation of the included studies. If the assessment results were inconsistent, they were discussed and resolved with the other researcher.

3.5. Statistical processing

Meta-analysis was performed using Revman 5.3 software, and the mean ± standard deviation (x ± s) was used as the effect

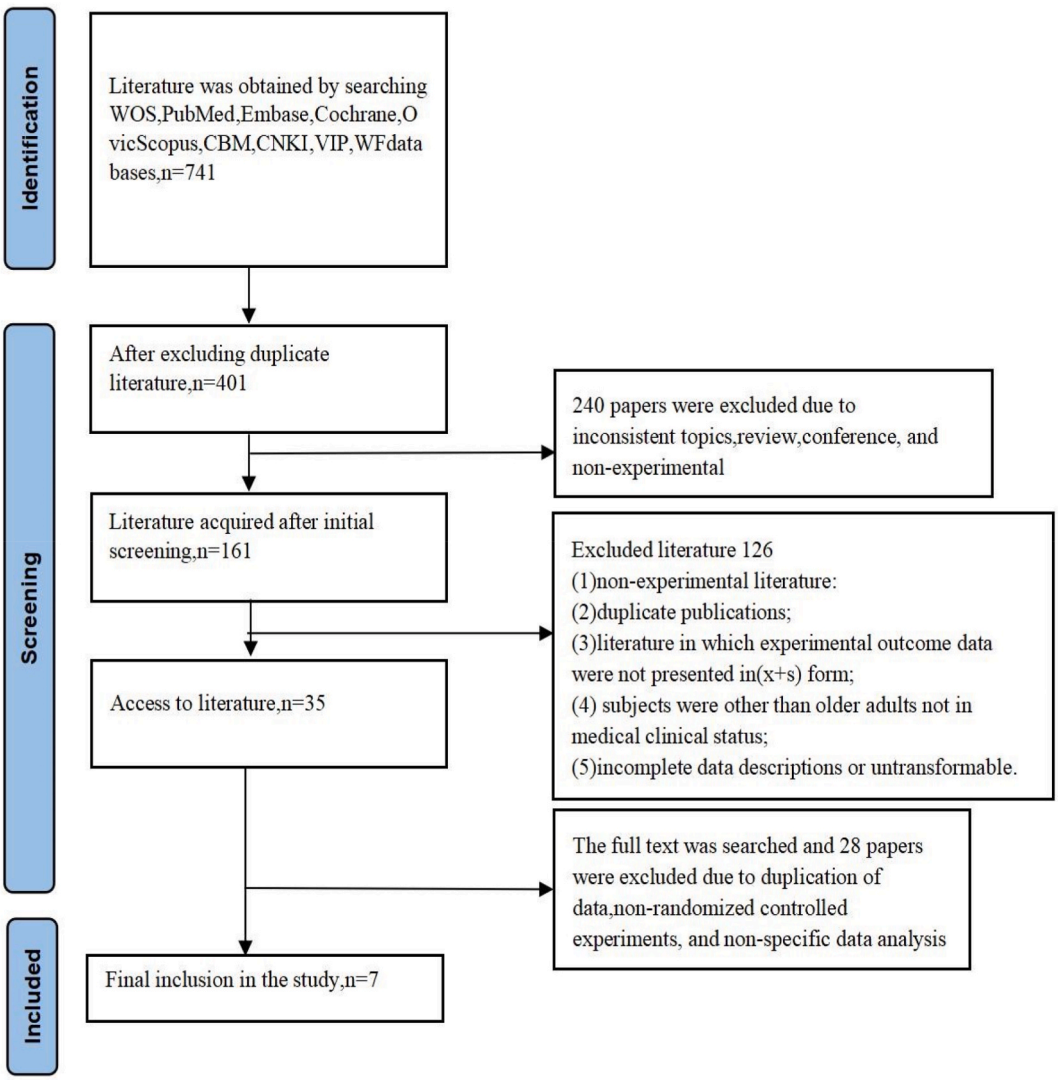

Fig. 1. Flow chart of literature screening.

indicator for the measurement data, and the risk ratio (RR) or ratio (OR) was used as the effect indicator for the count data, and each effect size was expressed with 95 % CI. Heterogeneity between the results of the included studies was analyzed using the χ^2 test (the test level was $\alpha = 0.1$), and the magnitude of heterogeneity was also determined by combining the I^2 quantitatively. If there was no statistical heterogeneity among the results of the studies, the fixed-effects model was used for Meta-analysis; if there was statistical heterogeneity among the results of the studies, the source of heterogeneity was further analyzed, and the random-effects model was used for Meta-analysis after excluding the influence of obvious clinical heterogeneity. Obvious clinical heterogeneity was dealt with by subgroup analysis or sensitivity analysis, or only descriptive analysis was performed, and the test level of Meta-analysis was set at $\alpha = 0.05$.

Table 1
Basic features of the included studies.

Study	Participants	Interventions	Measures of sleep	Conclusion	source
Li F et al./ USA 2004	118 community-dwelling adults with moderate complaints; Exp: n = 62 (10 males, aged 75.3 yrs) Con: n = 56 (12 males, aged 75.45 yrs)	Ex = 8-Form Yang style Easy Tai Chi exercise for 1 h*3 times/weekly *26 weeks (6 months); Con = low-impact exercise for 1 h* 3 times/weekly *26 weeks (6 months)	PSQI score; Epworth	Older adults with moderate sleep complaints benefited from Tai Chi exercise in terms of improving sleep duration and latency, reducing daytime sleepiness.	
Irwin MR et al./ USA 2008	102 healthy older adults; Exp: PSQI <5, n = 29 (10 males, aged 69.6 yrs) PSQI ≥5, n = 30 (8 males, aged 69.7 yrs) Con: PSQI <5, n = 31 (15 males, aged 69.8 yrs) PSQI ≥5, n = 22 (8 males, aged 70.7 yrs)	Ex = Tai Chi Chih for 40 min * 3times/weekly*16 weeks; Con = health education intervention involved 16 didactic presentations on a series of health related themes.	PSQI score	Tai Chi Chih has a positive role in improving self-rated sleep quality among older adults with moderate sleep complaints, with the potential to ameliorate sleep complaints possibly before syndromal insomnia develops.	
Hosseini H et al./ Iran 2011	62 old residents of elderly home with a score of 5 and above, all with PSQI score 5 and above Exp: n = 31 (16 males, aged 68.74 yrs) Con: n = 31 (14 males, aged 69.42 yrs)	Ex = Taichi exercise for 20–25 min* 3 times/week * 12 weeks; Con = daily activities	PSQI score	Consistent with other studies, Taichi exercise may have a positive, significant effect on sleep quality of life in older people.	
Ding YY/ China 2020	Chinese 93 elderly patients with insomnia who met the diagnostic criteria of Chinese medicine and Western medicine Exp: n = 29 (9 males, aged 65.24 yrs) Con: n = 36 (14 males, aged 65.83 yrs)	Ex = Tai Chi Chih for 80 min * 3 times/weekly *24 weeks; Con = Use of CBT-I short-course treatment protocol, 30min* 3 times/ Total 6 courses.	PSQI score; GDS; MMSE	Tai chi has a significant effect on insomnia in older adults and can significantly improve depression levels and cognitive function.	
Fan GD/ China 2020	Selected 20 elderly people with sleep problems in Tiantoni International Nursing Home were selected as experimental subjects. Exp: n = 10 (4 males, aged 83.6 yrs) Con: n = 10 (3 males, aged 81.6 yrs)	Ex = Taichi exercise for 30 min * more than 4 times/weekly *12 weeks; Con = daily activities	PSQI score; DBAS-16	Tai chi sleep aids reduce the voltage values in different frequency bands in the four brain regions of the elderly, lowering the arousal values and improving the quality of sleep; making the elderly less dependent on sleep medication and reducing the dose.	
Parco M. Siu et al./ Hong Kong, China 2021	This study involved 320 Chinese adults aged 60 years or older with chronic insomnia diagnosed according to the Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition) (DSM-5). Exp: n = 105 (21 males, aged 66.5 yrs) Con: n = 110 (22 males, aged 68.0 yrs)	Ex = Yang-style 24-form tai chi exercise for 1 h min*3times/ weekly* 12 weeks; Con = daily activities	PSQI score; ISI	The concomitant improvements in objective and subjective sleep, as well as the larger insomnia remission and treatment response rates, support the notion that tai chi can be an alternative approach for insomnia management for older adults with insomnia.	
Fang YY/ China 2021	68 older adults with sleep disorders who scored ≥7 on the PSQI scale and met the inclusion and exclusion criteria were selected. Sixty-eight older adults with sleep disorders were selected as subjects. Exp: n = 29 (aged 86.14 yrs) Con: n = 34 (aged 87.00 yrs)	Ex = Sitting Taijiquan for 1 h * 3times/weekly* 12 weeks; Con = daily activities	PSQI score; SAS; FS-14	The tai chi intervention improved subjective sleep quality, shortened sleep latency, effectively improved sleep efficiency, and reduced the degree of sleep disturbance in older adults; and reduced medication anxiety in older adults.	

4. Results

4.1. Literature search and screening

The initial screening obtained 741 pieces of literature, and after layers of screening, seven studies were finally included, and the screening process and results are detailed in Fig. 1.

4.2. Basic characteristics of the literature and assessment of methodological quality

A total of seven studies were eventually included, and the basic characteristics of all the included studies are detailed in Table 1 Overall, the seven RCTs included were from the United States (two) [48,49], Iran (one) [40], and China (four) [47,50–52]. These studies included a total of 589 participants, of whom 292 were assigned to the intervention group and 297 to the control group. Six of the seven trials (85 %) had adequate randomized sequence generation [47–49,51–53]; four (57 %) had adequate allocation concealment [47–49,53]. In addition, due to the specific nature of this exercise therapy, only 1 trial reported blinding of participants [49] and 3 reported blinding of assessors [47,48,53]. The results of the literature quality assessment are detailed in Figs. 2 and 3.

Characteristics of included studies All seven included studies used the PSQI scale as an outcome indicator, and three of them [47–49,51–53] reported data on the complete seven components of the PSQI. We conducted a meta-analysis of the PSQI and the total scores of its 7 components. The intervention in the observation group was tai chi; the control group in all trials either received no treatment and maintained their regular activities [47,50,52] or received health education [49] or low-intensity exercise for 1 h 3 times per week for 24 weeks [48] or the CBT-I short-course treatment program [53].

5. META analysis

5.1. PSQI total scores

All seven included studies reported post-intervention PSQI total scores. The effect of Tai Chi exercise on PSQI total scores was investigated by pooling data from 589 participants across the seven trials. The results of the meta-analysis showed that tai chi exercise had a large and significant effect on reducing the total PSQI score in elderly patients with sleep disorders compared with the control group [SMD = −0.66, 95 % CI (−0.91, −0.41), $p < 0.00001$] (Fig. 4). To explore the specific effects of tai chi exercise on sleep quality in elderly patients with sleep disorders, we analyzed the articles in subgroups according to the follow-up period: short-term (up to 12 weeks) and long-term (more than 13 weeks). Four articles had a follow-up period that was considered short-term [47,50–52]. The results of the meta-analysis showed that short-term tai chi exercise had a moderately significant effect on reducing the total PSQI score in older adults compared to the control group [SMD = −0.80, 95 % CI (−1.29, −0.32), $p = 0.001$] (Fig. 4). In addition, three articles had a follow-up period that was considered long-term [48,49,53]. The results of the meta-analysis showed that long-term tai chi exercise had a greater and significant effect in reducing the total PSQI score in the moderately to severely elderly sleep disordered population compared to the control group [SMD = −0.55, 95 % CI (−0.81, −0.29), $P < 0.0001$] (Fig. 4).

5.2. Subjective sleep quality on the PQSI

Three studies [48,49,51] reported data on the subjective sleep quality dimension of the PSQI. The results of the meta-analysis showed that tai chi exercise had a greater significant effect on improving subjective sleep quality in older adults compared to the

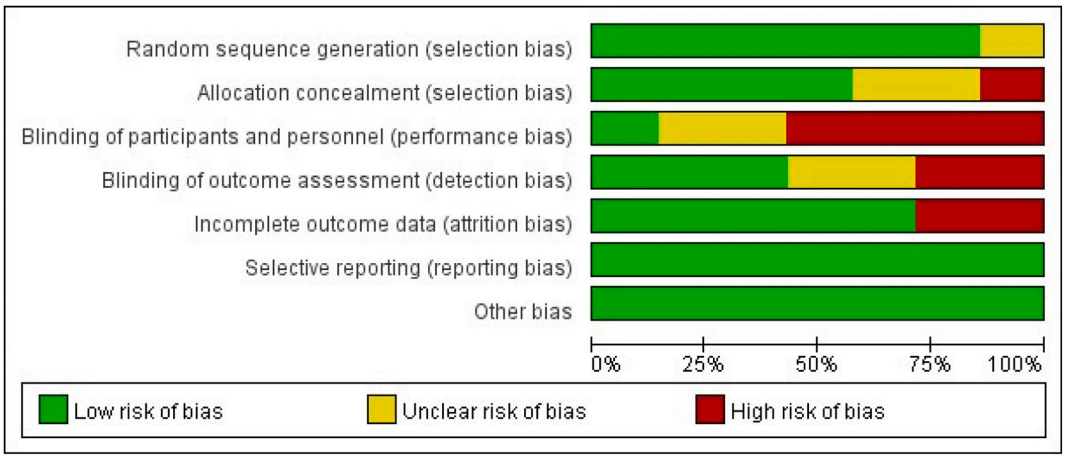

Fig. 2. Risk of bias graph review authors' judgements about each risk of bias item presented as percentages across all included studies.

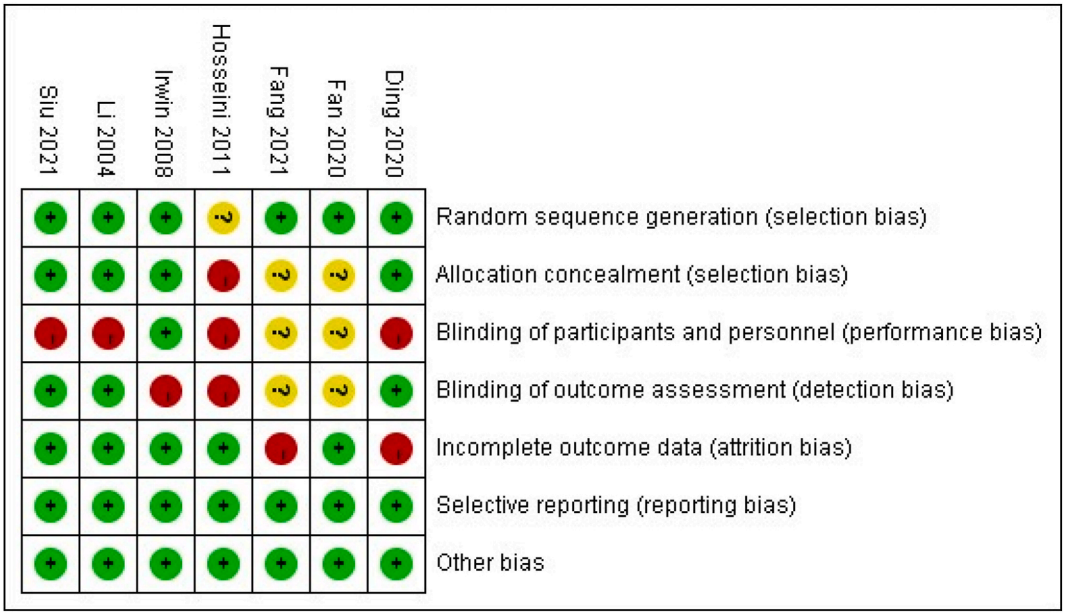

Fig. 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

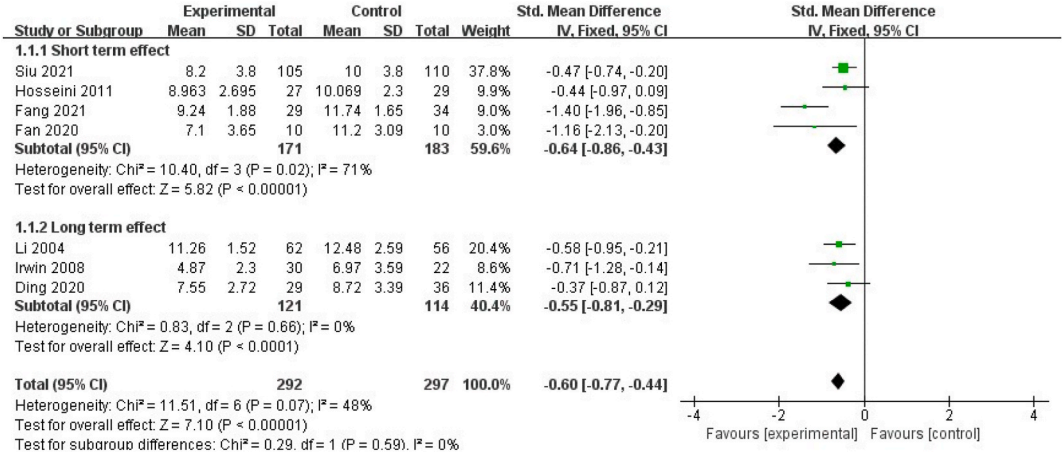

Fig. 4. Forest plot of effects of Taichi exercise on PSQI global score for older people including subgroup analysis.

control group [SMD = −0.79, 95 % CI (−1.06,-0.52), p < 0.00001] (Fig. 5).

5.3. Sleep latency of the PQSI

Four studies [47–49,51] reported data on the sleep latency dimension of the PSQI. The results of the meta-analysis showed that tai chi exercise had a moderately significant effect on reducing sleep latency in older adults compared to the control group [SMD = −0.80, 95 % CI (−1.21, −0.40), p < 0.00001] (Fig. 5A\5 B).

5.4. Sleep duration in PQSIs

Four studies [48,49,51,52] reported data on the sleep duration dimension of the PSQI, three of which [49,51,52] used converted scores (0–3), and the study by Li et al. (2004) used the actual number of hours of sleep per night. Therefore, we calculated the pooled effect by meta-analysis using data from the first 3 studies. The results of the meta-analysis showed that tai chi exercise had a moderately significant effect on improving sleep duration in older adults compared to the control group [SMD = −0.38, 95 % CI (−0.72, −0.04), p = 0.03] (Fig. 5C). In addition, Li et al. (2004) showed that at the end of the 6-month follow-up period, the tai chi exercise group had an increase in sleep time of 0.87 ± 1.041 h from baseline, whereas the low-intensity exercise control group had an

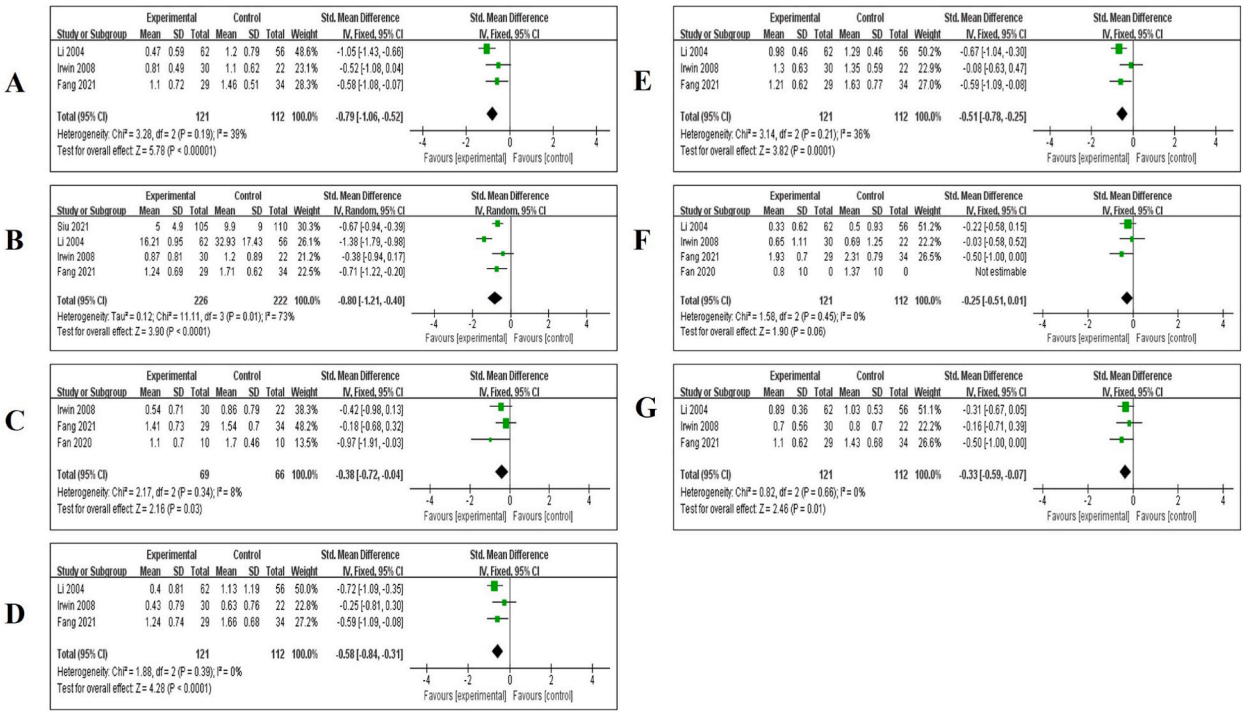

Fig. 5. Forest plot of effects of Taichi exercise on 7 components of PSQI for older people (**A** is Subjective sleep quality, **B** is Sleep latency, **C** is Sleep duration, **D** is Habitual sleep efficiency, **E** is Sleep disturbance, **F** is Sleep medication, **G** is Daytime dysfunction).

increase of 0.06 ± 1.68 h from baseline, which was a significant difference (P = 0.005).

5.5. Habitual sleep efficiency in the PQSI

Three studies [48,49,51] reported data on the habitual sleep efficiency dimension of the PSQI. The results of meta-analysis showed that tai chi exercise had a less significant effect on improving habitual sleep efficiency in older adults compared to the control group [SMD = −0.58, 95 % CI (−0.84, −0.31), p < 0.00001] (Fig. 5D).

5.6. Sleep disturbances in PQSIs

Three studies [48,49,51] reported data on sleep disturbances in PSQI. The results of the meta-analysis showed that tai chi exercise had a less significant effect on improving sleep disturbances in older adults compared to the control group [SMD = −0.51, 95 % CI (−0.78, −0.25), p = 0.0001] (Fig. 5E).

5.7. Sleep medication for PQSIs

Four studies [48,49,51,52] reported sleep medication data for PSQI. The results of meta-analysis showed that tai chi exercise did not have a statistically significant but favorable trend in reducing sleep medication use compared to the control group [SMD = −0.25, 95 % CI (−0.51, 0.01), P = 0.06 > 0.05] (Fig. 5F).

5.8. Duration of PQSI dysfunction

Three studies [48,49,51] reported data on daytime dysfunction of the PSQI. The results of the meta-analysis showed that tai chi exercise had a less significant effect on improving daytime dysfunction in older adults compared to the control group [SMD = −0.33, 95 % CI (−0.59, −0.07), P = 0.01] (Fig. 5G).

5.9. Daytime drowsiness

The study by Li et al. (2004) used the ESS scale to measure the level of sleepiness in individuals. The results showed that after 6 months of intervention, the ESS scores of tai chi exercise participants (6.35 ± 2.89) showed a greater decrease than those of control participants (8.36 ± 2.91), which was a significant difference (p = 0.002). The study by Parco M. Siu et al. (2021) used the ISI scale to

assess the severity of insomnia. The results showed a greater decrease in ISI scores (8.9 ± 5.6) in tai chi exercise participants compared to control participants (11.3 ± 5.2), with a significant difference ($p < 0.001$).

6. Discussion

Overall, this systematic review reviewed randomized controlled trials (RCTs) of the effects of tai chi exercise therapy on sleep quality in moderately severe older adults. Pooled analyses indicated that tai chi exercise had a significant benefit on sleep quality in older adults with moderate-to-severe sleep disorders, as evidenced by a decrease in total PSQI score (SMD = −0.66), an observation that is in line with the findings of the studies by Barrett B, Jurado-Fasoli L et al. [54,55], but differs from the findings of Chin LM. Chin LM et al. reported significant changes in cognitive function in the subject population after 12 weeks of vigorous aerobic exercise, but among them, the change in the total PSQI was not significant [56], which further validates the finding in the present study that long-term (more than 13 weeks) practice of taijiquan was more effective than short-term (12 weeks and less) practice as evidenced by the short-term effect (SMD = −0.80) and the long-term effect (SMD = −0.55) difference. Taijiquan exercise also had a significant effect in improving subjective sleep quality (SMD = −0.79), which is the same as the findings of De Nys L, Wang WL et al. [57,58]. There was also a significant improvement in sleep latency (SMD = −0.80), which is the same as the findings of Stutz J [59]. Tai chi exercise to improve habitual sleep efficiency (SMD = −0.58) was slightly different from Yang H's findings [60], whose findings showed no significant difference between the physical activity group and the usual care group in terms of habitual sleep efficiency and daytime dysfunction, which may be related to the duration of the intervention, as well as the mode of activity. Therefore, it is recommended that older adults with moderate-to-severe sleep disorders engage in more long-term tai chi practice to reduce prevalence and mortality. Tai chi exercise also alleviated sleep disorders (SMD = −0.51), as observed by Li CQ [61] and Yang M [62] et al. Also long-term taijiquan practice in older adults prolonged sleep duration (SMD = −0.38) as well as reduced daytime dysfunction (SMD = −0.33), which is the same as the findings of Chaudhuri D [63], Kocevska D [64] and Atoui S [65], inferring that there is a possibility that it could be related to the unique form of taijiquan exercise that induces melatonin to improve sleep, but the exact mechanisms and regions are not yet known. Therefore, more research is still needed in this area.

According to the World Health Organization, the global rate of sleep disorders is 27 %, and a 2016 survey by the China Sleep Research Society showed that the incidence of insomnia among Chinese adults was 38.2%-meaning that more than 300 million Chinese have sleep disorders and only 15.56 % of respondents were able to fall back to sleep, with more than half of the population reporting that they needed More than half of the respondents said it takes 10–30 min to fall asleep. Sleep disorders are a common problem among the elderly in particular, and while most elderly people with sleep disorders take medication to improve their sleep, older people around the world are also looking for alternatives to medicine to improve their sleep disorders. However, conventional treatments often do not provide good results and long-term treatment is not proven, and there are many alternative methods that have emerged that have been shown to be effective in the treatment of insomnia and sleep disorders in research studies.

Insomnia and sleep disorders have become worldwide human sleep problems [66], so exploring the effects of Tai Chi exercises on falling asleep and sleep disorders has become a hot and difficult research topic now and even in the future [67]. At present, in addition to Tai Chi exercises [68], other treatments for sleepiness and sleep disorders mainly include medication, health education, health lectures, psychotherapy, acupuncture therapy, maintenance of daily activities, relaxation training and low-intensity exercise. Although medication is the most effective means to significantly improve the problem of falling asleep and sleep disorders [69], medication produces strong side effects and dependence, and taking sleep medication for a long period of time will result in weakening of the medication's effect and aggravation of sleep disorders [70], which will increase the hazards to human health [71], especially for the elderly [72], and lead to a series of chronic diseases; health education, health lectures, and psychotherapy, Health education, health lectures, psychotherapy, acupuncture treatment, etc., even if they can solve the problems of sleep and sleep disorders, they cannot guarantee long-term improvement and require more time for the audience; daily activities, relaxation training, low-intensity exercise, etc., are not only difficult to choose the appropriate method and ensure the durability of the effect, but also more difficult for the elderly sleep disorder group. On the other hand, Tai Chi is a kind of aerobic exercise with more comfortable movements, focusing on the combination of rigidity and flexibility, sinking the shoulders and dropping the elbows, relaxing the body and mind, bringing the form with the intention, and unifying the form with the intention, which is a kind of safe and easy-to-learn method without the constraints of time and place. Tai Chi is different from other forms of exercise, which belongs to a kind of non-pharmacological therapy of traditional Chinese medicine with Chinese national characteristics. It can play the role of relaxing the muscles and soothing the mood, and it has a relatively good effect on the improvement of the symptoms of sleep disorders caused by high nervousness, metabolic disorders, and illnesses, etc., and the elderly group is particularly fond of this exercise. Based on this, it is of great significance to explore the effect of Tai Chi exercise on the intervention of elderly patients with sleep onset and sleep disorders.

In summary, the results of this study show that the use of Tai Chi to intervene in the elderly population suffering from insomnia and sleep disorders has significant efficacy, and especially the long cycle of Tai Chi intervention, for the elderly sleep disorders have been well improved. The strengths, weaknesses and limitations of the research study in this paper are as follows respectively.

6.1. Limitations

(1) The included studies were all in Chinese and English, and did not include literature in other languages, which may have potential publication bias;
(2) The number of the included literature is relatively small, which may be affected by the chance probability of a positive indication;

6.2. Strengths

(1) This meta-analysis provides a comprehensive and integrative evaluation of existing RCT studies, and for the first time, different exercise cycles of tai chi exercise were used to obtain the perspective that long-term (more than 13 weeks) tai chi exercise is more likely to improve the problem of sleep disorders in moderate-to-severe older adults, which increases the statistical power of the study and the reliability of the conclusions.
(2) In the era of aging trend, this study focuses on elderly patients, which helps to solve the prevalent sleep disorder problem in this specific population, which is of better value to reduce all kinds of physical and mental chronic diseases and mortality rate in the elderly worldwide.
(3) Tai Chi as a non-pharmacological therapy is of great value to patients seeking alternative or complementary treatments. And Tai Chi is easy to popularize and implement for a wide range of people at a low cost. This provides a deeper boost to exercise for health.

6.3. Weaknesses

The study lacked standardization of tai chi exercise protocols across the included trials, introducing potential heterogeneity. Differences in duration, frequency, and style of tai chi practice may affect the consistency of results and limit the ability to draw definitive conclusions about the best ways to improve sleep disorders in older adults.

The applied value of this study provides an important reference for other researchers. First, by thoroughly analyzing the effectiveness of Tai Chi exercise in improving moderate-to-severe sleep disorders in older adults, we provide a powerful non-pharmacological treatment option for the research community and clinical practice. Other scholars can further expand the relevant fields based on our findings and explore in depth the applicability and advantages of Tai Chi exercise for different populations and conditions. Second, our study found that Tai Chi exercise has a positive effect in improving the overall quality of life of the elderly, which provides a new perspective in the field of health care and rehabilitation for the elderly. Other scholars can draw on our findings to explore the mechanisms of Tai Chi exercise in promoting physical and mental health and reducing stress and anxiety in older adults and conduct more extensive empirical studies. Overall, this study provides a theoretical basis for the application of Tai Chi exercise and useful insights for academic research and practical application in related fields.

7. Conclusion

Current evidence suggests that tai chi can have different potential significance as an alternative or complementary approach to treating the elderly population with moderate to severe sleep disorders. Tai chi exercise therapy is effective in improving sleep in older adults with sleep disorders and is more effective with long-term adherence to tai chi exercise. Although the current meta-analysis showed statistical benefits, we would like to note potential pitfalls related to the quality of the included studies. Therefore, we recommend further well-designed studies that require more evidence and more rigorous research to draw more reliable conclusions.

Ethical statement

The ethical statement is not applicable in this study as this is a review paper, and we are using secondary published information.

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Data availability statement

The data related to the research in this paper have been stored in publicly available repositories. (figshare database) https://doi.org/10.6084/m9.figshare.24265009.v1.

CRediT authorship contribution statement

Lujia Li: Writing – original draft. **Xiaozheng Li:** Methodology. **Yuerong Huang:** Data curation. **Haojie Li:** Writing – review & editing. **Cuihan Li:** Formal analysis. **Yuxin Ma:** Software. **Jianwei Zhang:** Visualization. **Fang Peng:** Supervision. **Shaojun Lyu:** Conceptualization.

Declaration of competing interest

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

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