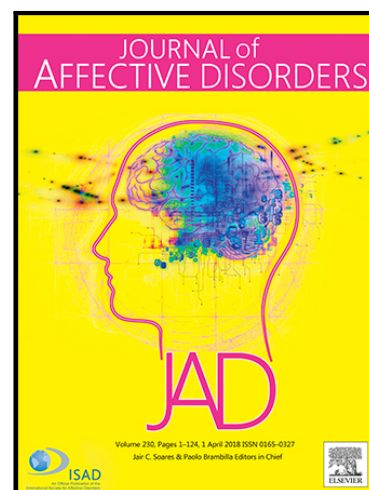# Journal Pre-proof

The Effect of Tai Chi for Improving Sleep Quality: A Systematic Review and Meta-analysis

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Introduction

Insomnia is defined as predominant dissatisfaction with sleep, leading to impairment in social,

occupational, educational, academic, behavioral, or other important areas of functioning. It also causes

significant distress[1]. Insomnia is common and usually persistent. One study in 10 countries covering

Africa, Asia and Europe, found that one in four individuals do not think they sleep well[2]. The results of a

survey of 25,575 people in seven European countries concluded that the prevalence of insomnia in the

general population is 6.6%[3], as defined by the DSM-V. A British population-based, longitudinal study

showed that 37% adults in Staffordshire suffer from insomnia[4]. Many factors contribute to insomnia. The

most influential are mental disorders and organic diseases[5]. As one of the world's most concerning health

problems, insomnia treatment focuses on improving quantitative and qualitative aspects of sleep and

reducing the distress and anxiety associated with sleep disturbance[6]. Treatments include lifestyle changes,

cognitive-behavioral therapy and medicines. Use of drugs like doxepin, ramelteon, and secobarbital is

increasingly being discouraged due to their potential toxicity[7]. In addition, patients often prefer

non-pharmacologic approaches as a means of avoiding long-term medication use[8]. According to the

European insomnia guidelines, cognitive-behavioral therapy, which usually consists of sleep hygiene,

relaxation training, sleep restriction therapy and cognitive therapy[9], is the most studied

nonpharmacologic treatment[10]. However, it requires frequent monitoring and high maintenance costs[11].

A new study suggests that several interventions may benefit patients with insomnia. However, there is lack

of definitive recommendations for clinical practice. This requires further study[12].

China has a long history of Tai Chi, also known as Tai Ji or Tai Chi Chuan, with the first written

mention in the 17th-century[13]. It has been described as an internal Chinese martial art, and has become increasingly popular in the West in recent years. Tai Chi is a complex intervention. It consists of a series of gentle physical activities that incorporate element and meditation, body awareness, imagery, and abdominal breathing[14]. In a broader philosophical sense, the primary goal of Tai Chi is to balance the *yin* and the *yang*. In this way, it is unique among other forms of exercise. Over the past 50 years, numerous studies that have shown that Tai Chi has multiple positive effects on health. A comprehensive study of 25 conditions reviewed evidence and then organized it according to the quality of the evidence for a beneficial Tai Chi effect. It showed that Tai Chi has a positive effect on osteoarthritis, Parkinson's disease, COPD rehabilitation, depression and dementia[15]. Additionally, a bibliometric analysis found that Tai Chi was involved in over 500 clinical trials, in 21 countries,between 1958 and 2013[16].

Tai Chi remains an area of active research. Recent research has focused on investigating the effects of Tai Chi on insomnia. Several randomized controlled trials have reported that Tai Chi improves sleep quality[17, 18], A randomized, partially blinded, noninferiority trial found Tai Chi to be statistically noninferior to cognitive behavioral therapy for insomniaamong breast cancer survivors[19]. A systematic reviewin 2012 analyzed eleven studiesand demonstrated Tai Chi's effect on improving sleep quality in both healthy adults and patients with chronic health conditions[20]. However, evidence-based research remains insufficient in this area, and analysis of the efficacy of different types of Tai Chi is lacking.

The aim of this systematic review is to strengthen evidence of Tai Chi's effect on sleep quality and inform future research, and to quantify Tai Chi's positive effect on sleep quality.

Methods

Inclusion Criteria

Studies

To collect high quality evidence, this review only includes randomized controlled trials (RCTs). Only full article are included.

Participants

All studies that reported on sleep quality were included. There was no restriction on the baseline for sleep quality. This meant that we did not set the criteria for sleep disorders. This increased the sample size.

Interventions

Trials of any form of Tai Chi were eligible, regardless of the treatment duration. We also included studies which used Tai Chi as the sole therapeutic. Control groups could receive either no intervention, pharmacotherapy, or any other non-pharmacotherapy.

Outcomes

Studies in which the Pittsburgh Sleep Quality Index (PSQI), Insomnia Severity Index (ISI), Stanford Sleepiness Scale (SSS), Epworth Sleepiness Scale, Athens Insomnia Scale (AIS) or Polysomnography (PSG) were the primary or secondary sleep quality outcome were included.

Search Strategy

This study was registered with the International Prospective Register of Systematic Reviews (CDR42018116002). We conducted a comprehensive search for all published and unpublished RCTs of Tai Chi for patients with insomnia or other diseases with sleep complaints, in both Chinese and English

language. We searched 4 English databases—MEDLINE, EMBASE, PsycINFO, CENTRAL, and 4

Chinese databases—CNKI, CBM, VIP, and Wanfang Data, from their inception to June 23, 2019. The

search strategy is outlined in Appendix 1. Other sources, such as the references of all included studies and

registries of clinical trials, were searched for additional relevant studies. If necessary, the original authors

were contacted for more information.

Study selection and data extraction

Two authors (HJL, JXC) independently screened the titles and abstracts of the articles' retrieved in the

search. Trials that were clearly ineligible were excluded. Disagreements were resolved through discussion.

Three authors (HJL, JXC, GZX) independently assessed whether the trials met the inclusion criteria, with

disagreements resolved by discussion. Data extraction for this study was performed by two independent

reviewers (DXH, YTD). Discrepancies were resolved by discussion, or in consultation with a third review

author (CZT). For each included trial, information was collected regarding the trial's location, methods,

interventions, duration, outcomes, and participants' age range and eligibility criteria.

Assessment of risk of bias in included studies

Two review authors (YTD, DXH) independentlyevaluated risk of bias for each study according to the

Cochrane Handbook for Systematic Reviews of Interventions. Disagreements were resolved by discussion

or by consultation with a third reviewer (JHL), when necessary. The following domains were assessed:

sequence generation, allocation concealment, blinding of participants, providers and outcome assessors,

completeness of outcome data, selective outcome reporting, and other sources of bias. Each potential

source of bias was classified as either high, low, or unclear.

Statistical Analysis

Review Manager (RevMan) version 5.3 was used for the meta-analysis. Since this meta-analysis

included only continuous data, we used the mean difference (MD) and 95% confidence interval (CI) for

analysis. If the data was not available in the article, and the authors could not be contacted, estimates were

made using the known data and the formula in the Cochrane Handbook for Systematic Reviews of

Interventions. The I^2 statistic was used to evaluate the heterogeneity revealed by data analysis. The

interpretation of the I^2 statistic is as follows[21]:

1. 10% to 40%: might not be important

2. 30% to 60%: may represent moderate heterogeneity

3. 50% to 90%: may represent substantial heterogeneity

4. 75% to 100%: considerable heterogeneity.

If substantial heterogeneity (above 50%) was detected, a random-effects model was used in the

meta-analysis. To assess heterogeneity, we used subgroup analyses to consider whether overall summaries

were meaningful. If there were 10 or more studies in the same analysis, publication bias was assessed with

a funnel plot.

Results

Search results

The review searched literature from eight databases. Figure 1 shows the search and selection process. A total of 1,463 potentially relevant articles were searched with the search strategy. By screening the meta-analysis of similar studies, four unique articles were also included. After removing duplicates, 726 articles needed to be filtered by abstract. 635 articles were excluded based on the titles and abstracts, leaving 91 articles for which full texts were requested. After readingthe full texts of these articles, 71 were excluded, mostly due to ineligible study design, ineligible interventions or incomplete data. 20 studies were included in the final analysis [17, 19, 22-39].

Characteristics of included studies

The study included 20 articles from 5 countries—9 from China, 8 from the United States, 1 from Iran, 1 from Italy and 1 from Germany. Their characteristics are presented in Table 1. In all of the studies, the mean total PSQI score at baseline was greater than or equal to 5. This is consistent with insomnia diagnosis [40]. In addition to insomnia, some patients also had other diseases such as depression, prostate cancer, knee osteoarthritis, fibromyalgia, post-stroke, or breast cancer. A total of 1,703 patients were included in this meta-analysis, of which 807 were allocated to the intervention group and 896 were allocated to the control group. Patient age was not limited, and the average age of the included patients was 58.49 years old. 5 articles [19, 32, 36, 37, 39] did not describe gender. Among the remaining literature, there were 512 male patients and 864 female patients.

For the interventions, all trials used Tai Chi as the sole treatment. Eleven studies [23, 24, 26, 28-31, 33, 36, 38, 39] described the style of Tai Chi used. Ten used Yang-style Tai Chi exercise [23, 24, 26, 28, 29, 31, 33, 36, 38, 39]One study used the the 10-stage Tai Chi recommended by Wolf et al.[30]. Nine studies described the type of Yang-style Tai Chi, of whichtwo used 8-form Yang-style Tai Chi[24, 36], fiveused 24-form Yang-style Tai Chi[23, 26, 28, 31, 33],one used 10-form Yang-style Tai Chi[39], and another used 37-form Yang-style Tai Chi[38]. Regarding Tai Chi training instructor qualifications, eleven studies used senior Tai Chi coaches [17, 22, 23, 26, 28-31, 33, 35, 36], one used medical staff [27], one used a therapist[25], and the others did not report. The Tai Chi duration was at least 1 month, the longest being 6 months. The majority were 2 to 4 months. The duration of the Tai Chi sessions ranged from 30 to 120 minutes, with a mode of 60 minutes. The frequency of the Tai Chi sessions ranged from 1 to 7 times each week. The longest treatment period was 6 months and the shortest was 8 weeks.

The control groups in this review were divided into 2 groups—a non-treatment group and an active treatment group. The non-treatment group included those studies in which the sleep quality assessment was performed before and after the test without any intervention. The active treatment group was divided into 4 groups—a CBT-I group, an exercise group, an acupuncture and moxibustion group,and a health education group. The exercise group was divided into control sub-groups based on which exercise was used, such as rehabilitation, aerobic exercise and low-impact exercise. The acupuncture and moxibustion group included those studies using acupuncture and moxibustion. The health education group referred to subjects receiving wellness education and psychological counseling related to sleep disorders in the control group. The CBT-I group referred to those studies using cognitive behavioral therapy for insomnia.

Risk of bias in the included studies

According to the Cochrane Handbook for Systematic Reviews of Interventions, we assessed the risk of

bias of the included literature. The results are shown in Figure 2. 11 RCTs described the appropriate

random sequence generation method in detail [19, 22-29, 36, 38]. The other 9 studies did not report the

RCT random sequence generation. Thus, the   risk for these domains was determined to be unclear. Only 7

of the studies reported using allocation concealment [19, 22, 25, 26, 28, 29, 36]. Only 2 reported blinding

the assessors [22, 29]. Due to the nature of Tai Chi, strict blinding of participants was difficult. All of the

included studies reported the complete outcome data, and we considered them to be low-risk for this item.

Most studies reported all of the outcomes. No other significant bias was found in any the literature. The

overall quality of the trialswas assessed as having unclear risk of bias, with the exception of 1 trial[29].

Meta-analysis results

This review did not limit the outcome for assessing sleep quality. However, when the global PSQI

score or the Athens Insomnia Scale (AIS) was used as the outcome measure, more than two studies were

available for meta-analysis. Therefore, we used Review Manager 5.3 to perform a random effects model

meta-analysis on the global PSQI score and the Athens Insomnia Scale.Since only one article used the

SPIEGEL Sleep Scale as the primary outcome, we could not perform meta-analysis on it[23].

Global PSQI score

15 articles reported the effect of Tai Chi on global PSQI score compared with an active treatment group[19, 22, 24-29, 31-33, 36-39]. The results of the meta-analysis showed that compared with active treatment group, Tai Chi had a large, significant effect on PSQI [MD= -0.97, 95% CI (-1.69, -0.25), P=0.0008] (Figure 3A). Additionally, the heterogeneity was significant [I^2 =89%, P<0.00001]. The studies included in this group produced an asymmetrical funnel plot (Figure 3B). The heterogeneity resultschanged little when deleting individual studies. Based on the abovementioned results, a subgroup analysis of the various control groups was necessary. 2 articles reported the effect of Tai Chi on global PSQI score compared with a CBT-I group[19, 25]. The results of the meta-analysis showed that CBT-I had a strong, significant effect on improving sleep quality [MD= 0.81, 95% CI (0.65,0.97), P<0.00001]. 8 articles reported the effect of Tai Chi on global PSQI score compared with an exercise group[26-29, 33, 36, 37, 39]. The results of the meta-analysis showed that Tai Chi exercise had a strong, significant effect on improving sleep quality [MD= -1.16, 95% CI (-1.59, -0.74), P<0.00001]. 5 articles reported the effect of Tai Chi on global PSQI score compared with a health education group[22, 24, 25, 32, 38]. The results of the meta-analysis showed that Tai Chi exercise had a strong, significant effect on improving sleep quality [MD= -1.14, 95% CI (-1.84,-0.44), P=0.001]. Only one article compared Tai Chi with anacupuncture and moxibustion group. Therefore, meta-analysis on it could not be performed [31](Figure 4A).

7 articles reported the effect of Tai Chi on global PSQI score compared with a non-treatment group[17, 30, 33-36, 39]. The results of the meta-analysis showed that Tai Chi had a strong, significant effect on PSQI. [MD= -2.25, 95% CI (-3.39, -1.10), P=0.0001], and the heterogeneity was significant [I^2 =74%, P=0.0007]. When Manh's study was excluded, the heterogeneity of the global PSQI score dropped to 0%(P=0.63), and the meta-analysis still showed a strong, significant effect[MD= -1.65, 95% CI (-2.24,-1.05), P<0.00001](Figure 3C).

Athens Insomnia Scale

2 articles reported the effect of Tai Chi on the Athens Insomnia Scale(AIS) compared with a control

group[19, 25]. The results of the meta-analysis showed that Tai Chi had no significant effect on AIS [MD=

-0.11, 95% CI (-1.31, 1.09), P=0.86] (Figure 3D). Based on the abovementioned results, subgroup analysis

of the CBT-I control group was needed. Compared with the CBT-I control group, the results of the

meta-analysis showed that CBT-I had a strong, significant effect, as assessed by AIS [MD= 0.31, 95% CI

(0.12, 0.49), P=0.001] (Figure 4B).

Yang-style Tai Chi

The articles which specifically described Yang-style Tai Chi reported the effect of Tai Chi on global

PSQI score compared with all the control groups. The results of the meta-analysis showed that Yang-style

Tai Chi had a strong, significant effect on PSQI. [MD= -1.38, 95% CI (-1.74, -1.03), P<0.00001](Figure

3E). Subgroup analysis was conducted onvariousforms of Yang-style Tai Chi. 5 articles reported the effect

of 24-form Yang-style Tai Chi on global PSQI score. The results of the meta-analysis showed that 24-form

Yang-style Tai Chi had a strong, significant effect on improving sleep quality [MD= -1.40, 95% CI

(-2.42,-0.37), P=0.008], andthe heterogeneity was significant [I^2 =67%, P=0.02]. When Ruth's 2014 study

was excluded, the heterogeneity of the global PSQI score dropped to 0% (P=0.61), and the results of the

meta-analysis still showed a strong, significant effect[MD= -1.97, 95% CI (-2.53,-1.41), P<0.00001]. 2

articles reported the effect of 8-form Yang-style Tai Chi on global PSQI score. The results of the

meta-analysis showed that 8-form Yang-style Tai Chi had a significant effect on improving sleep quality

[MD= -1.10, 95% CI (-2.16,-0.03), P=0.04] (Figure 4C).

Discussion

Tai Chi, a unique traditional exercise, has spread worldwide in recent years. This meta-analysis strengthens the evidence of Tai Chi's effects on improving sleep quality. It is the first comprehensive analysis of the effects of various types of Tai Chi. Tai Chi presents significant positive effects on sleep quality, when compared to non-treatment, exercise, or health education. However, there is no evidence that it is more effective than CBT-I, whichhas been verified and recommended by several studies [10]. Yang-style Tai Chi is a common form of Tai Chi. This study's findings suggest that 24-form and 8-form Yang-style Tai Chi have significant positive effects on sleep quality, as assessed by PSQI.

Several previous systematic reviews and meta-analyses have explored the effect of non-pharmaceutical therapy for sleep quality in adults. Among these, mind-body exercise is a hot issue. Mind-body medicine, also known as meditative movement, usually includesguided imagery, progressive relaxation, yoga, Tai Chi, and Qi Gong [41]. Wang Fang, et al. [42] conducted a comprehensive review to demonstrate that Tai Chi, yoga and Qi Gong may improve sleep quality among various populations. However, the study did not conduct a meta-analysis, which may diminish its generalizability. Similar to this study, Jerome, et al. [43] investigated the effects of mind-body therapy, including Tai Chi, on insomnia. However, their study did not focus on Tai Chi, only including two relevant articles on it. The focus of the present study is Tai Chi as the only intervention. Although a variety of mind-body exercises are effective, such as *Baduanjin*[44], which is also effective on insomnia, Tai Chi's status as China's intangible cultural

heritage is unshakable. Our review's design was more rigorous than existing studies and included a larger

sample. One study [45] reported that Tai Chi improved self-rated sleep quality for elderly people, but with

its simple search strategy, it may not have been comprehensive. Gowri et al's study [20] reported that Tai

Chi may improve sleep quality among both healthy adults and patients with chronic health conditions.

Indeed, while improving sleep, Tai Chi may also have a beneficial effect on accompanying conditions.

In most studies, insomnia is not the only outcome, and the occurrence of insomnia is limited by neither

age nor sex. It is also often accompanied by other conditions. In order to illustrate Tai Chi's adaptability,

and its value to society, we included patients of any age or sex, with or without other conditions.

Tai Chi is a common mind–body, low–intensity aerobic exercise. Evidence has shown that exercise is an

effective insomnia treatment. Melancon et al. proposed that aerobic exercise stimulates 5-HT in the brain

and in peripheral blood. The 5-HT released to the mesencephalon and the brain induces normal sleep and

prevents insomnia by inhibiting the non-5-HT spinal cord system [46]. Krueger et al. proposed that exercise

improves the plasma concentration of many pro-inflammatory cytokines, thus promoting sleep [47].

However, the mechanism of improving sleep through Tai Chi requires more evidence. Tai Chi is thought to

target insomnia's arousal mechanisms [48, 49]. This can decrease sympathetic activity [50]. Additionally,

Tai Chi is a useful intervention for reducing inflammation by circulating levels of IL-6, causing it to decline

in localized areas[51]. A recent study found that Tai Chi, especially with long-term training, may enhance

brain functional connections, as observed by functional magnetic resonance imaging [52]. This suggests

that the mechanism of Tai Chi in treating insomnia could be explained more directly and objectively by

medical imaging. This may be a hot new topic for future research.

Tai Chi developed based on ancient Chinese philosophy. *Qi*, an intermediary connecting the human body with nature, is an essential concept in Chinese medicine. From the perspective of modern medicine, quantum theory has revealed the essence of material existence [53]. Studies have used quantum theory as a basis for explaining TCM theory [54]. The quantum of the human body are the *qi* information of viscera and meridians in TCM [55]. Tai Chi is a combination of movement and regulating *qi*. In the included studies, the Tai Chi intervention was conducted by experienced coaches. This guaranteed the transmission of essential Tai Chi characteristics, not merely the teaching of movement.

The included studies were of moderate quality, as evaluated based on Cochrane. The main reason for this was that blinding was not strictly enforced in all studies. Due to Tai Chi's particularity, like acupuncture, it is difficult to find patients who are unaware of it. Thus, it is difficult to achieve blindness in research, so that the overall evidence in our study may appear low. However, the other items were mostly low-risk. Therefore, we considered the quality of evidence in this study to be compelling.

Additionally, since no adverse events were reported, Tai Chi can be promoted as a safe intervention for improving sleep quality.

Limitations

This review has several limitations. First, our meta-analysis was based on reporting data. More than half of included studies were considered as having unclear risk of bias. Second, we failed to get in touch with all

authors to request additional data to evaluate methodological quality. Third, although it is hypothesized that

Tai Chi has a positive effect on PSQI, conclusions were not reached for other insomnia outcomes. Since the

1920s, the Visual Analogue Scale (VAS) has been used to assess outcomes such a quality of life and pain.

Numerous recent studies have used the VAS as an assessment tool across fields such as cognitive

psychology,[56] , integrative psychology[57] , medicine [58], and public health[59] . Moreover, several

studies have used it to measure sleep quality because of its simplicity[60-62], although the BMJ Insomnia

guidelines do not mention this usage[7]. The VAS is a better reflection of sleep satisfaction than are

objective sleep indicators. However, our search did not find enough RCTs that used the VAS as the

measurement of sleep quality. Therefore, we did not conduct any analysis of this outcome. Finally, although

we conducted several subgroup analyses for the specific control groups and types of Tai Chi, the sample

sizes for the subgroup analysis were limited. In addition, we did not elucidate the relationship between the

efficacy and any of the factors. Also, our study included more male patients than female patients. However,

this is consistent with the insomnia guidelines which indicate that women report more subjective sleep

abnormalities than men [7]. The average age of the included patients was 58.49 years old. This is consistent

with the insomnia guidelines, which indicate that the likelihood of insomnia increases with age, due to

diminishing health as people age [7]. Li et al. have proposed that older participants have worse sleep

quality [18]. Additionally, exercise has a more positive effect on sleep quality among people with low sleep

quality than people with good sleep quality [30].However, due to insufficient data from the included

articles, this meta-analysis could not show what contributed to the varying levels of improvement, such as

whether it was age-related or baseline sleep quality-related.

Conclusions

Evidence from 20 RCTs indicates that Tai Chi improves sleep quality among patients, both those with and without other medical conditions. Furthermore, this study indicates that Tai Chi, especially Yang-style Tai Chi, both 24-form or 8-form, improves sleep quality. However, future systematic research needs further analysis on different durations and other Tai Chi styles, a lacuna in current research. Moreover, high-quality, well-designed RCTs about Tai Chi's effect on sleep quality are also needed.

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Authors' contributions

Huanjie Li and Juexuan Chen contributed equally. JHL conceptualized the study design. HJL and JXC wrote the draft and complemented this study's methods. GZX searched and screened the articles' titles and abstracts. DXH and YTD confirmed the data and the statistical analysis. CZT resolve differences.JHL supplied the funding. All authors provided input on the direction of the study and the content of the manuscript. All authors approved the final version of the manuscript.

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Abbreviations

MD: Mean Difference

CI: Confidence Interval

PSQI: Pittsburgh Sleep Quality Index

DSM-V: Diagnostic and Statistical Manual of Mental Disorders, 5th Version

RCTs: Randomized Controlled Trials