

# Effect of yoga on sleep quality and insomnia in women with sleep problems: a systematic review and meta-analysis

**Weili Wang**

Taoyuan Armed Forces General Hospital

**Kuang-Huei Chen**

Taoyuan Armed Forces General Hospital

**Ying-Chieh Pan**

Taoyuan Armed Forces General Hospital

**Szu-Nian Yang**

Tri-Service General Hospital Beitou Branch

**Yuan-Yu Chan** (✉ [xaviorchan@gmail.com](mailto:xaviorchan@gmail.com))

---

## Research article

**Keywords:** yoga, sleep quality, insomnia, women, complementary and alternative medicine, meta-analysis, review

**Posted Date:** October 31st, 2019

**DOI:** <https://doi.org/10.21203/rs.2.12592/v2>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

---

**Version of Record:** A version of this preprint was published at BMC Psychiatry on May 1st, 2020. See the published version at <https://doi.org/10.1186/s12888-020-02566-4>.

## Abstract

**Objectives** To examine the effectiveness and safety of yoga for women with sleep problems by performing a systematic review and meta-analysis. **Methods** Medline/PubMed, ClinicalKey, ScienceDirect, Embase, PsycINFO, and the Cochrane Library were searched throughout the month of June 2019. Randomized controlled trials comparing yoga groups with control groups in women with sleep problems were included. Two reviewers independently evaluated risk of bias by using the risk of bias tool suggested by the Cochrane Collaboration for programming and conducting systematic reviews and meta-analyses. The main outcome measure was sleep quality or the severity of insomnia, which was measured using subjective instruments, such as the Pittsburgh Sleep Quality Index (PSQI), Insomnia severity index (ISI), or objective instruments, such as polysomnography, actigraphy, and safety of the intervention. For each outcome, standardized mean difference (SMD) and 95% confidence intervals (CIs) were determined. **Results** Nineteen studies including 1832 participants were included in this systematic review. Meta-analyses revealed positive effects of yoga using PSQI or ISI scores in 16 randomized control trials (RCTs) compared with the control group in improving sleep quality in women, PSQI (SMD = -0.54; 95% CI = -0.89 to -0.19 ; P = 0.003). However, three RCTs revealed no effects of yoga compared with the control group in reducing the severity of insomnia in women using ISI (SMD = -0.13; 95% CI = -0.74 to 0.48; P = 0.69). Seven RCTs revealed no evidence for effects of yoga compared with the control group in improving sleep quality for women with breast cancer using PSQI (SMD = -0.15 ; 95% CI = -0.31 to 0.01; P = 0.5). Four RCTs revealed no evidence for the effects of yoga compared with the control group in improving the sleep quality for peri- or postmenopausal women using PSQI (SMD = -0.31; 95% CI = -0.95 to 0.33; P = 0.34). Yoga was not associated with serious adverse events. **Discussion** This systematic review and meta-analysis found that yoga intervention in some groups of women was beneficial in managing sleep problems. Despite certain disadvantages in methodology in the included studies, yoga may be recommended as a complementary therapy to women.

## Introduction

Sleep problems are one of the most common medical complaints. Lack of sleep is associated with significantly decreased work performance, impaired daytime function, and increased health care costs [1]. Sex-based differences in sleep problems have been widely published and discussed across sleep articles. Insomnia is approximately 1.41 times more common in women than in men [2]. Female populations at certain stages in their life span may be more vulnerable to insomnia. In these stages, hormonal changes associated with hormones, such as follicle-stimulating hormones (FSHs), luteinizing hormones (LHs), and progesterone, may play an important role in influencing women's sleep construction [3] during adolescence [4], pregnancy and postpartum [5] or menopause [6]. Several behavioral, psychological and pharmacological treatments are available for insomnia; however, their efficacy varies considerably. The evidence of efficacy for cognitive behavior therapy is now well established in many reviews [7, 8], but availability remain poor. Pharmacotherapy remains the most common treatment [9], although hypnotics have been associated with many side effects, such as drowsiness, cognitive impairment, dependence, tolerance and poor long term efficacy [10].

Yoga, which originated from India thousands of years ago, is one of the most popular complementary and alternative medicines. Yoga has been widely adapted in the modern Eastern and Western world in a variety of ways. Yoga is an ancient form of exercise that focuses on strength, flexibility, and breathing to boost physical, mental and spiritual health [11]. There are many different styles of yoga, such as Tibetan, Iyengar, and Hatha Yoga. Some styles are more vigorous than others, whereas some may have different areas of emphasis, such as posture or breathing. The main components of yoga in Europe or America are mostly associated with physical posture (*Asana*) and breathing control (*Pranayama*) and meditation (*Dhyana*) [11]. In women, yoga can help not only to develop a healthy and regular menstrual cycle but also to cope with the psychological changes that they may experience due to physical instability [12]. A trial in yoga for persistent fatigue breast cancer survivors showed yoga is safe and effective at improving fatigue severity, depressive moods, and sleep quality [13]. Yoga is also characterized as a mindful mode of physical activity. Mindfulness, as an important component of yoga, improves sleep disturbance by increasing melatonin levels, reducing hyperarousal, and addressing stress-related cardiac and respiratory abnormalities [14].

The term "sleep quality" is commonly used in sleep medicine. In 1989, Buysse et al. referred to sleep quality as a "complex phenomenon that is difficult to define and measure objectively" [15]. Good sleep quality is associated with better health, less daytime sleepiness, greater well-being and better psychological functioning [16]. Recently, sleep quality is defined as one's satisfaction of the sleep experience, integrating aspects of sleep initiation, sleep maintenance, sleep quantity, and refreshment upon awakening [17]. The National Sleep Foundation (NSF) released the key indicators of good sleep quality, as established by a panel of experts. They include sleeping more time while in bed (at least 85 percent of the total time), falling asleep in 30 minutes or less, waking up no more than once per night and being awake for 20 minutes or less after initially falling asleep. However, there was less or no consensus regarding sleep architecture or nap-related variables as elements of good sleep quality [18]. Poor sleep quality is one of the defining features of chronic insomnia [19].

Although recent systematic reviews and meta-analyses have assessed the efficacy and safety of yoga in specific groups of women, such as those with prenatal depression [20] and primary dysmenorrhea [21] in different stages, evidence for the efficacy of yoga in improving sleep quality and insomnia of women has not yet been systematically assessed. Thus, the aim of this review was to systematically evaluate and perform a meta-analysis of the available data on the efficacy and safety of yoga in terms of improving sleep quality and insomnia in women.

## Methods

Before beginning the review, we followed the checklist for systematic reviews in concurrence with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines [22] and suggestions by the Cochrane Collaboration for programming and conducting systematic reviews and meta-analyses [23].

## Eligibility criteria

### *Types of studies*

Randomized controlled trials (RCTs), randomized crossover studies, and cluster randomized trials were all eligible for this meta-analysis. No restrictions in terms of language and countries were applied.

### *Types of participants*

Studies that included women (aged  $\geq 18$  years) with sleep problems were eligible. No restrictions on the ethnicity and comorbidity of participants were applied.

### *Types of interventions*

No restrictions regarding yoga type, form, structure, frequency, duration or length of intervention programs were applied. Studies on cointerventions that included yoga as a part of multicomponent interventions were excluded because it would be difficult to distinguish the effects of yoga from additional modalities. Studies in control interventions that compared yoga treatments with nontreatment, usual care, wait-lists, and education without active physical exercise programs were all eligible.

### *Types of outcome measures*

*The primary outcome* of this study was sleep quality. To be included in this review, studies had to assess at least one of the sleep quality measures by using standardized instruments and provide outcomes both at the baseline and follow-up for primary outcomes. In particular, instruments in question included subjective measurements, such as the Pittsburgh Sleep Quality Index (PSQI) and Insomnia Severity Index (ISI), or objective measurements, such as polysomnography (PSG) and actigraphy. The PSQI score have been recommended as reliable, valid and standardized instruments to measure sleep quality and to identify good and bad sleepers. The widely employed Pittsburgh Sleep Quality Index (PSQI), provides a measure of global sleep quality, including sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction [15]. The seven components of the PSQI are standardized versions of areas routinely assessed sleep complaints with possible range 0-21 points. A global PSQI score of 5 or higher provided a sensitive and specific measure of poor sleep quality [24]. The ISI score is a reliable and valid instrument to quantify perceived insomnia severity. A global ISI score of 8 or higher is indicative of some degree of insomnia, being moderate insomnia with score 15-21 and severe insomnia with score 22-28 [25].

PSG or actigraphy report the most complete and precise information on the construction and distribution of sleep periods, such as total sleep time (TST), sleep efficiency (SE), and wake time after sleep onset (WASO) [26]. Sleep quality is also sometimes measured from PSG and actigraphy. Among these objective indices are measures such as sleep onset latency, total sleep time, wake time after sleep onset, sleep efficiency, and number of awakenings [27].

*Secondary outcomes:* The secondary outcome included in this study was the safety of the intervention, which was assessed as number of patients with adverse events (AEs), including serious adverse events or nonserious events. Serious adverse events referred to those events that caused death, life-threatening situations, hospitalization, disability or permanent damage, congenital anomaly/birth defect, or the need for medical or surgical intervention to prevent any of the aforementioned outcomes [28]. All other adverse events were regarded as nonserious.

## Search methods

The search strategy comprised four electronic databases from their inception through June 01, 2019: Medline/PubMed, Clinicalkey, ScienceDirect, Embase, PsycINFO, and the Cochrane Library. The literature search was constructed around search terms for "yoga," "women," and "sleep" and adapted for each database as necessary. The complete search strategy for PubMed was as follows: ("yoga" OR "asana" OR "pranayama" OR "dhyana" ) AND ( "women" OR "female" ) AND ("sleep" OR "sleep quality" OR "sleep disturbance" OR "insomnia"). Additional reference lists of identified original articles or reviews, the tables of the contents of the *Journal of Yoga and Physical Therapy*, and *Journal of National Taiwan Sports University* were searched manually.

Retrieved articles were scanned independently to verify their eligibility, and the entire text was assessed by two reviewers. A conflict of reviewers' opinions on inclusion or exclusion of any article was discussed with a third reviewer to reach a consensus.

## Data extraction and management

Two reviewers independently extracted data on design (e.g., article setting, author/year, country of studies, and sampling strategy), participants (e.g., age, body mass index, clinical characteristics, comorbid condition, and overall sample size), interventions (e.g., yoga type, frequency of sessions per week, duration of yoga intervention, and total length of intervention time), control interventions (e.g., type, frequency, length, and duration), and outcomes (e.g., outcome measures with sleep quality and safety-related events). A conflict of reviewers' opinions were discussed with a third reviewer until consensus was reached.

## Risk of bias in individual studies

Two reviewers independently assessed the risk of bias on the following seven domains: selection bias (random sequence generation and allocation concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other bias using the Cochrane risk of bias tool [23]. All domains were scored as low risk, high risk, or unclear risk of bias and assessed individually. A risk of bias table was completed for each included study. A conflict of reviewers' opinions were discussed with a third reviewer until consensus was reached.

### **Data assessment of overall effect size**

A meta-analysis was conducted with Review Manager 5 software (Version 5.3, The Nordic Cochrane Centre, Copenhagen) using a random effects model if at least 2 studies assessing this specific outcome were obtainable. For continuous outcomes, standardized mean differences (SMDs) with 95% confidence intervals (CIs)

were calculated as the difference in means between groups divided by the pooled standard deviation. For studies that did not report data with standard deviations, we calculated these values from standard errors, confidence intervals, or *t*-values. If adequate information was available, we planned to perform subgroup analysis. The *p* value of the summary effect < 0.05 were regarded as indicating statistical significance.

A negative SMD was provided a definition to display the beneficial effects of yoga intervention compared with the control intervention for sleep quality outcomes. Cohen's categories were used to assess the significance of the overall effect size, with SMD = 0.2–0.5: small effect size; SMD = 0.5–0.8: medium effect size; and SMD > 0.8: large effect size [29].

### **Assessment of heterogeneity**

Statistical heterogeneity between studies was analyzed using the  $I^2$  statistics, the Cochrane chi-square. The variance between studies was measured using the tau-square ( $\tau^2$ ). The level of heterogeneity was classified as  $I^2 = 0\%–24\%$ : low heterogeneity;  $I^2 = 25\%–49\%$ : moderate heterogeneity;  $I^2 = 50\%–74\%$ : substantial heterogeneity; and  $I^2 = 75\%–100\%$ : considerable heterogeneity. Given the low power of this test when only few studies or studies with a low sample size are included in a meta-analysis, a *P* value of  $\leq 0.1$  for the chi-square test was regarded as indicating significant heterogeneity [23].

### **Risk of publication bias**

Risk of publication bias was evaluated for each meta-analysis that included at least 10 studies. Funnel plots generated using Review Manager 5 software was estimated from individual studies against each study's standard error. Publication bias was evaluated through visual analysis, in which roughly symmetrical funnel plots generally means there isn't evidence of high risk of publication bias and asymmetrical funnel plots generally means there isn't evidence of low risk of publication bias[30].

## **Results**

### **Literature search**

The results of the literature search and screening process are summarized in Fig. 1. The literature search totaled 1338 records; one additional record was retrieved from the Journal of National Taiwan Sports University in the Chinese language database [31]. In all, 1295 records were excluded because they did not meet all predefined inclusion criteria or were duplicated. Forty-four full-text articles were assessed for eligibility. Twenty-five were excluded because they were not randomized [31, 32], did not include relevant outcomes [33-39], did not include only female participants [40-48], included yoga as a part of a multimodal intervention (or combined with other intervention) [49-52], lacked adequate control [53], and did not include a form of yoga intervention [54, 55]. Nineteen full-text articles with 1832 participants were included in the qualitative synthesis and were included in the meta-analysis. All articles were published in English.

### **Study characteristics**

A total of 19 studies were considered eligible for systematic reviews. Information regarding the characteristics of the sample, yoga or control group interventions, outcome measures, and results are listed in Tables 1 and 2.

#### ***Study and participant characteristics***

Of the 19 RCTs that were included in Table 1, six RCTs included healthy participants [56-61], including nurses [57], teachers [58], and women in the menopausal transition period or postmenopausal period [56, 59-61]. Other 13 RCTs included breast cancer patients undergoing treatment [62-65], breast

cancer patients who had completed treatment [13, 66-68], type 2 diabetes mellitus patients [69], fibromyalgia patients [70], knee osteoarthritis patients [71], restless leg syndrome patients [72], and patients experiencing dysfunctional uterine bleeding [73].

Overall, the 19 RCTs included were conducted in the United States [13, 56, 59, 60, 62-68, 71, 72], Brazil [61, 70], India [58, 73], Iran [69], and China [57]. Study participants were recruited from hospitals [57, 63-67, 69, 73], outpatient clinics [61, 62] and schools [58]. The process of recruitment also included using purchased lists and health-plan enrollment files [56, 59] and multiple other mechanisms, including flyers, newspaper advertisements, web-based announcements, brochures, public health departments, tumor registry systems, and doctor referrals [13, 60, 68, 71, 72]. One study did not reveal the source from which participants were recruited [70]. Nineteen studies included in the systematic review displayed a baseline of PSQI higher than 5 or ISI higher than 8, indicating poor sleep quality or insomnia. The only exceptions were two studies, with individual control groups in each study displaying a baseline of PSQI lower than 5 [58] or ISI lower than 8 [67]. The sample size ranged from 20 to 249 with a median of 96. Participant's mean age ranged from 29.8 to 71.9 years, with a median of 50.1 years. All participants were women.

### ***Intervention characteristics***

Of the 19 included studies in Table 1, three reported using Iyengar Yoga [13, 60, 72]; two reported using Hatha Yoga [68, 71]; two reported using Tibetan Yoga [61, 64]; two reported using Restorative Yoga [66, 67]; one reported using Vini Yoga [56]; one reported using Yoga Relaxation with MindSound Resonance Technique [58]; one reported using yoga breathing exercise in warm water [70]; and only seven RCTs revealed yoga programs with postures, breathing, relaxation or meditation, without defining the specific style of yoga [57, 59, 62, 63, 65, 69, 73]. All RCTs included yoga postures in their yoga intervention; 16 RCTs included yoga breathing; 15 RCTs included yoga relaxation; 12 RCTs included meditation; and 7 RCTs included all contents with postures, breathing, relaxation, and meditation for the yoga intervention group [57, 59, 63, 65, 67, 69, 73]. The duration of yoga interventions ranged from 1 week to 24 weeks, with a median of 10 weeks; the frequency of yoga interventions ranged from one to five weekly sessions of 45 to 120 min. Sixteen studies compared the yoga group with waitlist control groups with no specific treatment; three studies compared the yoga group with the control group, including two studies for education groups [13, 72] and one study for social support groups [62].

### ***Outcome measures***

All studies evaluated outcomes directly at the end of interventions. All studies assessed the subjective or objective measurements of sleep quality: 16 RCTs used the PSQI; three RCTs used the ISI [59, 61, 67]; two RCTs used PSG [61]; and one RCT used actigraphy [56,64]. Safety-related events were reported in two RCTs only [59, 68].

### **Risk of bias**

#### ***Risk of bias in individual assessments***

Graphical representation of the risk-of-bias assessment is represented in Fig. 2. All studies had a high or unclear risk of bias in at least one domain. All studies claimed to be randomized; however, three studies did not reveal their content and method of random sequence [61, 66, 69]. Twelve studies did not report methods applied to perform adequate allocation [56-58, 60-66, 69, 73]. Most studies offered no data material on blinding. Three studies clearly reported that participants and personnel were blinded [13, 62, 71]. Four studies clearly reported that researchers and outcome assessments were blinded [13, 62, 68, 71]. Six studies had insufficient data on attrition rates [59-61, 69, 70, 72]. Twelve studies had a low risk of selection reporting; only two studies had a high risk of selective reporting due to several reported outcome parameters not being revealed in study protocol or duplicate publications reporting different results of the same trial [59, 61]. Six studies had a high risk of other potential sources of bias due to poor participant compliance, intervention length, sample size or baseline differences [60, 67, 70-73].

#### ***Publication bias***

The meta-analysis of the effect of yoga on the sleep quality of women that involved yoga groups compared with control groups included 16 studies. The asymmetrical shape of the funnel plot indicated that subjective publication bias was detected (Fig. 3). Objective publication bias was analyzed using Egger's regression test with negative finding ( $P=0.05$ ) reveal no publication bias in the yoga or control subgroups using Egger's test.

### **Analysis of overall effects**

#### ***Primary outcomes***

The meta-analysis revealed the effects of yoga compared with the control group on the sleep quality and insomnia of women using the PSQI or ISI, as displayed in Fig. 4. Sixteen RCTs revealed evidence for effects of yoga compared with the control group in improving sleep quality in women using the PSQI (SMD = -0.54; 95% CI = -0.89 to -0.19;  $P = 0.003$ ). However, three RCTs revealed no effects of yoga compared with the control group in reducing the severity of insomnia in women using ISI (SMD = -0.13; 95% CI = -0.74 to 0.48;  $P = 0.69$ ). Two RCTs revealed no effects of yoga compared with control group in improving sleep efficiency (SMD = 0.85; 95% CI = -0.56 to 0.26;  $P = 2.26$ ) or total sleep time (SMD = -0.06; 95% CI = -0.26 to 0.13;  $P = -0.59$ ) in women using actigraphy.

## Secondary outcomes (safety)

Only two studies reported safety-related events. Two events revealed in one study could potentially be attributed to yoga intervention: two women reported the recurrence of chronic back and/or shoulder problems [68]. In another study, adverse events reported did not differ between the yoga intervention group and the control group ( $P = 0.41$ ). These adverse events included muscle aches and strains (6.7%, yoga group; 10.3%, control group), low back pain (4.2%, yoga group; 3.1%, control group), or changes in strength or sensation in arms or legs (5.5% yoga group; 8.9% control group). Dropouts were not regarded as being adverse events because it was not explicitly telling as the reason for dropout in the original study. No serious adverse effects were reported in the included studies.

## Subgroup analyses

Participants were divided into two separate subgroups. Meta-analyses revealed the effects of yoga compared with the control group for women with breast cancer in Fig. 5. Seven RCTs revealed no evidence for the effect of yoga compared with the control group in improving sleep quality for women with breast cancer using the PSQI (SMD = -0.15; 95% CI = -0.31 to 0.01;  $P = 0.5$ ). Four RCTs revealed no evidence for effects of yoga compared with the control group in improving sleep quality for women undergoing treatment for breast cancer (SMD = -0.08; 95% CI = -0.29 to 0.13;  $P = 0.45$ ). Three RCTs revealed no evidence for positive effects of yoga in terms of improving sleep quality for women with breast cancer who had completed treatment compared with the control group (SMD = -0.25; 95% CI = -0.50 to 0.00;  $P = 0.31$ ).

The meta-analysis showed evidence of the positive effects of yoga on sleep quality compared with control groups for peri- or postmenopausal women as displayed in Fig. 6. Four RCTs revealed no evidence for effects of yoga compared with control groups in improving sleep quality in peri- or postmenopausal women using the PSQI (SMD = -0.31; 95% CI = -0.95 to 0.33;  $P = 0.34$ ). Two RCTs revealed no evidence for effects of yoga compared with the control group in reducing severity of insomnia in peri- or postmenopausal using ISI (SMD = -0.29; 95% CI = -1.23 to 0.65;  $P = 0.55$ ).

## Sensitivity analyses

In the included studies with low risk of selection bias, reporting bias, and other bias, the effect of yoga group compared to control group on women sleep PSQI did not change substantially, including random sequence generation bias (SMD = -0.45; 95% CI = -0.84 to -0.11;  $P = 0.01$ ; heterogeneity:  $I^2 = 88\%$ ;  $\chi^2 = 107.43$ ,  $P < 0.00001$ ), allocation concealment bias (SMD = -0.77; 95% CI = -1.37 to -0.16;  $P = 0.01$ ; heterogeneity:  $I^2 = 88\%$ ;  $\chi^2 = 40.95$ ,  $P < 0.00001$ ), selective reporting bias (standard mean difference = -0.59; 95% CI = -1.10 to -0.08;  $P = 0.02$ ; heterogeneity:  $I^2 = 88\%$ ;  $\chi^2 = 93.11$ ,  $P < 0.00001$ ) and other bias (standard mean difference = -0.53; 95% CI = -1.03 to -0.04;  $P = 0.03$ ; heterogeneity:  $I^2 = 86\%$ ;  $\chi^2 = 44.03$ ,  $P < 0.00001$ ). The effect compared with the control group remained significant in terms of sensitivity analyses of performance bias, detection bias, or attrition bias after eliminating high risk bias or uncertain risk bias of the studies.

# Discussion

## Summary of evidence

In this systematic review of 19 studies for yoga's effect on improving women's sleep quality and severity of insomnia, 16 RCTs revealed evidence for yoga improving sleep quality in women. This 16 RCTs meta-analysis suggests yoga can bring 1.2 points improvement in PSQI score. However, seven RCTs revealed no evidence for yoga improving sleep quality in women with breast cancer. Four RCTs revealed no evidence for improving PSQI in peri- or postmenopausal women. Two RCTs revealed no evidence for improving ISI in peri- or postmenopausal women.

However, heterogeneity of effects were high across studies. Overall, the application of yoga was not associated with worsening of sleep problems or increased adverse effects. Only two studies explicitly assessed safety-related nonserious adverse events. Yoga is most likely a comparatively safe intervention in this population. However, future RCTs should take more measures to ensure stricter reporting of adverse events and reasons for dropouts.

## Comparison with prior reviews

No systematic review explicitly focusing on yoga for improving sleep quality and insomnia in a specific gender was accessible. Ours is the first systematic review and meta-analysis with 18 RCTs that to focus on the effects of yoga on women with sleep problems. A previous review published until February 2019 included subgroup analysis of yoga on mind-body therapies on insomnia [74]. This recent review illustrated that yoga had beneficial effects on subjective sleep quality in participants in all gender groups. Our meta-analysis with 16 RCTs uncovered evidence for the effects of yoga on the sleep quality in women. Only six RCTs were found to have overlapped with this previous review[75-80]. Our meta-analysis also examined the potential effect on specific subgroups, such as breast cancer and menopausal subgroups, with these subgroups serving as potential factors in sleep quality effects (although the result did not show any clear difference). Results from the peri- or postmenopausal subgroup of women in our systematic review also agreed with previous published reports that suggested that yoga had no significant effect on the severity of insomnia in middle-aged women [81]. There were baseline differences between participants based on intervention assignment in PSQI scores [59, 72]. This may have contributed to results displaying no significant effect in sleep quality in the peri- or

postmenopausal subgroup of women. Yoga seems to be effective for reducing total menopausal symptoms including psychological, somatic, vasomotor and in previous systematic review and meta-analysis [82]. Our reviews and meta-analysis reveal no effect on sleep quality maybe due to the small number of RCTs limited data presentation. A recent systematic review and meta-analysis suggest walking may a effective intervention than yoga at reducing sleep disturbance in cancer patients [83].

Comparison to other meta-analyses on the effects of complementary therapies on sleep quality. Taichi , Qigong exercise showed weak evidence beneficial effect in improving self-rated sleep quality, but heterogeneity are high due to difference of interventions and target populations [84, 85].

### **External and internal validity**

Major threats to external validity included the specificity of variables of sampled participants and multiple yoga types or styles. The majority of RCTs included participants from North America, South America, and Asia. The lack of studies from Europe and Africa could be seen. It might not be generalisable to other areas.

There were several other limitations in this review: the wide variety of diagnoses included; the inclusion of only certain types of people or professions, such as nurses, teachers, and peri- or postmenopausal women; and patients with breast cancer, type 2 diabetes mellitus, fibromyalgia syndrome, osteoarthritis of the knee, restless leg syndrome, and primary dysfunctional uterine bleeding. The heterogeneity of interventions with different types or styles of yoga (postures, breathing, relaxation, or meditation), and potential bias were included in this systematic review.

Other threat to internal validity was study bias. Only few effects were robust against all potential bias. All of our studies claimed to have applied randomization methods; however, three RCTs failed to provide the design protocol of randomization. Some of the included studies may not have been truly randomized. Erroneous allocation concealment has been empirically revealed to be a significant source of bias in RCTs [86]. Our included studies only had a low risk or an unclear risk of detection bias without high risk detection bias. The results of meta-analysis did no changed when studies excluded high risk or unclear risk reviews on selection bias or reporting bias. The internal validity of the review appeared to be limited but acceptable.

### **Strengths and weaknesses**

This is the first and latest systematic review and meta-analysis available on yoga for sleep quality in women. A large number of RCTs on female population-related physiological and physiological comorbidities and risk factors in insomnia were included. There were five primary limitations of this review. First, subjective publication bias revealed in this review may have been due to selective reporting bias, which means that articles with negative findings may have not been published or poor methodological quality of including articles. We have applied Egger's test for objective publication bias in our review. Second, the participant characteristics included in the review were heterogeneous; subgroups were included to analyze the effectiveness of different participant groups; and the small number of RCTs limited data presentation. Third, the severity of the sleep complaints and health status of participants was not considered or individually listed in each study. Baseline differences in PSQI scores were found between intervention and control groups in three studies [59, 68, 72]. This may have led to heterogeneity. The fourth limitation was the intensity, frequency, and duration of yoga interventions were heterogeneous; short term applications of less than 1 month yoga intervention were found in some studies [58, 64, 70]. Only four reviews reported long-term follow up effects, ranging from 3 months to 12 months [63-65, 68]. Lastly, lack of safety issue evaluation including serious adverse events or nonserious events in each study.

### **Implications for further research**

This systematic review and meta-analysis was limited by the low methodological quality of included studies. Further RCTs should ensure rigorous methodology and reporting, which would mean adequate sample size, adequate randomization, allocation concealment, intention-to-treat analysis, and blinding of at least outcome assessors [87]. Researchers for study interventions may need to apply a standard protocol. Adequate reporting of safety issues with yoga intervention should be discussed in future randomized controlled trials. Evidence was limited because few studies report safety-related adverse effects. Most of the included studies failed to report this aspect.

## **Conclusions**

This systematic review and meta-analysis demonstrated that yoga intervention in women has beneficial effects in term of managing sleep problems. In breast cancer and menopausal subgroups, it may improve sleep quality; but there is not evidence of it. Despite certain flaws in methodology in our included studies, yoga may be recommended as a complementary therapy to women with sleep problems. However, advanced strength of evidence should be a priority.

## **Abbreviations**

AEs: Adverse events; BMI: Body mass index; CI: Confidence interval; DSM4: Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition criteria; DUB: Dysfunctional uterine dysfunction; ECOG-PS: Eastern Cooperative Oncology Group Performance Status; FSH: Follicle-stimulating hormone; G1 = Group 1, G2 = Group 2, G3 = Group 3; ISI: Insomnia Severity Index; IV: Inverse variance; LH: Luteinizing hormones; MD: Mean differences; OA: osteoarthritis; OL: onset

latency; PRISMA: Preferred reporting items for systematic reviews and meta- analyses; PSQI: Pittsburgh Sleep Quality Index; RCT: Randomized controlled trial; SD: Standard deviation; SE: Sleep efficiency; SE: Standard error; SMD: Standardized mean differences; SWS: slow- wave sleep; TST: total sleep time; WASO: wake after sleep onset; XRT: radiotherapy treatment

## Declarations

### Acknowledgements

Not applicable.

### Funding

Authors would like to thank Taoyuan Armed Forces General Hospital for supporting this project with AFTYGH-10831

### Availability of data and materials

All data analyzed during this study are included in this published article and the original studies' publications.

### Authors' contributions

WLW, KHC, YCP, SNY and YYC designed the study. WLW conducted the literature searches. Selection of studies and data extraction: KHC and YCP. Disagreements were resolved by discussion or arbitration by YCP and SNY. Statistical analysis: WLW, KHC, YCP, SNY and YYC. FC drafted the manuscript. WLW, KHC, YCP, SNY and YYC critically revised the manuscript and approved the final version.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

### Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

## References

1. Kessler RC, Berglund PA, Coulouvrat C, Hajak G, Roth T, Shahly V, et al. Insomnia and the performance of US workers: results from the America insomnia survey. *Sleep*. 2011;34:1161-71.
2. Zhang B, Wing YK. Sex differences in insomnia: a meta-analysis. *Sleep*. 2006;29:85-93.
3. Kische H, Ewert R, Fietze I, Gross S, Wallaschofski H, Völzke H, et al. Sex hormones and sleep in men and women from the general population: a cross-sectional observational study. *J Clin Endocrinol Metab*. 2016;101:3968-77.
4. Calhoun SL, Fernandez-Mendoza J, Vgontzas AN, Liao D, Bixler EO. Prevalence of insomnia symptoms in a general population sample of young children and preadolescents: gender effects. *Sleep Med*. 2014;15:91-5.
5. Kizilirmak A, Timur S, Kartal B. Insomnia in pregnancy and factors related to insomnia. *Sci World J*. 2012;2012:197093.
6. Kravitz HM, Ganz PA, Bromberger J, Powell LH, Sutton-Tyrrell K, Meyer PM. Sleep difficulty in women at midlife: a community survey of sleep and the menopausal transition. *Menopause*. 2003;10:19-28.
7. van Straten, A., van der Zweerde T, Kleiboer A, Cuijpers P, Morin CM, Lancee J. Cognitive and behavioral therapies in the treatment of insomnia: a meta-analysis. *Sleep Med Rev*. 2018;38:3-16.
8. Riemann D, Baglioni C, Bassetti C, Bjorvatn B, Dolenc Groseelj L, et al. European guideline for the diagnosis and treatment of insomnia. *J Sleep Res*. 2017;26(6):675-700.
9. Winkler A, Auer C, Doering BK, Rief W. Drug treatment of primary insomnia: a meta-analysis of polysomnographic randomized controlled trials. *CNS Drugs*. 2014;28:799-816.
10. Schroeck JL, Ford J, Conway EL, Kurtzhals KE, Gee ME, Vollmer KA, et al. Review of safety and efficacy of sleep medicines in older adults. *Clin Ther*. 2016;38(11):2340-72.
11. Feuerstein G. *The yoga tradition: its history, literature, philosophy and practice*. Hohm Press; 2012.
12. Pujari H. Health benefits of yoga for women. *Int J Phys Educ Sports Health*. 2015;1:152-4.

13. Bower JE, Garet D, Sternlieb B, Ganz PA, Irwin MR, Olmstead R, et al. Yoga for persistent fatigue in breast cancer survivors: a randomized controlled trial. *Cancer*. 2012;118:3766-75.
14. Zeichner SB, Zeichner RL, Gogineni K, Shatil S, Ioachimescu O. Cognitive behavioral therapy for insomnia, mindfulness, and yoga in patients with breast cancer with sleep disturbance: a literature review. *Breast Cancer (Auckl)*. 2017;11:1178223417745564.
15. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193-213.
16. Hyypa MT, Kronholm E. Quality of sleep and chronic illnesses. *J Clin Epidemiol*. 1989;42(7):633-8.
17. Gellman MD, Turner JR. Sleep quality. *Encyclopedia Behav. Med.*, 2013.
18. Ohayon M, Wickwire EM, Hirshkowitz M, Albert SM, Avidan A, Daly FJ, et al. National Sleep Foundation's sleep quality recommendations: first report. *Sleep Health*. 2017;3(1):6-19.
19. Edinger JD, Bonnet MH, Bootzin RR, Doghramji K, Dorsey CM, Espie CA, et al. Derivation of research diagnostic criteria for insomnia: report of an American Academy of Sleep Medicine Work Group. *Sleep*. 2004;27(8):1567-96.
20. Gong H, Ni C, Shen X, Wu T, Jiang C. Yoga for prenatal depression: a systematic review and meta-analysis. *BMC Psychiatry*. 2015;15:14.
21. McGovern CE, Cheung C. Yoga and quality of life in women with primary dysmenorrhea: a systematic review. *J Midwifery Womens Health*. 2018;63:470-82.
22. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Reprint—preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Phys Ther*. 2009;89:873-80.
23. Higgins JPT, Green S; Cochrane Collaboration. *Cochrane handbook for systematic reviews of interventions*. Cochrane Book Series. 2008, Chichester, England ; Hoboken, NJ: Wiley-Blackwell. xxi, 649 p.
24. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28:193-213.
25. Bastien, C.H., A. Vallieres, and C.M. Morin, Validation of the Insomnia Severity Index as an outcome measure for insomnia research. *Sleep Med*. 2001;2:297-307.
26. Ibanez V, Silva J, Cauli O. A survey on sleep assessment methods. *Peer J*. 2018;6:e4849.
27. Buysse DJ, Ancoli-Israel S, Edinger JD, Lichstein KL, Morin CM. Recommendations for a standard research assessment of insomnia. *Sleep*. 2006;29(9):1155-73.
28. Administration UFA. What is a serious adverse event? 2019. <http://www.fda.gov/safety/reporting-serious-problems-fda/what-serious-adverse-event>.
29. Cohen J. *Statistical power analysis for the behavioral science*. 2nd ed. Hillsdale, NJ: L. Erlbaum Associates; 1988.
30. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. 1997;315:629-34.
31. Yen CY. Effect of body balance sport training on depressive tendencies and sleep quality of female college students. *J Natl Taiwan Sports Univ*. 2008;19:37-50.
32. Sun YC, Hung YC, Chang Y, Kuo SC. Effects of a prenatal yoga programme on the discomforts of pregnancy and maternal childbirth self-efficacy in Taiwan. *Midwifery*. 2010;26:e31-6.
33. Lengacher CA, Reich RR, Ramesar S, Alinat CB, Moscoso M, Cousin L, et al. Feasibility of the mobile mindfulness-based stress reduction for breast cancer (mMBSR(BC)) program for symptom improvement among breast cancer survivors. *Psychooncology*. 2018;27:524-31.
34. Carson JW, Carson KM, Porter LS, Keefe FJ, Seewaldt VL. Yoga of Awareness program for menopausal symptoms in breast cancer survivors: results from a randomized trial. *Support Care Cancer*. 2009;17:1301-9.
35. Chattha R, Nagarathna R, Padmalatha V, Nagendra HR. Effect of yoga on cognitive functions in climacteric syndrome: a randomised control study. *BJOG*. 2008;115:991-1000.
36. Vadiraja SH, Rao MR, Nagendra RH, Nagarathna R, Rekha M, Vanitha N, et al., Effects of yoga on symptom management in breast cancer patients: a randomized controlled trial. *Int J Yoga*. 2009;2:73-9.
37. Witek Janusek, L., D. Tell, and H.L. Mathews, Mindfulness based stress reduction provides psychological benefit and restores immune function of women newly diagnosed with breast cancer: a randomized trial with active control. *Brain Behav Immun*. 2019;80:358-73.
38. Lotzke D, Wiedemann F, Rodrigues Recchia D, Ostermann T, Sattler D, Ettl J, et al. Iyengar-yoga compared to exercise as a therapeutic intervention during (neo)adjuvant therapy in women with stage I-III breast cancer: health-related quality of life, mindfulness, spirituality, life satisfaction, and cancer-related fatigue. *Evid Based Complement Alternat Med*. 2016;2016:5931816.
39. Ghaffarilaleh G, Ghaffarilaleh V, Sanamno Z, Kamalifard M. Yoga positively affected depression and blood pressure in women with premenstrual syndrome in a randomized controlled clinical trial. *Complement Ther Clin Pract*. 2019;34:87-92.
40. Mustian KM, Sprod LK, Janelsins M, Peppone LJ, Palesh OG, Chandwani K, et al. Multicenter, randomized controlled trial of yoga for sleep quality among cancer survivors. *J Clin Oncol*. 2013;31:3233-41.
41. Kohn M, Persson Lundholm U, Bryngelsson IL, Anderzén-Carlsson A, Westerdahl E. Medical yoga for patients with stress-related symptoms and diagnoses in primary health care: a randomized controlled trial. *Evid Based Complement Alternat Med*. 2013;2013:215348.
42. Sakuma Y, Sasaki-Otomaru A, Ishida S, Kanoya Y, Arakawa C, Mochizuki Y, et al. Effect of a home-based simple yoga program in child-care workers: a randomized controlled trial. *J Altern Complement Med*. 2012;18:769-76.

43. Chen KM, Chen MH, Chao HC, Hung HM, Lin HS, Li CH. Sleep quality, depression state, and health status of older adults after silver yoga exercises: cluster randomized trial. *Int J Nurs Stud.* 2009;46:154-63.
44. Jain M, Tripathy PR, Manik R, Tripathy S, Behera B, Barman A. Short term effect of yoga asana - an adjunct therapy to conventional treatment in frozen shoulder. *J Ayurveda Integr Med.* 2019. pii: S0975-9476(18)30654-5.
45. Carson JW, Carson KM, Jones KD, Bennett RM, Wright CL, Mist SD. A pilot randomized controlled trial of the Yoga of Awareness program in the management of fibromyalgia. *Pain.* 2010;151:530-9.
46. Zhang, J.X., Liu XH, Xie XH, Zhao D, Shan MS, Zhang XL, et al. Mindfulness-based stress reduction for chronic insomnia in adults older than 75 years: a randomized, controlled, single-blind clinical trial. *Explore.* 2015;11:180-5.
47. Yurtkuran M, Alp A, Yurtkuran M, Dilek K. A modified yoga-based exercise program in hemodialysis patients: a randomized controlled study. *Complement Ther Med.* 2007;15:164-71.
48. Ward L, Stebbings S, Athens J, Cherkin D, David Baxter G. Yoga for the management of pain and sleep in rheumatoid arthritis: a pilot randomized controlled trial. *Musculoskeletal Care.* 2018;16:39-47.
49. Field T, Diego M, Delgado J, Medina L. Tai chi/yoga reduces prenatal depression, anxiety and sleep disturbances. *Complement Ther Clin Pract.* 2013;19:6-10.
50. Andersen SR, Würtzen H, Steding-Jessen M, Christensen J, Andersen KK, Flyger H, et al. Effect of mindfulness-based stress reduction on sleep quality: results of a randomized trial among Danish breast cancer patients. *Acta Oncol.* 2013;52:336-44.
51. Vardar Yaglı N, Şener G, Arkan H, Sağlam M, İnal İnce D, Savcı S, et al. Do yoga and aerobic exercise training have impact on functional capacity, fatigue, peripheral muscle strength, and quality of life in breast cancer survivors? *Integr Cancer Ther.* 2015;14:125-32.
52. Guthrie KA, Larson JC, Ensrud KE, Anderson GL, Carpenter JS, Freeman EW, et al. Effects of pharmacologic and nonpharmacologic interventions on insomnia symptoms and self-reported sleep quality in women with hot flashes: a pooled analysis of individual participant data from four MsFLASH trials. *Sleep.* 2018;41(1).
53. Reed SD, Guthrie KA, Newton KM, Anderson GL, Booth-LaForce C, Caan B, et al. Menopausal quality of life: RCT of yoga, exercise, and omega-3 supplements. *Am J Obstet Gynecol.* 2014;210:244.e1-11.
54. Ashrafinia, F., Mirmohammadali M, Rajabi H, Kazemnejad A, Sadeghniaithaghighi K, Amelvalizadeh M, et al., The effects of Pilates exercise on sleep quality in postpartum women. *J Bodyw Mov Ther.* 2014;18:190-9.
55. Aibar-Almazána A, Hita-Contreras F, Cruz-Díaz D, de la Torre-Cruz M, Jiménez-García JD, Martínez-Amat A. Effects of Pilates training on sleep quality, anxiety, depression and fatigue in postmenopausal women: a randomized controlled trial. *Maturitas.* 2019;124:62-7.
56. Buchanan DT, Landis CA, Hohensee C, Guthrie KA, Otte JL, Paudel M, et al. Effects of yoga and aerobic exercise on actigraphic sleep parameters in menopausal women with hot flashes. *J Clin Sleep Med.* 2017;13:11-18.
57. Fang R, Li X. A regular yoga intervention for staff nurse sleep quality and work stress: a randomised controlled trial. *J Clin Nurs.* 2015;24:3374-9.
58. Rao M, Metri KG, Raghuram N, Hongasandra NR. Effects of mind sound resonance technique (yogic relaxation) on psychological states, sleep quality, and cognitive functions in female teachers: a Randomized, Controlled Trial. *Adv Mind Body Med.* 2017;31:4-9.
59. Newton KM, Reed SD, Guthrie KA, Sherman KJ, Booth-LaForce C, Caan B, et al. Efficacy of yoga for vasomotor symptoms: a randomized controlled trial. *Menopause.* 2014;21:339-46.
60. Elavsky S, McAuley E. Lack of perceived sleep improvement after 4-month structured exercise programs. *Menopause.* 2007;14:535-40.
61. Afonso RF, Hachul H, Kozasa EH, Oliveira Dde S, Goto V, Rodrigues D, et al. Yoga decreases insomnia in postmenopausal women: a randomized clinical trial. *Menopause.* 2012;19:186-93.
62. Porter LS, Carson JW, Olsen M, Carson KM, Sanders L, Jones L, et al. Feasibility of a mindful yoga program for women with metastatic breast cancer: results of a randomized pilot study. *Support Care Cancer.* 2019.
63. Chandwani KD, Thornton B, Perkins GH, Arun B, Raghuram NV, Nagendra HR, et al. Yoga improves quality of life and benefit finding in women undergoing radiotherapy for breast cancer. *J Soc Integr Oncol.* 2010;8:43-55.
64. Chaoul A, Milbury K, Spelman A, Basen-Engquist K, Hall MH, Wei Q, et al. Randomized trial of Tibetan yoga in patients with breast cancer undergoing chemotherapy. *Cancer.* 2018;124:36-45.
65. Ratcliff CG, Milbury K, Chandwani KD, Chaoul A, Perkins G, Nagarathna R, et al. Examining mediators and moderators of yoga for women with breast cancer undergoing radiotherapy. *Integr Cancer Ther.* 2016;15:250-62.
66. Danhauer SC, Mihalko SL, Russell GB, Campbell CR, Felder L, Daley K, et al. Restorative yoga for women with breast cancer: findings from a randomized pilot study. *Psychooncology.* 2009;18:360-8.
67. Taylor TR, Barrow J, Makambi K, Sheppard V, Wallington SF, Martin C, et al. A restorative yoga intervention for African-American Breast Cancer Survivors: a pilot study. *J Racial Ethn Health Disparities.* 2018;5:62-72.
68. Kiecolt-Glaser JK, Barrow J, Makambi K, Sheppard V, Wallington SF, Martin C, et al. Yoga's impact on inflammation, mood, and fatigue in breast cancer survivors: a randomized controlled trial. *J Clin Oncol.* 2014;32:1040-9.
69. Ebrahimi M, Guilan-Nejad TN, Pordanjani AF. Effect of yoga and aerobics exercise on sleep quality in women with Type 2 diabetes: a randomized controlled trial. *Sleep Sci.* 2017;10:68-72.
70. Ide MR, Laurindo LMM, Rodrigues-Junior AL, Tanaka C. Effect of aquatic-respiratory exercise-based program in patients with fibromyalgia. *Int J Rheumatic Diseases.* 2008;11:131-40.

71. Cheung C, Wyman JF, Resnick B, Savik K. Yoga for managing knee osteoarthritis in older women: a pilot randomized controlled trial. *BMC Complement Altern Med.* 2014;14:160.
72. Innes KE, Selfe TK. The effects of a gentle yoga program on sleep, mood, and blood pressure in older women with restless legs syndrome (RLS): a preliminary randomized controlled trial. *Evid Based Complement Alternat Med.* 2012;2012:294058.
73. Nalgirkar SP, Vinchurkar SA, Saoji AA, Mohanty S. Yoga as a therapeutic intervention in the management of dysfunctional uterine bleeding: a Controlled Pilot Study. *J Midlife Health.* 2018;9(1):8-13.
74. Wang X, Li P, Pan C, Dai L, Wu Y, Deng Y. The effect of mind-body therapies on insomnia: a systematic review and meta-analysis. *Evid Based Complement Alternat Med.* 2019;2019:9359807.
75. Fang R, Li X. A regular yoga intervention for staff nurse sleep quality and work stress: a randomised controlled trial. *J Clin Nurs.* 2015;24(23-24):3374-9.
76. Newton KM, Reed SD, Guthrie KA, Sherman KJ, Booth-LaForce C, Caan B, et al. Efficacy of yoga for vasomotor symptoms: a randomized controlled trial. *Menopause* 2014;21(4):339-46.
77. Afonso RF, Hachul H, Kozasa EH, Oliveira Dde S, Goto V, Rodrigues D, et al. Yoga decreases insomnia in postmenopausal women: a randomized clinical trial. *Menopause* 2012;19(2):186-93.
78. Chaoul A, Milbury K, Spelman A, Basen-Engquist K, Hall MH, Wei Q, et al. Randomized trial of Tibetan yoga in patients with breast cancer undergoing chemotherapy. *Cancer* 2018;124(1):36-45.
79. Cheung C, Wyman JF, Resnick B, Savik K. Yoga for managing knee osteoarthritis in older women: a pilot randomized controlled trial. *BMC Complement Altern Med.* 2014;14:160.
80. Innes KE, Selfe TK. The effects of a gentle yoga program on sleep, mood, and blood pressure in older women with restless legs syndrome (RLS): a preliminary randomized controlled trial. *Evid Based Complement Alternat Med.* 2012;2012:294058.
81. Rubio-Arias JA, Marín-Cascales E, Ramos-Campo DJ, Hernandez AV, Pérez-López FR. Effect of exercise on sleep quality and insomnia in middle-aged women: a systematic review and meta-analysis of randomized controlled trials. *Maturitas.* 2017;100:49-56.
82. Cramer H, Peng W, Lauche R. *Yoga for menopausal symptoms-A systematic review and meta-analysis.* *Maturitas.* 2018;109:13-25.
83. Tang MF, Chiu HY, Xu X, Kwok JY, Cheung DST, Chen CY, et al. Walking is more effective than yoga at reducing sleep disturbance in cancer patients: a systematic review and meta-analysis of randomized controlled trials. *Sleep Med Rev.* 2019;47:1-8.
84. Du S, Dong J, Zhang H, Jin S, Xu G, Liu Z, et al. Taichi exercise for self-rated sleep quality in older people: a systematic review and meta-analysis. *Int J Nurs Stud.* 2015;52(1):368-79.
85. Wang X, Li P, Pan C, Dai L, Wu Y, Deng Y. The effect of mind-body therapies on insomnia: a systematic review and meta-analysis. *Evid Based Complement Alternat Med.* 2019;2019:9359807.
86. Schulz KF, Chalmers I, Hayes RJ, Altman DG. Empirical evidence of bias. Dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA.* 1995;273:408-12.
87. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. *J Pharmacol Pharmacother.* 2010;1:100-7.

## Tables

**Table 1** Characteristics of included studies

Authors, year, country	Main characteristics of the studied population	Sample characteristics (sample size, age)	BMI, kg/m <sup>2</sup> (SD)	Intervention group comparison	Sleep outcome measures	Outcomes
Danhauer SC et al. 2009 America	Women ( ≥18 y ) with breast cancer (any stage), 2-24 months post-primary treatment (surgery) following initial diagnosis and/or had a recurrence of breast cancer within the past 24 months, physically able to attend yoga class	44, G1 = 22, G2 = 22 Mean age: G1 = 54.3 y/o (SD = 9.6), G2 = 57.2 y/o (SD = 10.2)	-	G1 = Restorative Yoga G2 = Control group (wait list control)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved:  No statistically significant finding  G1 vs. G2 (P = 0.97)
Chandwani KD et al. 2010 America	Women ( ≥18 y ) with breast cancer (stage 0-stage III) who were scheduled to undergo radiotherapy at The University of Texas M.D Anderson Cancer Center who were able to read, write and speak English	61, G1 = 30, G2 = 31 Mean age: G1 = 51.39 y/o (SD = 7.97), G2 = 54.02y/o (SD = 9.96)	-	G1 = Yoga G2 = Control group (wait list control)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved:  No statistically significant finding  G1 vs. G2 (P > 0.05)
Bower JE et al. 2012 America	Post-menopausal women (aged 40-60 y ) diagnosed with Stage 0 - II breast cancer; completed local and/or adjuvant cancer therapy (with the exception of hormonal therapy) at least 6 months; previously no other cancer in last 5 years and experiencing persistent cancer-related fatigue	31, G1 = 16, G2 = 15 Mean age: G1 = 54.4 y/o (SD = 5.7), G2 = 53.3 y/o (SD = 4.9)	G1 = 24.0 (2.5) G2 = 25.3 (3.4)	G1 = Iyengar Yoga G2 = Control group (Health education)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved:  No statistically significant finding  G1 vs. G2 (P > 0.05)
Kiecolt-Glaser JK et al. 2014 America	Women ( Stage 0-IIIa breast cancer survivors in age from 27-76 y ) had completed cancer treatment within the past 3 years (except for tamoxifen / aromatase inhibitors) and were at least 2 months post surgery or adjuvant therapy or radiation	200, G1 = 100, G2 = 100 Mean age: G1 = 51.8 y/o (SD = 9.8) , G2 = 51.3y/o (SD = 8.7)	G1 = 27.9 (5.3) G2 = 27.6 (6.0)	G1 = Hatha Yoga G2 = Control group ( wait list control)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved:  G1 vs. G2 (P = 0.03)
Ratcliff CG et al. 2016 America	Women (aged ≥18 y) with breast cancer ( diagnosed with stage 0 to III ), ability to read, write, and speak English; and	163, G1 = 53, G2 = 56, G3 = 54	-	G1 = Yoga G2 = Stretching	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved:

scheduled to undergo daily adjuvant XRT (radiotherapy treatment) for 6 weeks at MD Anderson Cancer Center	Mean age: G1 = 52.38 y/o (SD = 1.35), G2 = 51.14t/o (SD = 1.32), G3 = 52.11y/o (SD = 1.34)	G3 = Control group ( wait list control)	No statistically significant finding  G1 vs. G3 (P > 0.05)
---	---	--	--

Taylor T R et al. 2017  America	Women ( aged 18-65 y ), no pregnant, breast cancer survivor of at least 12 months post-surgery and treatment ( excluding hormone therapy), free of medical contraindications reported by their physician	33, G1 = 18, G2 = 15  Mean age: G1 = 54.9 y/o (SD = 8.8), G2 = 52.6 y/o (SD = 8.2)	G1 = 33.8 (9.23)  G2 = 33.9 (5.33)	G1 = Restorative yoga  G2 = Control group ( wait list control)	Insomnia Severity Index (ISI)	The total score of ISI improved :  No statistically significant finding  G1 vs. G2 (P = 0.89)
Chaoul A et al. 2018  America	Women ( aged ≥18 y ) with breast cancer stage (American Joint Committee on Cancer (AJCC) TNM) I to III who were undergoing chemotherapy, were able to read, write and speak English; and were scheduled to undergo neoadjuvant or adjuvant therapy (weekly or every 21 days) at The University of Texas MD Anderson Cancer Center	227, G1 = 74, G2 = 68, G3 = 85  Mean age: G1 = 49.5 y/o (SD = 9.80) , G2 = 50.4y/o (SD = 10.3), G3 = 49.0 y/o (SD = 10.1)	-  -	G1 = Tibetan Yoga  G2 = Stretching group  G3 = Control group (Usual care)	Pittsburgh Sleep Quality Index (PSQI)  Actigraphy	The total score of PSQI improved:  No statistically significant finding  G1 vs. G3 (P = 0.32)  Actigraphy:  Statistically significant finding in sleep efficiency (SE) G1 vs. G3 (P = 0.02), wake after sleep onset (WASO) G1 vs. G3 (P = 0.0003), but no statistically signify finding on sleep onset latency (OL) G1 vs. G3 (P = 0.89), total sleep time (TST) G1 vs. G3 (P = 0.19)

Porter LS et al. 2019 America	Women (aged $\geq 18$ y) receiving treatment for metastatic breast cancer had a life expectancy $\geq 9$ months as estimated by their treating oncologist; could speak and read English	63, G1 = 43, G2 = 20 Mean age: G1 = 56.3 y/o (11.6) G2 = 59.4 y/o (11.3)	-	G1 = Yoga G2 = Control group (social support group)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: No statistically significant finding G1 vs. G2 (P > 0.05)
Elavsky s et al. 2007 America	Sedentary or low-active middle-aged women (aged 42-58 y) during the menopausal transition who had no history of surgical menopause and had not used hormone therapy or at least 6 months. Baseline analyses revealed that overall sleep quality was poor in the sample (Mean PSGI = 6.21, SD = 3.46) with 88% of sample scoring	163, G1 = 61, G2 = 63, G3 = 39 Age range:42-58 y/o Mean age:49.9 y/o (SD:3.6)	-	G1 = Yoga G2 = walking G3 = Control group	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: No statistically significant finding G1 vs. G3 (P > 0.05)
Afonso RF et al. 2012 Brazil	Postmenopausal women (aged 50-65 y) with insomnia diagnosed by specialist based on DSM4 (Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition criteria), amenorrhea for 1 year or longer, had follicle-stimulating hormone (FSH) $\geq 30$ mIU/ml, and had a BMI (Body mass index) $<30$ kg/m <sup>2</sup>	61, G1 = 16, G2 = 21, G3 = 24 Age range:50-65 y/o	$<30$	G1 = Yoga G2 = Passive stretching G3 = Control group	Insomnia Severity Index (ISI) Polysomnography	The total score of ISI improved : G1 vs. G3 (P < 0.05) Polysomnography: No statistically significant finding G1 vs. G3 (P > 0.05)
Newton KM et al. 2014 America	Previous sedentary women (aged 40-62 y) in menopausal transition or postmenopausal or had hysterectomy with FSH $\geq 20$ mIU/mL and estradiol $\leq 50$ pg/mL, with $\geq 14$ vasomotor symptoms /week in each of three consecutive weeks and had not used hormone therapy for past one month.	249, G1 = 107, G2 = 142 Age range:40-62 y/o	G1 = 27.1 (4.6) G2 = 26.9 (4.6)	G1 = Yoga G2 = Control group (usual activity)	Pittsburgh Sleep Quality Index (PSQI) Insomnia Severity Index (ISI)	The total score of PSQI improved: G1 vs. G2 (P = 0.049) The total score of ISI improved : G1 vs. G2 (P = 0.007)
Buchanan, D.T. et al. 2017	Women (aged 40-62 y) in menopausal transition or postmenopausal or had hysterectomy with FSH $\geq 20$ mIU/mL	186, G1 = 52, G2 = 54, G3 = 80	G1 = 27.6	G1 = Yoga	Actigraphy	Statistically no significant finding in sleep efficiency

America and estradiol  $\leq$  50 pg/mL, generally in good health; experiencing 14 or more hot flashes/night sweats per week ( on 2-w screening diaries); and hot flashes rated as bothersome or severe on four or more occasions/week

Mean age: (4.3) G2 = Exercise (SE) G1 vs.G3 (P > 0.05), wake after sleep onset (WASO) G1 vs. G3 (P > 0.05), sleep onset latency G1 vs. G3 (P > 0.05), total sleep time(TST) G1 vs. G3 (P > 0.05)

G1 = 55.3 y/o (SD = 3.9) , G2 = 26.9 (4.3) G3 = 26.7 (4.8)

G2 = 55.6 y/o (SD = 3.5), G3 = 54.2 y/o (SD = 3.7)

IDE MR et al. 2008 Brazil Women with fibromyalgia syndrome (1990 American College of Rheumatology criteria) with time availability

40, G1 = 20, G2 = 20

Mean age:G1 = 46.61 y/o (SD = 9.80) , G2 = 45.47y/o (SD = 8.65)

- G1 = Yoga breathing exercises in warm water G2 = Control group

Pittsburgh Sleep Quality Index (PSQI)

The total score of PSQI improved: G1 vs. G2 (P = 0.004)

Innes KE et al. 2012 America Nonsmoking women (aged 45-79 y), post-menopausal ( $\geq$ 12months amenorrheic) physical inactive (exercising less than 20 minutes, 3 times per week) and overweight (BMI $\geq$ 25 kg/m<sup>2</sup> and/or waist circumference  $\geq$  88cm) with restless legs syndrome

20, G1 = 10, G2 = 10

Mean age: G1 = 58.4 y/o (SD = 6.32) , G2 = 58.9y/o (SD = 9.10)

G1 = 33.59 (4.17) G2 = 32.27 (3.82)

G1 = Iyengar Yoga G2 = Control group (Education film group)

Pittsburgh Sleep Quality Index (PSQI)

The total score of PSQI improved: G1 vs. G2 (P = 0.01)

Cheung C et al. 2014 America Community-dwelling women ( aged 65-90 y) had symptomatic osteoarthritis (OA) of knee diagnosis for at least 6 months without previous training in any form of yoga

36, G1 = 18, G2 = 18

Mean age: G1 = 71.9 y/o, G2 = 71.9 y/o

G1 = 29.1 G2 = 28.8

G1 = Yoga G2 = Control group (Wait list control)

Pittsburgh Sleep Quality Index (PSQI)

The total score of PSQI improved: No statistically significant finding G1 vs. G2 (P = 0.15)

Fang R et al. 2015 China Female nurses (aged of 25-51 y) with normal communication abilities and willingness to participate study

120, G1 = 61, G2 = 59

Mean age: G1 = 35.13 y/o (SD = 10.98) , G2 = 36.05y/o (SD = 9.91)

- G1 = Yoga G2 = Control group

Pittsburgh Sleep Quality Index (PSQI)

The total score of PSQI improved: G1 vs. G2 (P < 0.001)

Ebrahimi M et al. 2017 Iran	Women (aged 38-53 y) with Type 2 Diabetes mellitus lack of any diabetic complications, no participation in any kind of regular aerobic exercise and resistance training over the last 6 months, BMI<40 kg/m <sup>2</sup> , not being under insulin treatment	45, G1 = 15, G2 = 15, G3 = 15 Mean age: G1 = 48.18 y/o, G2 = 44.69y/o, G3 = 47.93y/o	G1 = 31.28 (5.43) G2 = 29.35 (4.57) G3 = 29.35 (5.31)	G1 = Yoga based, G2 = Aerobic exercise G3 = Control group	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: G1 vs. G3 (P < 0.05)
Rao M et al. 2017 India	Female teachers, aged between 30 and 55 years were willing to participate in the study and had no previous exposure to any form of yoga practice.	60, G1 = 30, G2 = 30 Mean age: G1 = 43.0 y/o (SD = 9.77) G2 = 40.0y/o (SD = 7.32)	-	G1 = Yoga-based, mindfulness relaxation G2 = Control group (wait list control)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: G1 vs. G2 (P < 0.01)
Nalgirkar SP et al. 2018 India	Women (aged 20-50 y) and diagnosed for primary dysfunctional uterine bleeding ( DUB ) with no underlying systemic pathology	30, G1 = 15, G2 = 15 Mean age: G1 = 29.85 y/o (4.45) G2 = 30.85y/o (4.42)	-	G1 = Yoga based, G2 = Control group ( wait list control)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: No statistically significant finding G1 vs. G2 (P > 0.05)

BMI: Body mass index; DSM4: Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition criteria; DUB: Dysfunctional uterine dysfunction; ECOG-PS: Eastern Cooperative Oncology Group Performance Status; FSH: follicle-stimulating hormone; G1 = Group 1, G2 = Group 2, G3 = Group 3; ISI: Insomnia Severity Index ; OA: osteoarthritis; OL: onset latency; PSQI: Pittsburgh Sleep Quality Index; SE: sleep efficiency; TST: total sleep time; WASO: wake after sleep onset; XRT: radiotherapy treatment.

**Table 2** Characteristics of yoga programs and outcome assessment of studies included in the systematic review

Authors, year country	Specific type of yoga	Yoga frequency (sessions/week)	Session length (mins/week)	Study duration (weeks/study)	Number of sessions/study Total lengths (h)/study	Safety (adverse events)	Basal score of PSQI (SD) and follow-up	Basal score of ISI (SD) and follow-up
Elavsky s et al.2007 America	Iyengar Yoga (Hatha Yoga)	2	90	16	32 (24 h)	Not reported	G1 = 6.9 (3.94) G1 = 6.48 (4.22) G3 = 5.46 (2.96) G3 = 5.44 (3.63)	-
Afonso RF et al. 2012 Brazil	Yoga (Asanas Yoga, Bhastrika , and etc )	2	120	16	32 (32 h)	Not reported	-	G1 = 14.1 (5.87) G1 = 9.7 (4.64) G3 = 15.2 (4.8) G3 = 13.7 (4.64)
Newton KM et al. 2014 America	Yoga program	2	90	12	24 (18 h)	Muscle aches and strains (6.7% yoga and 10.3% usual activity), low back pain (4.2% yoga and 3.1 usual activity), no participants stopped the intervention due to	G1 = 7.7 (3.34) G1 = 5.6 (3.30) G2 = 8.4 (3.30) G2 = 5.8 (2.91)	G1 = 11.8 (5.25) G1 = 7.4 (5.07) G2 = 12.2 (5.13) G2 = 6.8 (4.35)

						adverse events		
Buchanan, D.T. et al. 2017 America	Viniyoga	1	90	12	12 (18 h)	-	-	-
Danhauer SC et al. 2009 America	Restorative Yoga (Asanas, Pranayama, Savasana Yoga)	1	75	10	10 (12.5 h)	Not reported	G1 = 8.3 (4.7) G1 = 6.1 (4.3) G2 = 8.6 (5.3) G2 = 7.0 (4.2)	-
Chandwani KD et al. 2010 America	Yoga	2	120	6	12 (12 h)	Not reported	G1 = 7.3 (3.83) G1 = 7.3 (4.67) G2 = 7.1 (3.89) G2 = 7.1 (5.38)	-
Bower JE et al. 2012 America	Iyengar Yoga	2	90	12	24 (36 h)	Not reported	G1 = 9.2 (3.3) G1 = 8.1 (2.5) G2 = 9.1 (3.5) G2 = 7.7 (2.6)	-
Kiecolt-Glaser KJ et al. 2014	Hatha Yoga	2	180	12	24 (36 h)	2 events in yoga intervention	G1 = - G1	-

America						group reported the recurrence of chronic and /or shoulder problems	=7.0 (2.15) G2= - G2 = 6.3 (2.18)	
Cheung C et al.2014 America	Hatha Yoga	1	60	8	8 (8 h)	Not reported	G1 = 6.5 (4.2) G1 = 5.0 (2.2) G2 = 5.4 (2.8) G2 = 6.1 (2.2)	-
Ratcliff CG et al. 2016 America	Yoga program (Asanas,Pranayama, and etc.)	3	180	6	18 (18 h)	Not reported	G1 = 8.3 (3.9) G1 = 6.7 (3.1) G3 = 8.2 (3.7) G2 = 7.3 (3.7)	-
Taylor TR et al.2017 America	Restorative Yoga	1	75	8	8 (10 h)	Not reported	-	G1=10.18 (8.74) G1=7.89(7.17) G2=7.56 (6.82) G2=6.20(7.11)
Chaoul A et al. 2018 America	Tibetan Yoga	4	300-360	1	4 (5-6 h)	Not reported	G1 = 7.8 (3.7) G1 = 7.3 (3.6)	-

							G3 = 8.1 (4.2) G3 = 8.1 (4.4)	
Porter LS et al.2019 America	Mindful Yoga	1	120	8	8 (16 h)	Not reported	G1 = 8.6 (3.34) G1 = 8.6 (3.01) G2 = 7.6 (2.73) G2 = 7.6 (3.42)	-
IDE MR et al.2008 Brazil	Yoga breathing exercises in warm water	4	240	4	16 (16 h)	Not reported	G1 = 13.17 (4.00) G1 = 9.95 (1.15) G2 = 11.82 (5.05) G2 = 13.88 (1.28)	-
Innes K E et al.2012 America	Iyengar yoga	2	180	8	16 (24 h)	Not reported	G1 = 8.71 (3.63) G1 = 3.57 (1.49) G2 = 9.25 (3.32) G2 = 8.00 (2.94)	-
Fang R et al. 2015 China	Yoga	>2	>100-120	24	>48 (40-48 h)	Not reported	G1 = 9.98 (1.89)	-

							G1 = 7.61 (1.25) G2 = 10.24 (2.35) G2 = 10.31 (2.42)	
Ebrahimi M et al.2017 Iran	Yoga program	3	270	12	36 (54 h)	Not reported	G1 = 14.40 (5.92) G1 = 3.73 (3.49) G3 = 13.91 (5.52) G3 = 13.27 (5.58)	-
Manas Rao, MSc et al. 2017 India	Yoga-based, mindfulness relaxation	5	150	4	20 (10 h)	Not reported	G1 = 5.63 (3.31) G1 = 3.10 (1.26) G2 = 4.86 (2.52) G3 = 5.9 (1.93)	-
Nalgirkar SP Et al.2018 India	Yoga program	3	180	12	36 (h)	Not reported	G1 = 15.16 (8.29) G1 = 12.75 (4.73) G2 = 9.91 (4.69) G2 = 10.08 (3.75)	-

# Figures

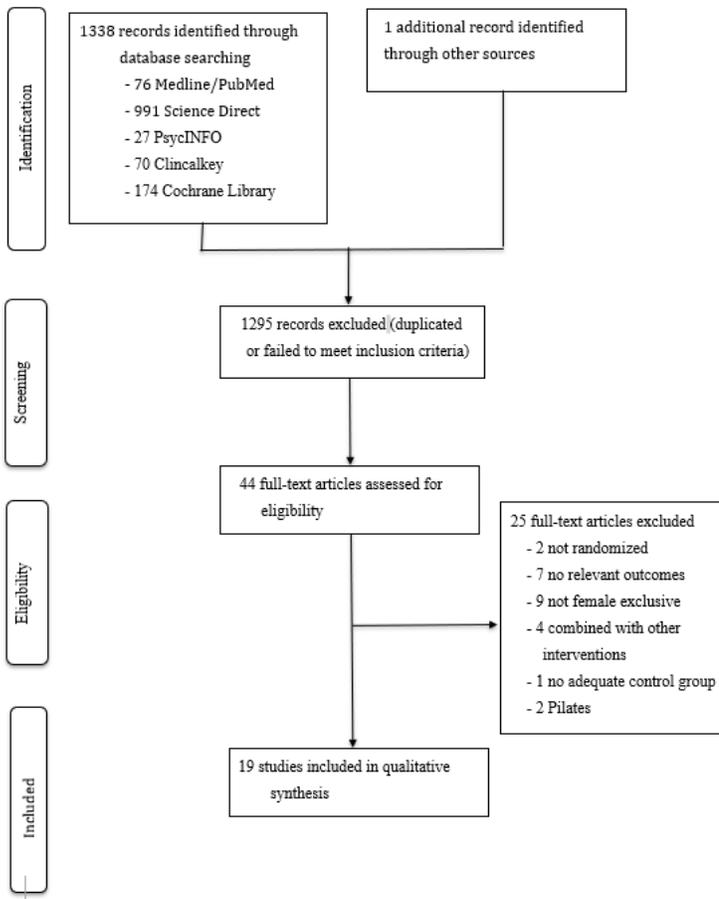


Figure 1

Flowchart of the results of the literature search

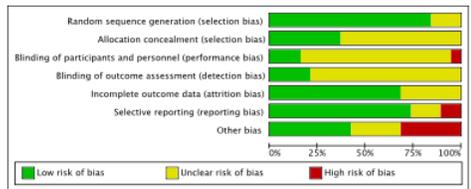
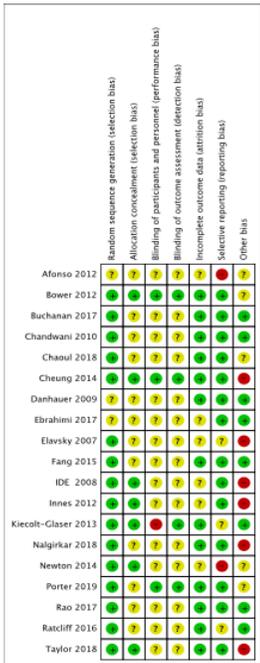


Figure 2

Risk of bias in individual studies. +, low risk of bias; ?, unclear risk of bias; -, high risk of bias (top). Risk of bias for each criterion presented as percentages across all included studies (bottom).

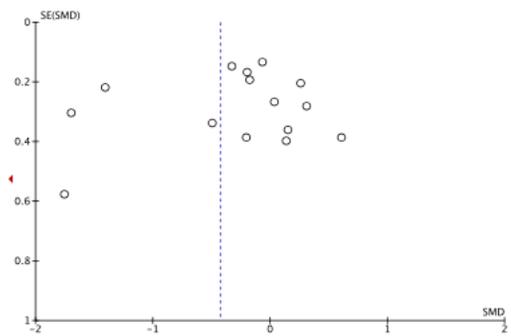
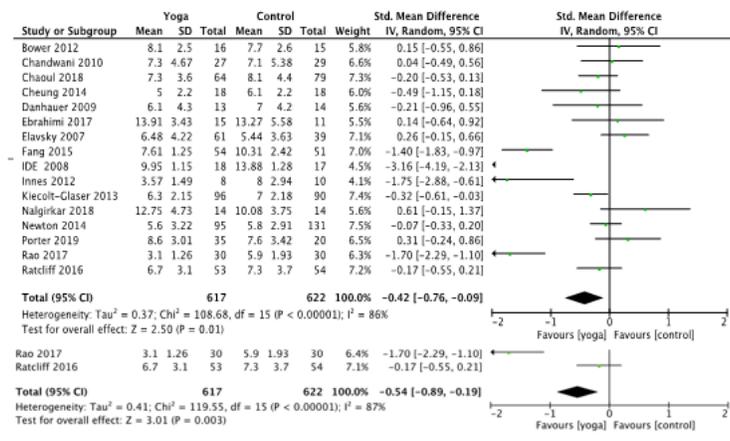


Figure 3

Funnel plot of estimate of publication bias in meta-analysis of the effects of yoga on women's sleep quality compared to control groups (PSQI). SE: standard error; SMD: standardized mean difference.

A.



B.

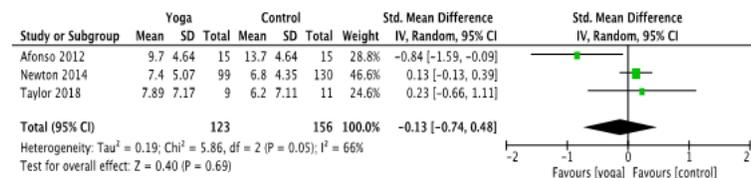


Figure 4 Forest plots for the effects of yoga on sleep quality in women versus control groups. (A) the global score of the Pittsburgh Sleep Quality Index (PSQI) (B) the global score of the Insomnia Severity Index (ISI). CI, confidence interval; IV, inverse variance; SD, standard deviation

C.

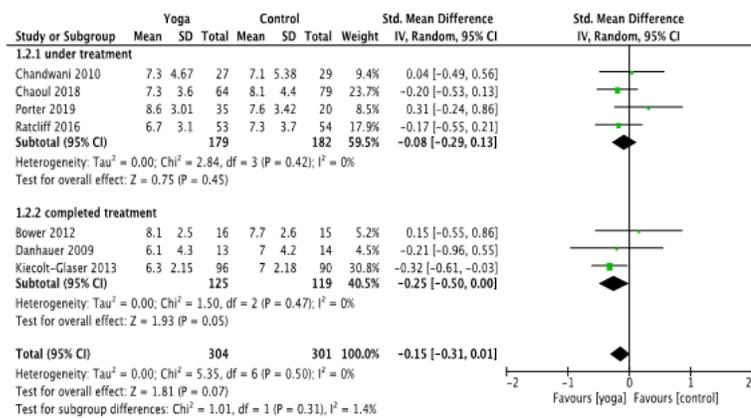
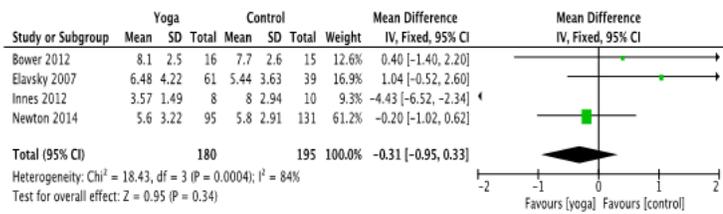


Figure 5 (C) Forest plots of the effects of yoga on the sleep quality of women with breast cancer (including women under treatment and women who had completed treatment) versus a control group using the global score of the Pittsburgh Sleep Quality Index (PSQI). CI, confidence interval; IV, inverse variance; SD, standard deviation.

D.



E.

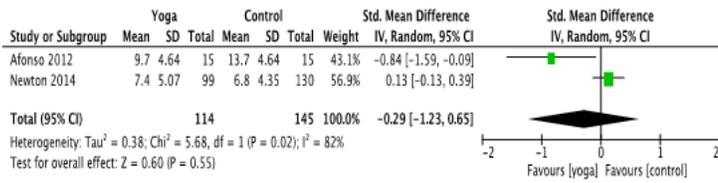


Figure 6

Forest plots displaying the effects of yoga versus control groups on sleep quality in peri- or postmenopausal women in (D) the global score of the Pittsburgh Sleep Quality Index (PSQI) (E) the global score of Insomnia Severity Index (ISI). CI, confidence interval; IV, inverse variance; SD, standard deviation