

Effect of yoga on sleep quality in women: 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)

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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, which was measured using subjective instruments, such as the Pittsburgh Sleep Quality Index (PSQI), 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 = -0.42; 95% CI = -0.76 to -0.09 ; P = 0.01). However, three RCTs revealed no effects of yoga compared with the control group in improving sleep quality 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 various groups of women was beneficial in managing sleep problems. Despite certain disadvantages in methodology in the included studies, yoga may be recommended as an additional therapy to women in addition to pharmacological treatment.

Background

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. Although pharmacotherapy remains the most common treatment [7], hypnotics have been associated with many side effects, such as drowsiness, cognitive impairment, dependence, and tolerance.

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 [8]. 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*) [8]. 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 [9]. Yoga is also safe and effective at improving fatigue severity, depressive moods, and sleep quality [10].

Although systematic reviews and meta-analyses have assessed the efficacy and safety of yoga in specific groups of women, such as those with prenatal depression [11] and primary dysmenorrhea [12] in different stages, evidence for the efficacy of yoga in improving sleep quality 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 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 [13] and suggestions by the Cochrane Collaboration for programming

and conducting systematic reviews and meta-analyses. [14].

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 ≥ 18 years) with or without 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 and ISI scores have been recommended as reliable and valid instruments to measure sleep quality. A global PSQI score of 5 or higher is indicative of poor sleep quality [15]. A global ISI score of 8 or higher is indicative of some degree of insomnia [16].

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 percentage of slow-wave sleep (SWS) [17].

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 [18]. 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 [14]. 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. Values of $P < 0.05$ were regarded as indicating statistical significance. 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.

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 [19].

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 (τ^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 ≤ 0.1 for the chi-square test was regarded as indicating significant heterogeneity [14].

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 defined a low risk of publication bias and asymmetrical funnel plots generally defined a high risk of publication bias [20].

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 [21]. 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 [21, 22], did not include relevant outcomes [23-29], did not include only female participants [30-38], included yoga as a part of a multimodal intervention (or combined with other intervention) [39-42], lacked adequate control [43], and did not include a form of yoga intervention [44, 45]. Nineteen full-text articles with 1832 participants were included in the qualitative synthesis. One RCT had unique measurements of sleep quality that could not be compared with other RCTs in the meta-analysis [46]. Finally, 18 full-text articles with 1646 participants met the inclusion criteria 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, six RCTs included healthy participants [46-51], including nurses [47], teachers [48], and women in the menopausal transition period or postmenopausal period [46, 49-51]. Other 13 RCTs included breast cancer patients undergoing treatment [52-55], breast cancer patients who had completed treatment [10, 56-58], type 2 diabetes mellitus patients [59], fibromyalgia patients [60], knee osteoarthritis patients [61], restless leg syndrome patients [62], and patients experiencing dysfunctional uterine bleeding [63].

Overall, the 19 RCTs included were conducted in the United States [10, 46, 49, 50, 52-58, 61, 62], Brazil [51, 60], India [48, 63], Iran [59], and China [47]. Study participants were recruited from hospitals [47, 53-57, 59, 63], outpatient clinics [51, 52] and schools [48]. The process of recruitment also included using purchased lists and health-plan enrollment files [46, 49] and multiple other mechanisms, including flyers, newspaper advertisements, web-based announcements, brochures, public health departments, tumor registry systems, and doctor referrals [10, 50, 58, 61, 62]. One study did not reveal the source from which participants were recruited [60]. Nineteen studies included in the systematic review displayed a baseline of PSQI higher than 5 or ISI higher than 8, indicating poor sleep quality. The only exceptions were two studies, with individual control groups in each study displaying a baseline of PSQI lower than 5 [48] or ISI lower than 8 [57]. 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, three revealed that Iyengar Yoga [10, 50, 62] was used; two revealed that Hatha Yoga [58, 61] was used; two revealed that Tibetan Yoga [51, 54] was used; two revealed that Restorative Yoga [56, 57] was used; one revealed that Vini Yoga [46] was used; one revealed that Yoga Relaxation with MindSound Resonance Technique [48] was used; one revealed that yoga breathing exercise in warm water [60] was used; and only seven RCTs revealed yoga programs with postures, breathing, relaxation or mediation, without defining the specific style of yoga [47, 49, 52, 53, 55, 59, 63]. 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 [47, 49, 53, 55, 57, 59, 63]. 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 [10, 62] and one study for social support groups [52].

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 [49, 51, 57]; two RCTs used PSG [46, 51]; and one RCT used actigraphy [54]. Safety-related events were reported in two RCTs only [49, 58].

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 [51, 56, 59]. Twelve studies did not report methods applied to perform adequate allocation [46-48, 50-56, 59, 63]. Most studies offered no data material on blinding. Three studies definitely revealed that participants and personnel were blinded [10, 52, 61]. Four studies definitely revealed that researchers and outcome assessments were blinded [10, 52, 58, 61]. Six studies had insufficient data on attrition rates [49-51, 59, 60, 62]. 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 [49, 51]. Six studies had a high risk of other potential sources of bias due to poor participant compliance, intervention length, sample size or baseline differences [50, 57, 60-63].

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 publication bias was detected (Fig. 3).

Analysis of overall effects

Primary outcomes

The meta-analysis revealed the effects of yoga compared with the control group on the sleep quality 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 = -0.42; 95% CI = -0.76 to -0.09; P = 0.01). However, three RCTs revealed no effects of yoga compared with the control group in improving sleep quality in women using ISI (SMD = -0.13; 95% CI = -0.74 to 0.48; P = 0.69)

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 [58]. 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 uncovered 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 improving sleep quality 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, 16 RCTs revealed evidence for yoga improving sleep quality in women. 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 deteriorating 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 in a specific gender was accessible. Ours is the first and largest systematic review and meta-analysis with 18 RCTs that examined 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 [64]. 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. 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 [65]. There were baseline differences between participants based on intervention assignment in PSQI scores [49, 62]. This may have contributed to results displaying no significant effect in sleep quality in the peri- or postmenopausal subgroup of women.

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 as a geographical limitation. 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 mediation), and potential bias were included in this systematic review.

Other threat to internal validity was the 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 [66]. Our included studies only had a low risk or an unclear risk of detection bias without high risk detection bias, and the results of meta-analysis did not convert when studies with a high risk of bias or an unclear risk of bias were excluded. 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 psychological comorbidities and risk factors in insomnia could be included. Subgroup analyses were performed to evaluate the effects on different participant groups. There were five primary limitations of this review. First, 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. Second, 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 [49, 58, 62]. This may have led to heterogeneity. Third, 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 [48, 54, 60]. Only four reviews reported long-term follow up effects, ranging from 3 months to 12 months [53-55, 58]. The fourth limitation was the lack of objective measures and safety issues in each study. The interpretation of findings was limited due to insufficient data on research methodology. Lastly, 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.

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 [67]. Researchers for study interventions may need to apply a standard protocol, such as at least three sessions of yoga programs with unified yoga component programs per week for at least 3 months would helpful for the further interference. Adequate reporting with safety issue should adhere to future yoga trials, although yoga for a long time has been promoted as being harmless. 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; however, it had no statistically significant effect on sleep quality. Despite certain flaws in methodology in our included studies, yoga may be recommended as a complementary therapy to women in addition to pharmacological treatment. However, advanced strength of evidence should be status established 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

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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.

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Tables

Table 1 Characteristics of included studies

Authors, year, country	Main characteristics of the studied population	Sample characteristics (sample size, age)	BMI, kg/m ² (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/o) 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	200, G1 = 100, G2 = 100 Mean age: G1 = 51.8 y/o (SD = 9.8) ,	G1 = 27.9 (5.3) G2 = 27.6	G1 = Hatha Yoga G2 = Control group	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: G1 vs. G2 (P = 0.03)

	months post surgery or adjuvant therapy or radiation	G2 = 51.3y/o (SD = 8.7)	(6.0)	(wait list control)		
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 scheduled to undergo daily adjuvant XRT (radiotherapy treatment) for 6 weeks at MD Anderson Cancer Center	163, G1 = 53, G2 = 56, G3 = 54 Mean age: G1 = 52.38 y/o (SD = 1.35), G2 = 51.14t/o (SD = 1.32), G3 = 52.11y/o (SD = 1.34)	-	G1 = Yoga G2 = Stretching G3 = Control group (wait list control)	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: 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 ≥ 18y) receiving treatment for metastatic breast cancer had a life expectancy ≥ 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,	61, G1 = 16, G2 = 21, G3 = 24	<30	G1 = Yoga G2 = Passive	Insomnia Severity Index (ISI)	The total score of ISI improved :

	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 ²	Age range:50-65 y/o		stretching	Polysomnography	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 20m IU/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 America	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, 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	186, G1 = 52, G2 = 54, G3 = 80 Mean age: G1 = 55.3 y/o (SD = 3.9) , G2 = 55.6 y/o (SD = 3.5), G3 = 54.2 y/o (SD = 3.7)	G1 = 27.6 (4.3) G2 = 26.9 (4.3) G3 = 26.7 (4.8)	G1 = Yoga G2 = Exercise G3 = Control group (usual activity)	Actigraphy	Statistically no significant finding in sleep efficiency (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)
IDE MR et al. 2008	Women with fibromyalgia syndrome (1990 American College of Rheumatology criteria) with time availability	40, G1 = 20, G2 = 20	-	G1 = Yoga breathing	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved:

Brazil		Mean age:G1 = 46.61 y/o (SD = 9.80) , G2 = 45.47y/o (SD = 8.65)		exercises in warm water G2 = Control group		G1 vs. G2 (P = 0.004)
Innes KE et al. 2012	Nonsmoking women (aged 45-79 y), post- menopausal (≥ 12 months amenorrheic) physical inactive (exercising less than 20 minutes, 3 times per week) and overweight (BMI ≥ 25 kg/m ² and/or waist circumference ≥ 88 cm) 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	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	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	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 ² , not being under insulin treatment	45, G1 = 15, G2 = 15, G3 = 15 Mean age: G1 = 48.18 y/o,	G1 = 31.28 (5.43) G2 = 29.35 (4.57)	G1 = Yoga G2 = Aerobic exercise G3 = Control group	Pittsburgh Sleep Quality Index (PSQI)	The total score of PSQI improved: G1 vs. G3 (P < 0.05)

G2 = 44.69y/o, G3 =

G3 = 47.93y/o 29.35

(5.31)

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 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 = 9.7 (4.64) G3 = 15.2 (4.8) G3 = 13.7 (4.64)	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%	G1 = 7.7 (3.34) G1 = 5.6 (3.30) G2 = 8.4 (3.30)	G1 = 11.8 (5.25) G1 = 7.4 (5.07) G2 = 12.2 (5.13) G2 = 6.8 (4.35)

yoga and G2 =
 3.1 usual 5.8
 activity), no (2.91)
 participants
 stopped the
 intervention
 due to
 adverse
 events

Buchanan, D.T. et al. 2017	Viniyoga	1	90	12	12 (18 h)	-	-	-
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America

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)	-
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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 =	-
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							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 America	Hatha Yoga	2	180	12	24 (36 h)	2 events in yoga intervention group reported the recurrence of chronic and /or shoulder problems	G1= - G1 =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	Yoga program	3	270	12	36 (54 h)	Not reported	G1 =	-	
Iran							14.40		
							(5.92)		
							G1 =		
							3.73		
							(3.49)		
							G3 =		
							13.91		
							(5.92)		
							G3 =		
							13.27		
							(5.58)		
Manas Rao, MSc et al. 2017	Yoga-based, mindfulness relaxation	5	150	4	20 (10 h)	Not reported	G1 =	-	
India							5.63		
							(3.31)		
							G1 =		
							3.10		
							(1.26)		
							G2 =		
							4.86		
							(2.52)		
							G3 =		
							5.9		
							(1.93)		
Nalgirkar SP Et al.2018	Yoga program	3	180	12	36 (h)	Not reported	G1 =	-	
							15.16		
							(8.29)		
							G1 =		

Figures

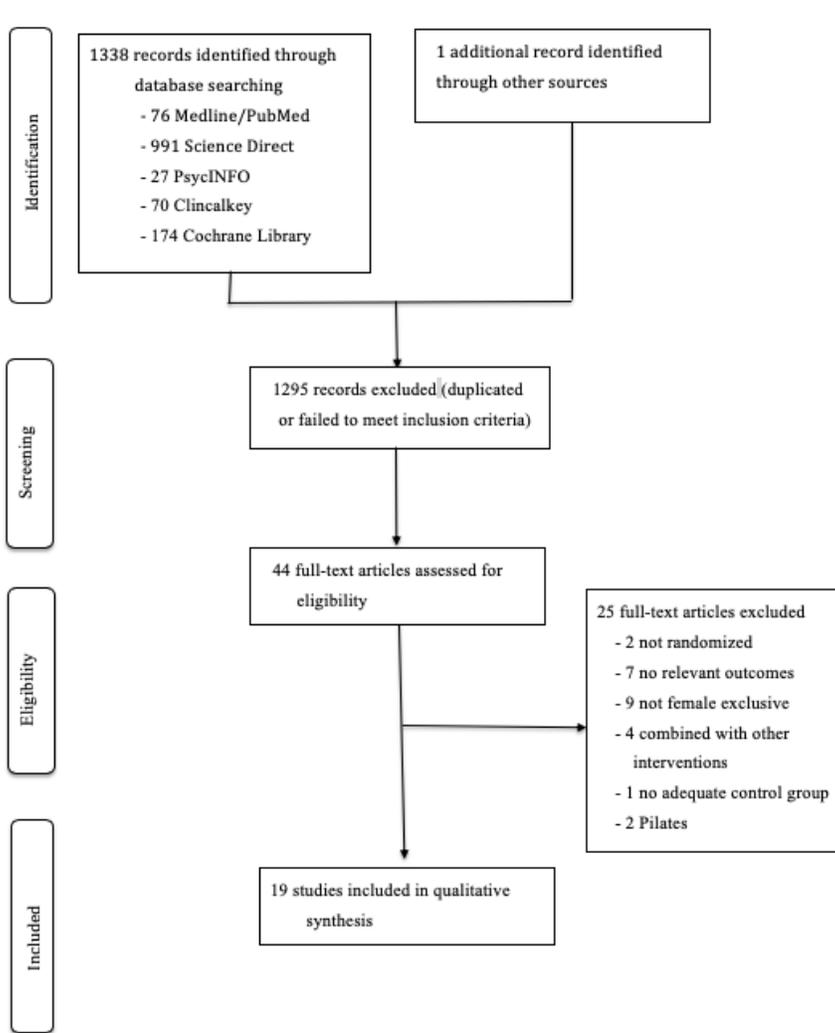


Figure 1

Flowchart of the results of the literature search.

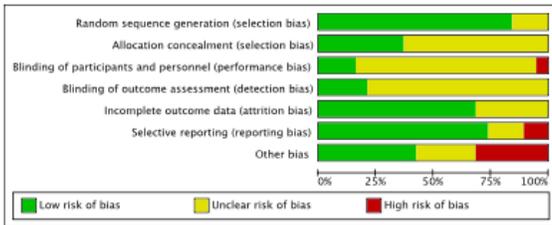
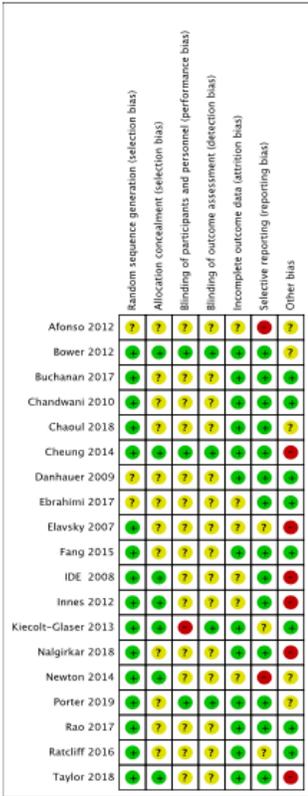


Figure 2

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).

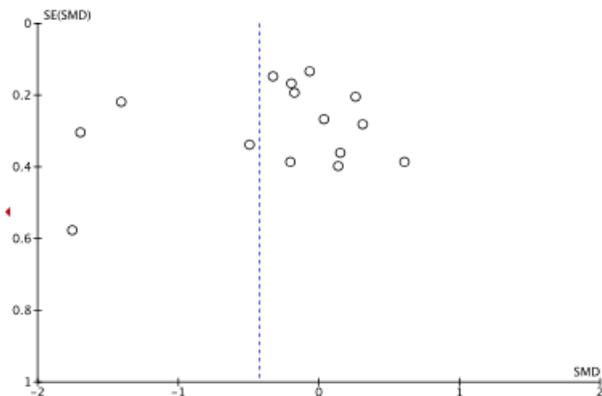
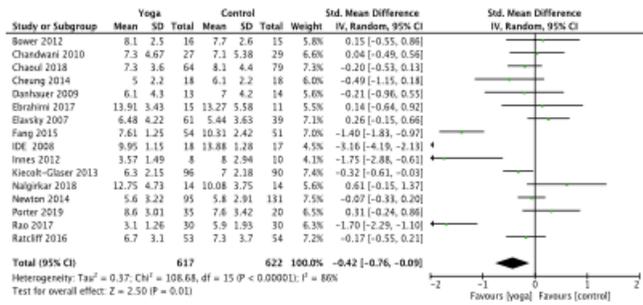


Figure 3

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.

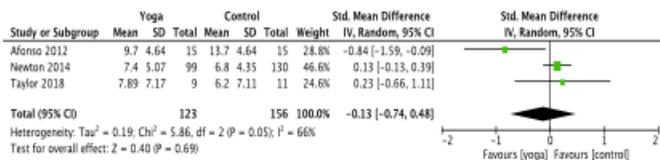


Figure 4

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.

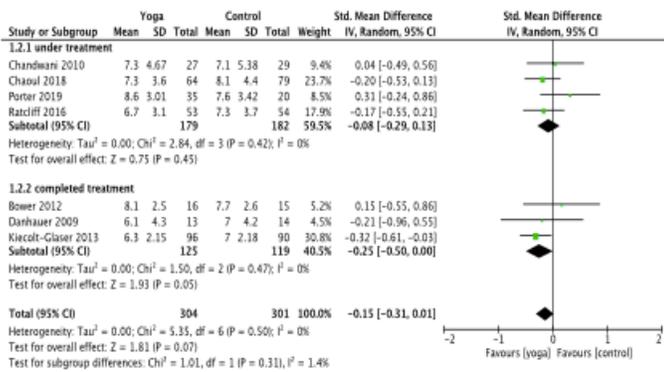
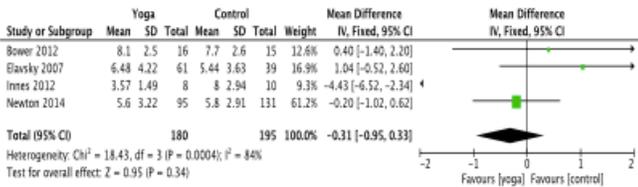


Figure 5

(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.

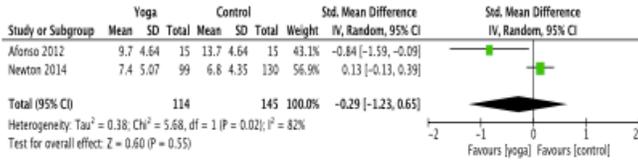


Figure 6

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.