Breast Cancer Research and Treatment (2019) 176:1–15
https://doi.org/10.1007/s10549-019-05217-9

REVIEW

Effects of physical and mind–body exercise on sleep problems during and after breast cancer treatment: a systematic review and meta-analysis

Charlotte Kreutz[1,2] · Martina E. Schmidt[1] · Karen Steindorf[1,3]

Received: 18 February 2019 / Accepted: 26 March 2019 / Published online: 6 April 2019

Abstract

Purpose We conducted a meta-analysis evaluating the effects of different exercise interventions on self-reported and objective sleep measurements during or after breast cancer treatment.

Methods Three databases were systematically searched for randomized controlled trials with any type of exercise intervention in women with breast cancer. Outcomes were self-reported or objective sleep measurements. Standardized mean differences (SMDs) were calculated using random-effects models.

Results The meta-analysis included 22 trials with 2107 participants. Of these, 17 studies used the Pittsburgh Sleep Quality Index (PSQI), six studies included objective sleep assessments (ActiGraph). Physical exercise interventions included walking, aerobic exercise, resistance exercise or a combination of both. Mind–body exercise interventions included yoga, Tai Chi and Qigong. Most interventions were supervised. Both, physical (SMD − 0.32; 95% CI − 0.54 to − 0.10) and mind–body exercise interventions (SMD − 0.27; 95% CI − 0.44 to − 0.09), resulted in improvements of total sleep scores. Subgroup analyses revealed no clear differences between interventions conducted during versus after breast cancer treatment. Considering the PSQI subscales, exercise resulted in improvements of sleep quality (SMD − 0.28; 95% CI − 0.44 to − 0.11) and sleep disturbances (SMD − 0.26; 95% CI − 0.45 to − 0.06). Regarding the objective measurements, no significant effects were found.

Conclusions Physical as well as mind–body exercise can improve subjective sleep problems in breast cancer patients. In contrast, there was no effect of exercise on objective sleep measures. Future studies should clarify which type of intervention might be most effective depending on individual patients' and treatments' characteristics.

Keywords Breast neoplasm · Sleep · Exercise interventions · Yoga · Insomnia · Actigraphy

Introduction

In healthy people, especially in elderly women, sleep disturbances are associated with increased risk for depression [1], chronic pain [2], cardiovascular diseases [3–6], and dementia [7, 8]. In breast cancer survivors, sleep problems are among the most frequent long-term health issues [9–11]. Schmidt et al. found that 38% of disease-free breast cancer survivors report sleep problems 5 years after diagnosis [9]. Although sleep problems are generally common after menopause, breast cancer survivors experience significantly more insomnia than women of comparable age of the general population [9, 10]. Chemotherapy but also hot flashes, poor physical functioning, depressive symptoms, distress [10, 12, 13], quality of life, fatigue, and anxiety [14–16] have been found as significant predictors or correlates.

✉ Karen Steindorf
k.steindorf@dkfz.de

[1] Division of Physical Activity, Prevention and Cancer, German Cancer Research Center (DKFZ), National Center for Tumor Diseases (NCT) Heidelberg, Im Neuenheimer Feld 460, 69120 Heidelberg, Germany

[2] Faculty of Medicine Heidelberg, Im Neuenheimer Feld 672, 69120 Heidelberg, Germany

[3] Division of Physical Activity, Prevention and Cancer (C110), German Cancer Research Center (DKFZ), National Center for Tumor Diseases (NCT) Heidelberg, Im Neuenheimer Feld 581, 69120 Heidelberg, Germany

Exercise interventions during and after cancer treatment can significantly improve quality of life and physical fitness, and decrease fatigue [17], depression [18] as well as anxiety [19]. It is proven that exercise is safe and well tolerated in patients undergoing treatment and in cancer survivors [20]. The effects on sleep are less conclusive so far, although there are already five meta-analyses and one systematic review that investigated the effects of exercise interventions in cancer patients considering also sleep disturbances as an outcome. Five of them found small improvements in self-reported sleep problems [21–25], whereas one did not [26]. An analysis of objective measurements of sleep problems was carried out in only one meta-analysis and found no significant effect [26]. As none of the meta-analyses directly contrasted different types of exercise in breast cancer patients, it is still unclear which type is the best. Likewise, it needs to be determined whether the effects of exercise during acute cancer therapy are comparable to the effects after completion of therapy. Further, sleep problems can be very heterogeneous with regard to aspects such as subjective sleep quality, duration, disturbances, latency (i.e. time until falling asleep), efficiency (i.e. time in bed that was actually asleep), and daily dysfunction. Moreover, objective measures of sleep, e.g. using accelerometry, are increasingly propagated to get a better discrimination of sleep parameters. However, meta-analysis of exercise interventions on sleep problems differentiating by these various subjective and objective sleep measures are lacking.

Thus, our aims were to perform a systematic and quantitative analysis on the effects of exercise on sleep in women with breast cancer during and after treatment that adds to current knowledge by (1) comparing different types of exercise (2) investigating different aspects of sleep such as sleep quality, latency, duration, disturbance, efficiency, daily dysfunction, and use of sleep medication, and (3) investigating whether the effects of exercise interventions differ between self-reported and objective sleep measures.

Methods

Data sources and searches

Eligible studies were identified in August 2018 via systematic searches in PubMed, Web of Science and Cochrane databases and by checking the references in the published studies, systematic reviews and meta-analyses. The search was limited to publications in English and German.

Study selection

Studies were eligible if they were randomized controlled trials (RCTs) with more than 20 participants that evaluated the effects of any type of exercise interventions on sleep parameters in adult women with a breast cancer diagnosis. The participants could be at any stage of breast cancer care trajectory (during or after treatment). All forms of exercise interventions were considered eligible including aerobic, resistance or a combination of both, walking, yoga, Pilates, Qigong or Tai Chi. Exercise interventions could be combined with flexibility exercises or with another type of intervention. No restriction was made regarding frequency, intensity or duration of the program. Interventions could be home-based or supervised. The initial search was also not restricted by type of the control group. RCTs had to contain at least one self-reported or objective measure of sleep.

Data extraction

For questionnaires, the total score and, if applicable, all reported subscales were extracted. From accelerometry, sleep efficiency and latency were extracted. The pre- and post-intervention means, standard deviations (SD) or standard errors (SE), and numbers of participants in the intervention and control groups were extracted from the publications independently by two persons. In studies with two control groups, these were combined to one control group according to the Cochrane handbook [27]. If not all minimally needed information was available in the publication, the corresponding author of the respective study was contacted.

Quality assessment

The methodological quality of each trial was examined using the risk of bias criteria recommended by the Cochrane Collaboration [27]. The scoring was carried out by two independent reviewers.

Statistical analysis

Standardized mean differences (SMDs) with 95% confidence intervals (CIs) were calculated for each study as the difference of the mean changes from pre- to post-intervention between the intervention and the control group divided by a pooled pretest standard deviation [28]. Random-effects models were calculated using the Cochrane-Software RevMan 5.3. Potential risk of publication bias was assessed through visual analysis of funnel plot symmetry and heterogeneity between studies using the χ^2 test and the I^2 statistic. Further, we conducted subgroup analyses to investigate effects of different types of exercise and timing.

To compare the effect of different types of exercise we grouped interventions as “physical exercise” (resistance training, aerobic training, a combination of both or walking intervention) or “mind–body exercise” (yoga, Tai Chi or Qigong).

Table 1 Study characteristics; studies written in grey were included in the qualitative review only

Study	N, mean age (SD)	Timing	Intervention	Delivery mode	Duration (weeks)	Frequency/ duration	Control	Sleep outcome
Bower 2012 (USA) [52]	IG: N=16 54.4 (5.7) CG: N=15 53.3 (4.9)	After treatment	Yoga	Supervised, group based	12	90 minutes, twice weekly	Health education	PSQI
Carson 2009 (USA) [51]	N=37 54.4 (7.5)	After treatment	Yoga	Supervised	8	120 minutes, weekly	Wait-list	0-9 scales
Chandwani 2010 (USA) [53]	IG: N=30 51.4 (8.0) CG: N=31 54.0 (10.0)	During radiotherapy	Yoga	Supervised	6	60 minutes, twice weekly supervised, daily home-based (audio CD)	Wait-list	PSQI
Chandwani 2014 (USA) [54]	IG: N=53 52.4 (1.4) CG1: N=54 52.1 (1.3) CG2: N=56 51.1 (1.3) SE!	During radiotherapy	Yoga	Supervised	6	60 minutes, 3 times/week	CG1: Wait-list CG2: Stretching	PSQI
Chaoul 2017 (USA) [55]	IG: N=74 49.5 (9.8) CG1: N=85 49 (10.1) CG2: N= 68 50.4 (10.3)	During (neo) adjuvant chemotherapy	Yoga	4 classes supervised 1-on-1; home-based	4-12	Supervised 75-90 minutes, daily home-based	CG1: Usual care CG2: Stretching	PSQI, ActiGraph
Chen 2013 (China) [56]	IG: N=49 45.3 (6.3) CG: N=47 44.7 (9.7)	During radiotherapy	Qigong	Supervised, group-based	5-6	40 minutes, 5 times/week	Wait-list	PSQI
Courneya 2014 (Canada) [36]	IG1: N=95 49.5 (8.0) IG2: N=99 49.9 (8.7) IG3: N=102 50.5 (9.4)	During chemotherapy	Aerobic exercise	supervised	Duration of chemo-therapy	IG1: 25-30 minutes, 3 times/week; IG2: 50-60 minutes, 3 times/week; IG3: 25-30 minutes aerobic exercise + 30-35 minutes strength exercise, 3 times/week	IG2: higher dose of aerobic exercise IG3: aerobic and resistance exercise	PSQI
Danhauer 2009 (USA) [57]	IG: N=22 54.3 (9.6) CG: N=22 57.2 (10.2)	During or after completion of treatment	Yoga	Supervised, group-based	10	75 minutes, once/week	Wait-list	PSQI
Ghavami 2017 (Turkey) [37]	IG: N=40 48.8 (9.5) CG: N=40 49.2 (9.5)	After treatment	Aerobic exercise + dietary energy restriction	Supervised	24	50 minutes, 3-5 times/week	Usual care	PSQI
Irwin 2017 (USA) [31]	IG: N=45 59.6 (7.9) CG: N=45 60 (9.3)	After treatment	Tai Chi	Supervised	12	120 minutes/week	Cognitive behavioral therapy for insomnia	PSQI
Kiecolt-Glaser 2014 (USA) [58]	IG: N=100 51.8 (9.8) CG: N=99 51.3 (8.7)	After treatment	Yoga	Supervised	12	90 minutes, twice/week	Usual care	PSQI

Table 1 (continued)

Study	N, mean age (SD)	Timing	Intervention	Delivery mode	Duration (weeks)	Frequency/ duration	Control	Sleep outcome
Kröz 2017 (Germany) [32]	IG1: N=20 59.8 (9.8) IG2: N=34 60.3 (9.5) IG3: N=51 56.6 (7.9)	After treatment	IG1: Aerobic exercise	Supervised + homebased	10	140-165 minutes/week	IG2: Multimodal program; IG3: Multimodal program + aerobic exercise	PSQI
Larkey 2015 (USA) [30]	IG: N=28 57.7 (8.9) CG: N=30 59.8 (8.9)	After treatment	Qigong/ Tai Chi Easy	Supervised	12	60 minutes, once/week	Sham Qigong	PSQI
Lötzke 2016 (Germany) [29]	IG: N=45 51 (11) CG: N=47 51.4 (11.1)	During chemotherapy/ hormonal therapy	Yoga	Supervised + homebased	12	60 minutes supervised, once/week; 20 minutes homebased, twice/week	Physical exercise	EORTC-QLQ-C30
Mock 1997 (USA) [48]	IG: N=23 48.1 (5.4) CG: N=23 50.3 (8.5)	During radiotherapy	Walking	Home-based	Beginning to end of radiotherapy	Individual duration, 4 -5 times/week	Usual care	SAS
Mustian 2013 (USA) [38]	IG: N=116 54.3 (0.8)* CG: N=113 54.0 (0.7)*	After treatment	Yoga	Supervised	4	75 minutes, twice/week	Usual care	PSQI, ActiGraph
Payne 2008 (USA) [49]	N:20 64.7 (6.3)	During radiotherapy	Walking	Home-based	14	20 minutes, 4 times/week	Usual care	PSQI, ActiGraph
Rogers 2009 (USA) [33]	IG: N=20 52 (15.0) CG: N=18 54 (8.0)	During hormonal therapy	Walking	Supervised, home-based	12	BEAT: 150 minutes per week moderate to vigorous physical activity behavior change intervention	Wait-list	PSQI
Rogers 2013 (USA) [39]	IG: N=12 58.0 (6.1) CG: N=9 53.7 (13.9)	After primary treatment	Aerobic exercise and resistance exercise	Supervised, home-based	12	Adapted from BEAT: 150 minutes per week of aerobic exercise, twice/week resistance training	Wait-list	PSQI, ActiGraph
Rogers 2015 (USA) [34]	N=42 56.2 (7.7)	After primary treatment	Aerobic walking and resistance training	Supervised, home-based	12	Adapted from BEAT: 160 minutes per week of aerobic exercise, twice/week resistance training	Usual care	PSQI, ActiGraph
Rogers 2017 (USA) [40]	N=214 54.4 (8.5)	After primary treatment	Physical activity	Supervised, home-based	12	BEAT: 150 minutes per week	Usual care	PSQI, ActiGraph

Table 1 (continued)

Study	N, mean age (SD)	Timing	Intervention	Delivery mode	Duration (weeks)	Frequency/ duration	Control	Sleep outcome
						moderate to vigorous, physical activity behavior change intervention		
Roveda 2017 (Italy) [59]	IG: N=19 55.2 (6.8) CG: N=21 58.2 (6.4)	After treatment	Aerobic exercise	Supervised	12	60 minutes, twice/week	Usual care	ActiGraph
Steindorf 2016 (Germany) [60]	N=155 55.6 (9.0)	During radiotherapy	Resistance training	Supervised	12	60 minutes, twice/week	Relaxation training	EORTC-QLQ-C30
Vardar Yagli 2015 (Turkey) [61]	IG1: N=19 49.9 (4.7) IG2: N=21 47.4 (7.6)	After treatment	IG1: Yoga and aerobic exercise	Supervised	6	30 minutes, 3 times/week	IG2: Aerobic exercise	EORTC-QLQ-C30
Vardar Yagli 2015 (Turkey) [62]	IG1: N=10 68.6 (6.2) IG2: N=10 68.9 (2.9)	After treatment	Yoga	Supervised, home-based	4	60 minutes, twice/week	IG2: exercise	VAS
Vadiraja 2009 (India) [63]	IG: N=42 CG: N=33	During radiotherapy	Yoga	Supervised, home-based	6	60 minutes, 3 times/ week (supervised), home-based at the other days	Brief counseling	EORTC-QLQ-C30
Wang 2011 (Taiwan) [64]	IG: N=35 48.4 (10.2) CG: N=37 52.3 (8.8)	After breast surgery/during chemotherapy	Walking	Home-based	6	30-50 minutes, 3-5 times/week	Usual care	PSQI
Yang 2010 (Taiwan) [50]	IG: N=19 50.8 (7.1) CG: N=21 52.7 (8.1)	During chemotherapy	Walking	Home-based	12	40 minutes, 3 times/week	Usual care	MDASI-T

*for the whole study, not just breast cancer

Abbreviations: CG: control group; EORTC-QLQ-C30: European Organization for the Research and Treatment of Cancer – Quality of Life version 1; IG: intervention group; MDASI-T: Taiwanese Version of the M. D. Anderson Symptom Inventory; N: number of subjects included in the quantitative analyses; PSQI: Pittsburgh Sleep Quality Index; SAS: Symptom Assessment Scales; VAS: Visual Analog Scale

Results

Literature search

Three databases yielded 398 articles and 3 further articles were found through checking the references of other publications. By removing duplicates, 313 articles were left. After screening titles and abstracts, 266 studies were excluded. After reviewing the full text of the remaining 47 publications, 28 were considered eligible. Of those 28 suitable studies, 5 could not be included in the quantitative meta-analysis due to missing information and no response to our request. One further study was excluded due to a low number of subjects and high scoring of risk of bias. Thus, 22 studies were included in the meta-analysis (Fig. 1).

Characteristics of the studies

The 22 trials included in the meta-analysis compromised 2107 participants with a mean age of 52.8 years. Sleep was

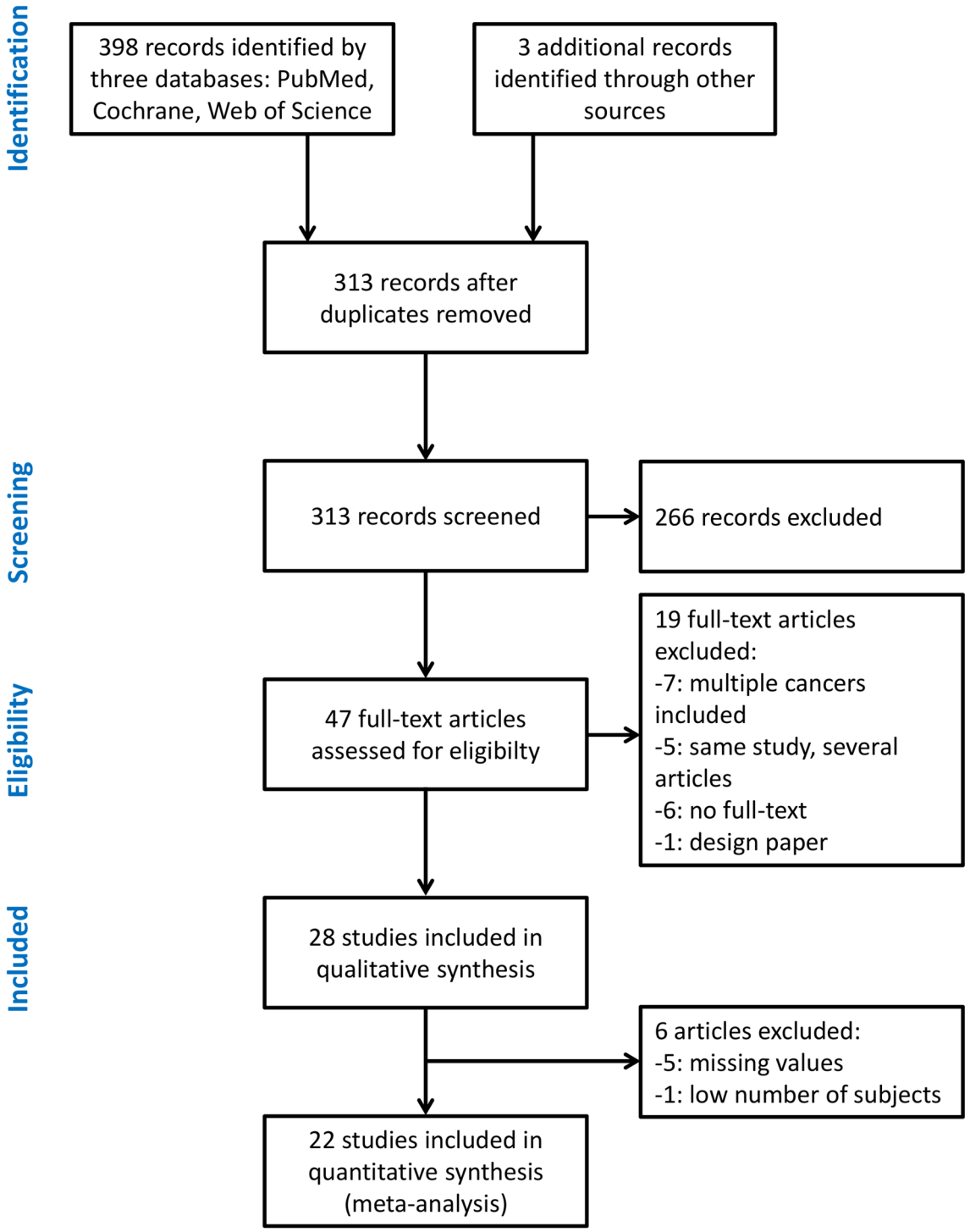


Fig. 1 Flow chart

assessed in 17 studies with the Pittsburgh Sleep Quality Index (PSQI) and in 4 studies with the European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire of Cancer Patients (EORTC-QLQ-C30). Six studies included objective sleep assessments using accelerometers (ActiGraph). Interventions included aerobic training (3 studies), resistance training (one study), or a combination of both (4 studies), walking (one study), yoga (10 studies), Qigong (two studies), or Tai Chi (one study). The duration of the interventions ranged from 4 to

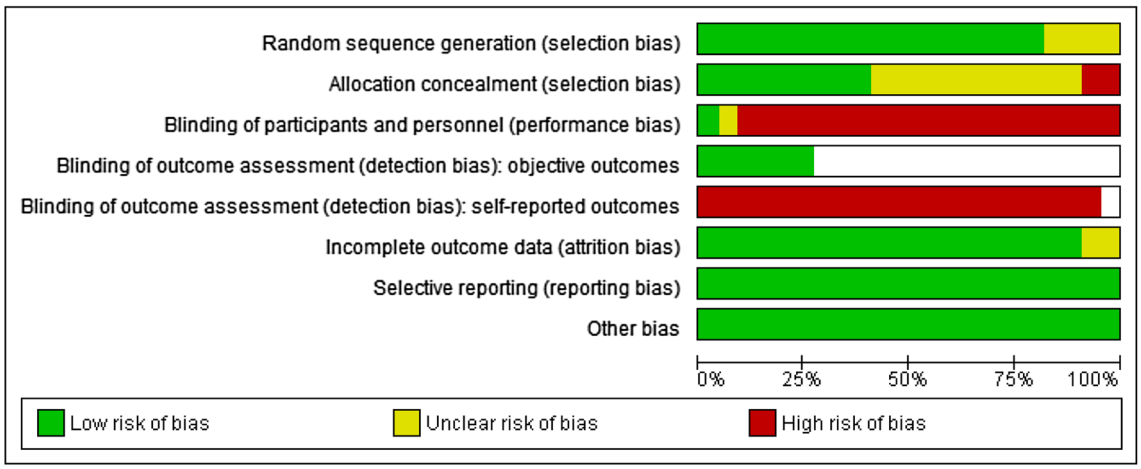


Fig. 2 Risk of bias summary

24 weeks, with a wide range of frequency and duration of training units. One intervention was home-based only, 13 interventions were supervised, and 8 interventions a combination of both. Of the 22 included studies, 13 control groups were usual care/waitlist control, of which two were combined with an additional stretching. One study made relaxation training, one brief counselling, one health education, two behavioral therapy, and three absolved another exercise intervention (Table 1).

Quality evaluation

The risk of bias summary for all studies included in the meta-analysis can be found in Fig. 2. Figure 3 shows the risk of bias for self-reported and objective measurement of each RCT according to the Cochrane risk of bias tool. Regarding blinding of outcome assessment we judged studies separately for objective or self-reported outcomes, thus, not 100% of studies have these assessments. Blinding of outcome assessment is not possible for self-reported outcomes. Only studies with an objective measurement—here with ActiGraph, were rated at low risk.

To check for publication bias we used a funnel plot (Fig. 4).

Outcomes

For all parameters, lower values indicate better sleep. Physical exercise interventions (SMD −0.32; 95% CI −0.54 to −0.10; heterogeneity: p-HET = 0.18; $I^2 = 34\%$) and mind–body exercise interventions (SMD −0.27; 95% CI −0.44 to −0.09; p-HET = 0.02; $I^2 = 54\%$) resulted in significant improvements of sleep problems. There was no significant difference between the effects of physical exercise and mind–body exercise ($p = 0.73$). Considering subgroups by time of intervention, the effects of physical exercise seemed to be somewhat stronger during therapy than after therapy, whereas mind–body exercise effects seemed to be stronger after therapy. Yet, differences between the subgroups were not statistically significant, the number of studies per subgroup were small, and effects of mind–body exercise interventions during treatment were very heterogeneous ($I^2 = 67\%$) (Fig. 5). Further examination of different exercise types, e.g. comparing aerobic vs. resistance training, was not meaningful due to too small numbers of studies in such groups.

Regarding PSQI subscales, physical exercise and mind–body exercise studies were summarized due to the limited number of studies reporting PSQI subscales. The results showed significant improvements of sleep quality (SMD −0.28; 95% CI −0.44 to −0.11; p-HET = 0.62; $I^2 = 0\%$) and of sleep disturbances (SMD −0.26; 95% CI −0.45 to −0.06; p-HET = 0.31; $I^2 = 15\%$). For sleep latency and daytime dysfunction there were tendencies for a beneficial influence (Fig. 6).

Regarding the objective sleep measurements measured by ActiGraph, i.e. sleep efficiency and sleep onset latency, no significant effects of exercise were found. Especially, the three largest of the six available studies consistently showed SMDs close to zero (Fig. 7).

The study of Lötzke et al. directly comparing yoga vs. physical exercise [29] found no significantly different effect on sleep problems (SMD 0.08; 95% CI −0.3 to 0.47). Larkey et al. compared Qigong/Tai Chi with Sham Qigong, i.e. an intervention that was completely identical in setting, duration, and frequency to the Qigong/Tai Chi classes but containing only the physical activity components without the focus on meditation and breathing [30]. There was no

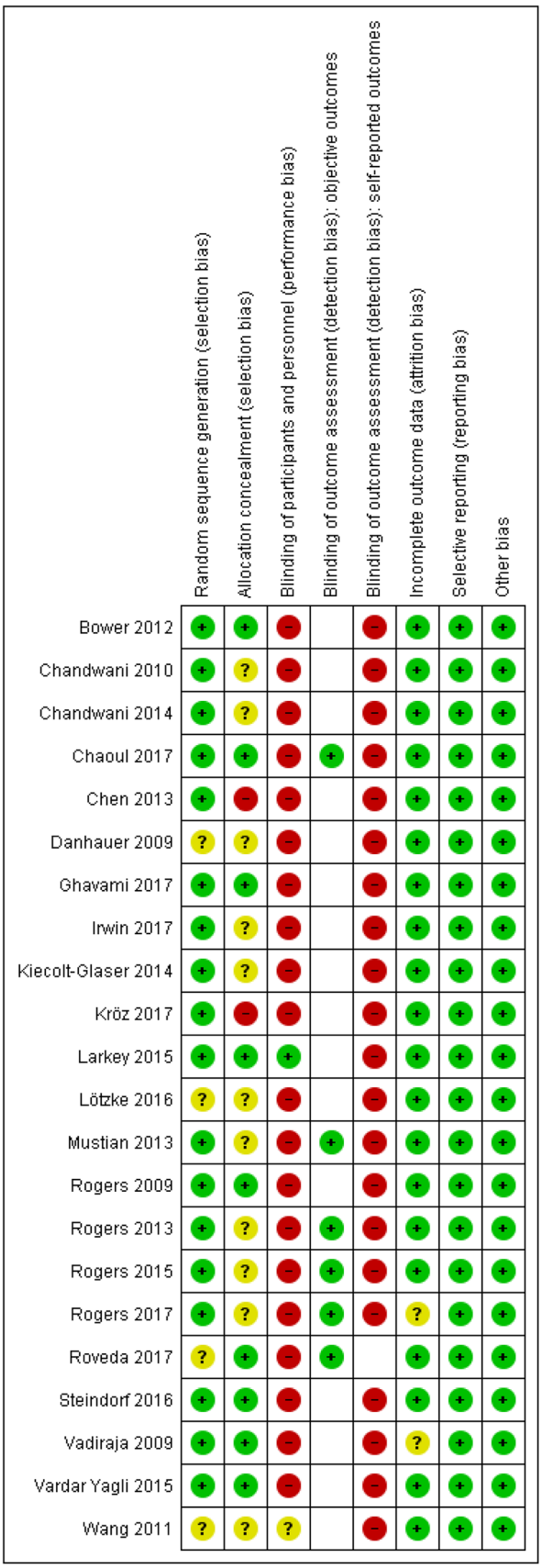


Fig. 3 Risk of bias

group effect on sleep problems (SMD −0.18; 95% CI −0.67 to 0.31) (Fig. 8).

The study of Ghavami et al. in overweight and obese breast cancer survivors showed a strong benefit of a combined exercise and dietary intervention focusing on weight reduction with respect to subjective sleep problems compared to a group with no intervention (SMD −1.74; 95% CI −2.24 to −1.24) (Fig. 8). Finally, two studies compared exercise (Tai Chi [31] or aerobic exercise [32]) with a cognitive behavioral therapy intervention. Both found a significantly better effect of the cognitive behavioral therapy intervention on sleep problems (SMD 0.38; 95% CI 0.06–0.69; p-HET = 0.48; $I^2 = 0\%$) (Fig. 8).

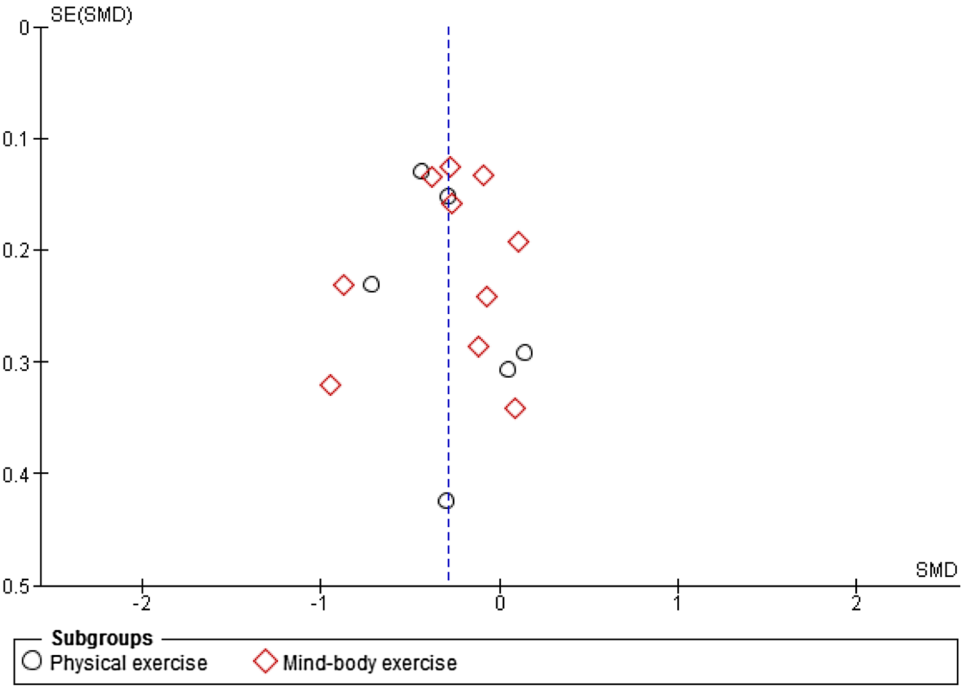
Discussion

This is the first meta-analysis considering various subjective as well as objective sleep aspects in breast cancer patients. Our quantitative analysis indicated that both physical and mind–body exercise can improve sleep in breast cancer patients. Effects did not differ significantly between interventions during cancer therapy versus interventions after cancer therapy. During cancer treatment, however, physical exercise tended to outperform mind–body exercise whereas after end of treatment mind–body exercise tended to be better. Results also suggest that benefits of exercise on sleep might manifest in significant improvements on subjective sleep quality and sleep disturbances. In contrast to the subjective sleep measures, there was no effect of exercise on objective sleep measures.

The meta-analysis did not reveal a clear superiority of one of both physical or mind–body exercise interventions on sleep problems. Likewise, two studies directly comparing yoga with physical exercise [29] or a Qigong intervention with sham Qigong, including the physical movements only [30], found no significant differences between the physical and the mind–body exercise groups.

A qualitative review [24] suggested walking as an effective intervention against sleep problems in cancer patients whereas effects on mind–body interventions remained inconclusive. Our analyses did not support this suggestion. Although in two of the five identified walking intervention studies significant effects were seen, they were limited to only one among several PSQI subscales and did not relate to the overall PSQI score [33, 34]. Moreover, in one of these studies, the significant effect was seen only at a later follow-up but not directly at end of intervention [33, 35]. In the other (pilot) walking intervention study, the meaning is unclear as the significant group effect appeared to be mainly due to a markedly shorter baseline sleep duration among the controls that post-intervention aligned with the unchanged values in the walking group. Thus, from the current available

Fig. 4 Funnel plot



evidence it cannot be concluded that walking has a stronger effect on sleep problems than other types of exercise.

Due to a (still) small number of studies, it was not meaningful to carry out quantitative analyses that further differentiate by type (more than physical versus mind–body exercise) or intensity of exercise. However, the multicenter RCT from Courneya et al. with breast cancer patients undergoing chemotherapy found that a higher dose of aerobic exercise (50–60 min, thrice weekly) or a combination of aerobic and resistance exercise (50–60 min, thrice weekly) yielded better sleep quality compared to standard aerobic intervention (25–30 min, thrice weekly) [36].

The largest reduction of sleep problems was reported by the RCT by Ghavami et al. [37]. A substantial reduction in body mass index (from 29.4 ± 2.6 to 25.1 ± 2.9) as well as in fatigue, breast and arm symptoms has also been observed. It investigated a 24-week supervised aerobic training at 3–5 days per week in combination with an individualized energy restriction diet in overweight or obese breast cancer survivors compared to a control group without any intervention. In contrast to the other exercise trials, this study exerted on a specific pathway, i.e. weight reduction and increased aerobic fitness in inactive overweight or obese women. Thus, in this subgroup of patients this type of intervention might be recommendable.

In our quantitative analysis, the two studies comparing exercise interventions with cognitive behavioral therapy (CBT) indicated an advantage of CBT with effect sizes of 0.3 [31] and 0.5 [32]. One of them investigated Tai Chi [31], the other one aerobic exercise [32]. CBT has been commonly considered as a gold standard for insomnia treatment. The intervention included cognitive therapy, stimulus control, relaxation, sleep restriction and hygiene. These components are aimed at to reestablish a restful sleep.

The results of subjective and objective sleep measurement did not agree in our meta-analyses. The six studies including objective measures in sleep latency and efficiency yielded no overall effect. Whereas in the same studies subjective sleep measurements regarding these two sleep aspects as PSQI subscales show a tendency of beneficial effects. In two studies, the intervention was yoga, one aerobic exercise and three aerobic exercise combined with resistance training. Five of the six studies performed both self-reported and objective sleep measurements. Only one study found a significant effect on sleep efficiency by ActiGraph measurement [38], whereas no significant effect was reported on sleep latency. Looking at the PSQI subscales, one study showed a significant effect on sleep latency [39] and another on sleep efficiency [40].

Actigraphy shows high agreement with the gold standard polysomnography (PSG) [41, 42] and shows high sensitivity with low specificity [43]. A review by Chen et al. of different measurement methods especially for cancer patients summarized that different measurement methods can detect different sleep disorders in the same patients and, therefore, always recommended a combination of objective and subjective measurement. Actigraphy is used as the best choice for objective measurement because PSG is very expensive and difficult to implement [44]. So it is possible that the subjective PSQI measures other forms

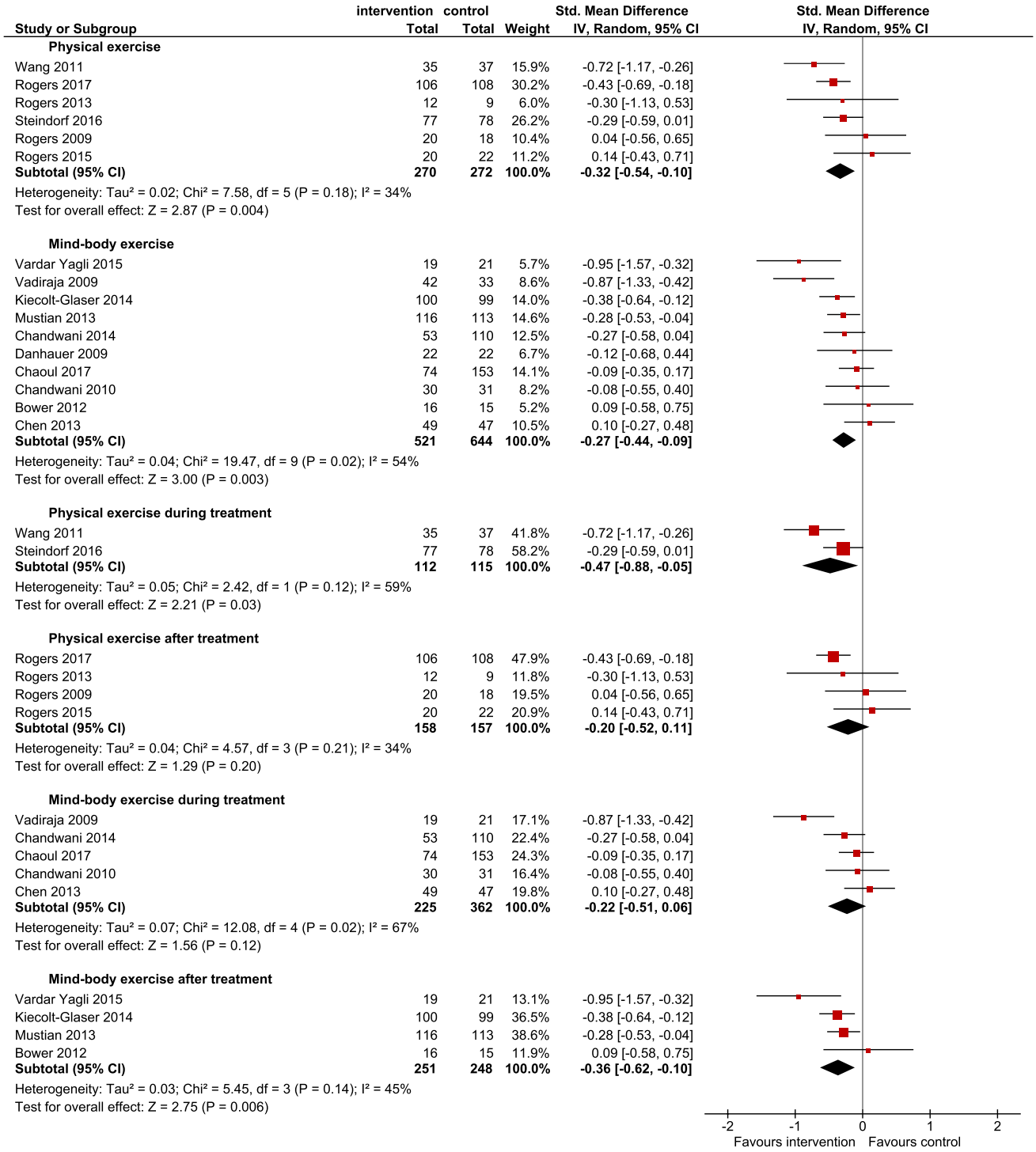


Fig. 5 Forest plots for self-reported sleep problems, stratified by type and timing of exercise

of sleep disorders than the ActiGraph. There is a need for more differentiated consideration of sleep disorders in clinical trials and clinical practice.

Based on our analysis, it seems likely that more individualized interventions may be needed to efficiently help cancer patients with sleep problems. This can be derived from the observations that (1) for most exercise

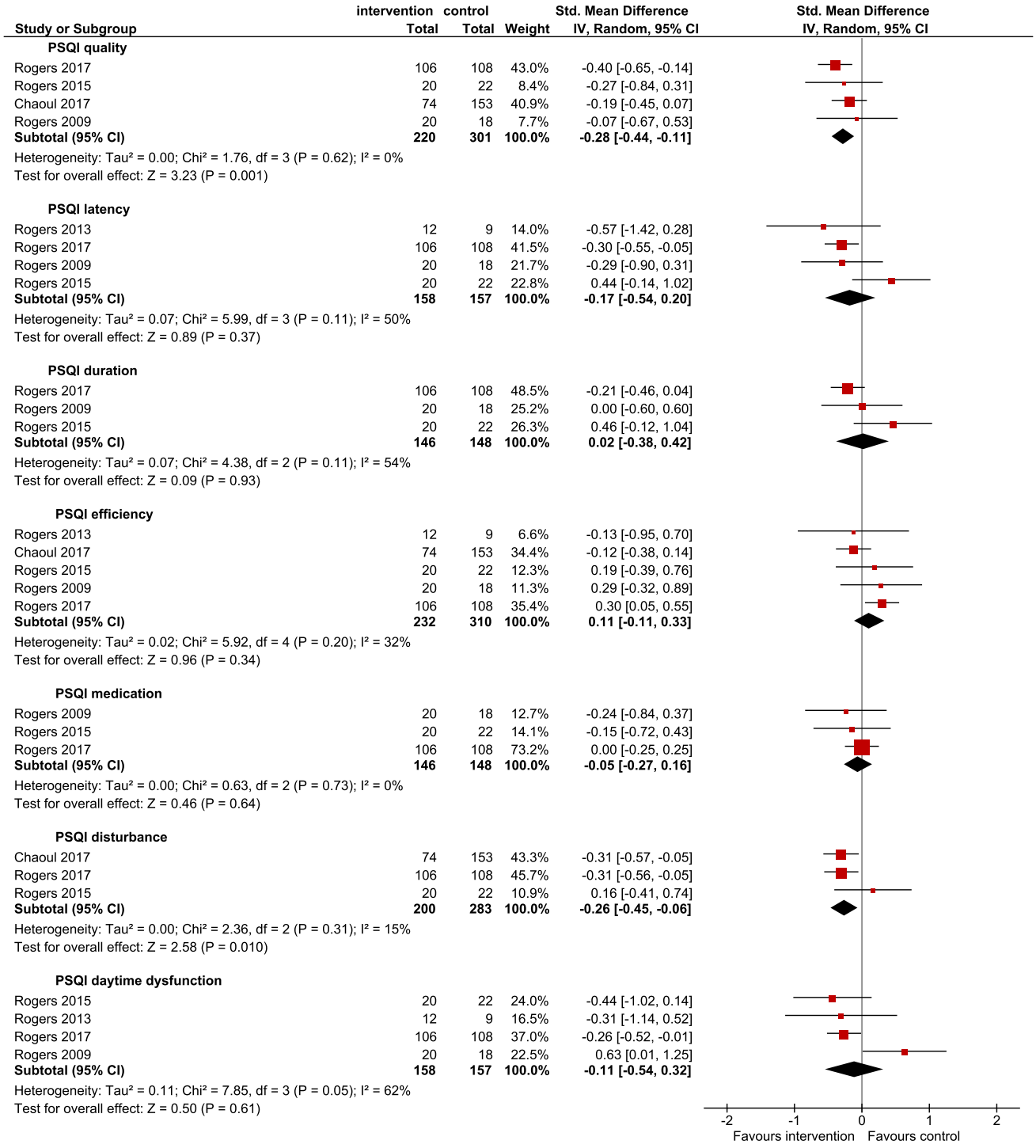


Fig. 6 Forest plots for self-reported measurements (PSQI subscales)

interventions the effect sizes were rather small to moderate (2) very different types of interventions such as progressive resistance training, walking, or yoga yielded benefits on sleep in several but not all patients (3) effects might depend on timing of the intervention as well as on the subtype of sleep problems, and (4) that interventions which targeted specific problems showed strongest effects. Obese patients might need combined dietary, exercise, and behavior change interventions aiming for enduring weight reduction; patients who are depressed or have disturbed

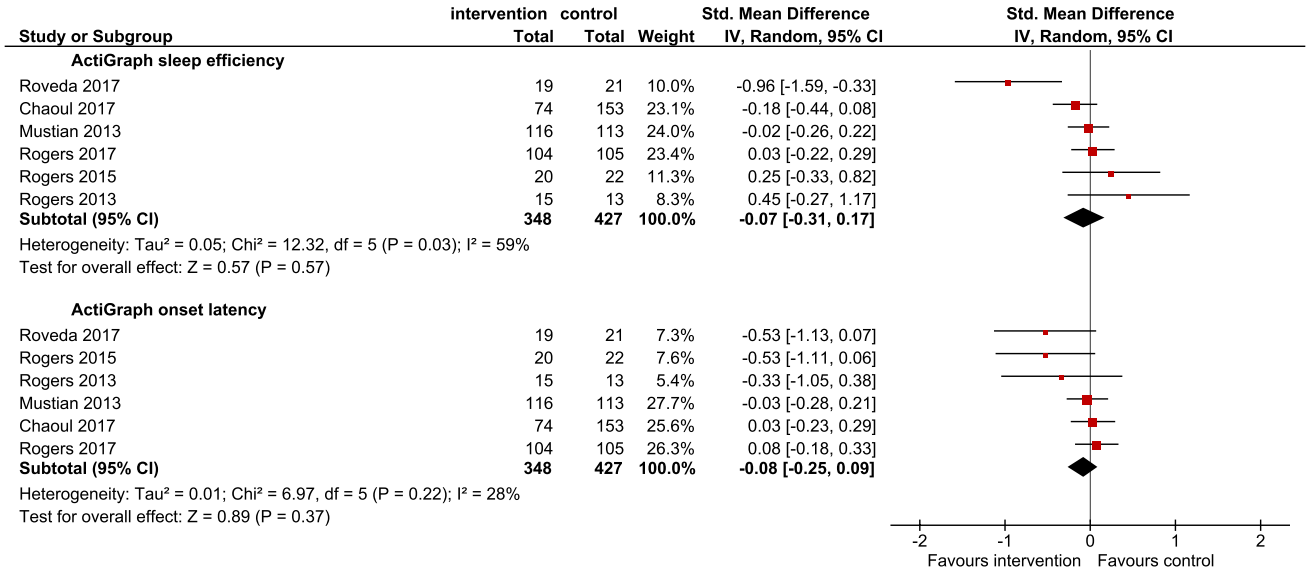


Fig. 7 Forest plots for objective measurement (ActiGraph)

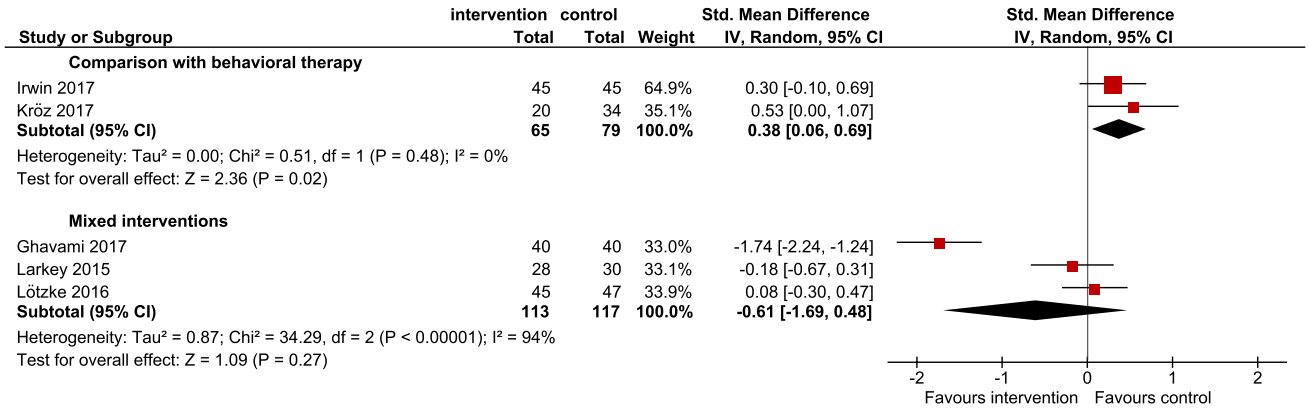


Fig. 8 Forest plots for studies comparing exercise with other interventions

sleep due to anxious thoughts or worries possibly might rather need psycho-oncological counselling in combination with a mind–body exercise, whereas patients who had engaged in exercise before their cancer diagnosis but now suffer from reduced physical functioning due to the cancer therapy might profit from a supervised, progressive physical exercise program. Future research should investigate more individualized interventions.

The mechanisms how exercise affects sleep are largely unclear. A meta-analysis showed that exercise is an effective intervention to control inflammation [45]. It is also known that sleep disorders are associated with inflammation [46, 47]. Thus, it is possible that the effects of exercise on sleep quality in women with breast cancer can be attributed to changes in inflammation [34]. Yet, the evidence is still limited. Within our meta-analysis, only four studies reported data on inflammation, with heterogeneity in results.

Strengths and limitations

Strengths of our analysis include the quantitative comparison of physical and mind–body exercise interventions in breast cancer patients both during and after therapy, the consideration of various sleep subscales, as well as the meta-analysis regarding objective sleep measures. A limitation of our analysis was that the training adherence in the included studies could not be clearly specified and compared. This would be of high relevance for concrete recommendations and the development of intervention strategies. Moreover, the number of studies was too low for in-depth analyses stratified by duration, intensity and

frequency of the exercise interventions. Further, in our quantitative analysis, five published studies could not be included as neither the relevant data could be extracted from the publication nor repeated requests to the authors yielded additional information. Of these five studies, four were studies with physical exercise interventions and one with mind–body exercise. However, the published results of the five studies were consistent with those of our meta-analysis. The studies concluded that walking during radiation therapy [48], walking during hormonal therapy [49], walking during adjuvant chemotherapy [50], and yoga after treatment [51] had positive effects on sleep in breast cancer patients. In addition to the self-reported sleep problems, one study also dealt with an objective sleep measurement and found a significantly shorter actual wake time and less movement in the exercise group [49].

Conclusion

Beneficial effects were found for a variety of interventions, treatment phases and settings. Thus, it might be worthwhile to clarify in future studies which type of intervention might be most effective depending on individual patients' and treatment characteristics. In addition, a better understanding of the different types of sleep problems as well as the best objective or subjective measures are needed.

Compliance of ethical standards

Conflict of interest Author KS has received research grants from the German Cancer Aid Foundation, awards from the Claudia-von-Schilling Foundation and Lilly Pharma Germany, as well as speaker and consulting honoraria from Pfizer Pharmaceuticals, BIC health insurance, Asklepios hospitals, and Adviva.

Research involving human participants and/or animals This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. Zhai L, Zhang H, Zhang D (2015) Sleep duration and depression among adults: a meta-analysis of prospective studies. Depress Anxiety 32:664–670
2. Rissling BM, Gray KE, Ulmer CS (2016) Sleep disturbance, diabetes, and cardiovascular disease in postmenopausal veteran women. Gerontologist 56:54–66
3. Ikehara S, Iso H, Date C (2009) Association of sleep duration with mortality from cardiovascular disease and other causes for Japanese men and women: the JACC study. Sleep 32:295–301
4. Suzuki E, Yorifuji T, Ueshima K (2009) Sleep duration, sleep quality and cardiovascular disease mortality among the elderly: a population-based cohort study. Prev Med 49:135–141
5. Sabanayagam C et al (2011) Insomnia symptoms and cardiovascular disease among older American Indians: the Native Elder Care Study. J Environ Public Health. https://doi.org/10.1155/2011/964617
6. Wang C et al (2017) Correlations between sleep patterns and cardiovascular diseases in a Chinese middle-aged population. Chronobiol Int 34:601–608
7. Kabeshita Y, Adachi H, Matsushita M (2017) Sleep disturbances are key symptoms of very early stage Alzheimer disease with behavioral and psychological symptoms: a Japan multi-center cross-sectional study. Int J Geriatr Psychiatry 32:222–230
8. Yaffe K, Laffan AM, Harrison SL (2011) Sleep-disordered breathing, hypoxia, and risk of mild cognitive impairment and dementia in older women. JAMA 306:613–619
9. Schmidt ME, Wiskemann J, Steindorf K (2018) Quality of life, problems, and needs of disease-free breast cancer survivors 5 years after diagnosis. Qual Life Res 27(8):2077–2086
10. Otte JL et al (2010) Prevalence, severity, and correlates of sleep-wake disturbances in long-term breast cancer survivors. J Pain Symptom Manag 39(3):535–547
11. Savard J et al (2001) Prevalence, clinical characteristics, and risk factors for insomnia in the context of breast cancer. Sleep 24(5):583–590
12. Savard J et al (2009) Breast cancer patients have progressively impaired sleep-wake activity rhythms during chemotherapy. Sleep 32(9):1155–1160
13. Savard J et al (2004) The association between nocturnal hot flashes and sleep in breast cancer survivors. J Pain Symptom Manag 27(6):513–522
14. Vargas S et al (2010) Sleep dysfunction and psychosocial adaptation among women undergoing treatment for non-metastatic breast cancer. Psychooncology 19(6):669–673
15. Liu L et al (2009) Pre-treatment symptom cluster in breast cancer patients is associated with worse sleep fatigue and depression during chemotherapy. Psychooncology 18(2):187–194
16. Bower JE (2014) Cancer-related fatigue—mechanisms, risk factors, and treatments. Nat Rev Clin Oncol 11:597–609
17. Mustian KM, Alfano CM, Heckler C, Kleckner AS, Kleckner IR, Leach CR, Mohr D, Palesh OG, Peppone LJ, Piper BF (2017) Comparison of pharmaceutical, psychological, and exercise treatments for cancer-related fatigue: a meta-analysis. JAMA Oncol 3:961–968
18. Brown JC, Huedo-Medina TB, Pescatello LS, Ryan SM, Pescatello SM, Moker E, LaCroix JM, Ferrer RA, Johnson BT (2012) The efficacy of exercise in reducing depressive symptoms among cancer survivors: a meta-analysis. PLoS ONE 7(1):e30955
19. Carayol M, Delpierre C, Bernard P, Ninot G (2015) Population-, intervention- and methodology-related characteristics of clinical trials impact exercise efficacy during adjuvant therapy for breast cancer: a metaregression analysis. Psychooncology 24:737–747
20. Wolin KY, Schwartz AL, Matthews CE, Courneya KS, Schmitz KH (2012) Implementing the exercise guidelines for cancer survivors. J Support Oncol 10:171–177
21. Mishra SI, Scherer RW, Snyder C, Geigle PM, Berlanstein, Topaloglu O (2012) Exercise interventions on health-related quality of life for people with cancer during active treatment (review). Cochrane Database Syst Rev 8:CD008465
22. Tomlinson D, Diorio C, Beyene J, Sung L (2014) Effect of exercise on cancer-related fatigue: a meta-analysis. Am J Phys Med Rehabil 93:675–686
23. Cramer H et al (2017) Yoga for improving health-related quality of life,mental health and cancer-related symptoms inwomen

diagnosed with breast cancer (review). Cochrane Database Syst Rev 1:CD010802
24. Matthews EE et al (2018) Effects of exercise on sleep in women with breast cancer: a systematic review. Sleep Med Clin 13:395–417
25. Nakano J et al (2018) Effects of aerobic and resistance exercises on physical symptoms in cancer patients: a meta-analysis. Integr Cancer Ther 17(4):1048–1058
26. Mercier J, Savard J, Bernard P (2017) Exercise interventions to improve sleep in cancer patients: a systematic review and meta-analysis. Sleep Med Rev 36:43–56
27. Higgins JPT, Green S (2011) Cochrane handbook for systematic reviews of interventions. [Cited 2018, 27 December]
28. Morris SB (2008) Estimating effect sizes from pretest-posttest-control group designs. Org Res Methods 11:364–386
29. Lötzke D et al (2016) 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, mindfulnesslife, spirituality, life satisfaction, and cancer-related fatigue. Evid Based Complem Altern Med. https://doi.org/10.1155/2016/5931816
30. Larkey LK et al (2015) Randomized controlled trial of Qigong/Tai Chi easy on cancer-related fatigue in breast cancer survivors. Ann Behav Med 49(2):165–176
31. Irwin MR et al (2017) Tai Chi Chih compared with cognitive behavioral therapy for the treatment of insomnia in survivors of breast cancer: a randomized, partially blinded noninferiority trial. J Clin Oncol 35:2656–2665
32. Kröz M et al (2017) Impact of a combined multimodal-aerobic and multimodal intervention compared to standard aerobic treatment in breast cancer survivors with chronic cancerrelated fatigue—results of a three-armed pragmatic trial in a comprehensive cohort design. BMC Cancer 17(1):166
33. Rogers LQ et al (2009) A randomized trial to increase physical activity in breast cancer survivors. Med Sci Sports Exerc 41(4):935–946
34. Rogers LQ et al (2015) Inflammation and psychosocial factors mediate exercise effects on sleep quality in breast cancer survivors: pilot randomized controlled trial. Psychooncology 24(3):302–310
35. Rogers LQ et al (2009) Physical activity and health outcomes three months after completing a physical activity behavior change intervention: persistent and delayed effects. Cancer Epidemiol Biomark Prev 18(5):1410–1418
36. Courneya KS et al (2014) Effects of exercise dose and type on sleep quality in breast cancer patients receiving chemotherapy: a multicenter randomized trial. Breast Cancer Res Treat 144:361–369
37. Ghavami H, Akyolcu N (2017) The impact of lifestyle interventions in breast cancer women after completion of primary therapy: a randomized study. J Breast Health 13:94–99
38. Mustian KM et al (2013) Multicenter, randomized controlled trial of yoga for sleep quality among cancer survivors. J Clin Oncol 31:3233–3241
39. Rogers LQ et al (2013) Effects of a physical activity behavior change intervention on inflammation and related health outcomes in breast cancer survivors: pilot randomized trial. Integr Cancer Ther 12(4):323–335
40. Rogers LQ, Courneya KS, Oster RA, Anton PM, Robbs RS, Forero A, Mcauley E (2017) Physical activity and sleep quality in breast cancer survivors: a randomized trial. Med Sci Sports Exerc 49:2009–2015
41. Sadeh A, Acebo C (2002) The role of actigraphy in sleep medicine. Sleep Med Rev 6(2):113–124
42. Madsen MT, Rosenber J, Gogenur I (2013) Actigraphy for measurement of sleep and sleep-wake rhythms in relation to surgery. J Clin Sleep Med 9(4):387–394
43. Sadeh A (2011) The role and validity of actigraphy in sleep medicine: an update. Sleep Med Rev 15(4):259–267
44. Chen D, Yin Z, Fang B (2018) Measurements and status of sleep quality in patients with cancer. Support Care Cancer 26:405–414
45. Meneses-Echavez JF et al (2016) The effect of exercise training on mediators of inflammation in breast cancer survivors: a systematic review with meta-analysis. Am Assoc Cancer Res 25(7):1009–1017
46. Milrad SF et al (2017) Poor sleep quality is associated with greater circulating pro-inflammatory cytokines and severity and frequency of chronic fatigue syndrome/myalgic encephalomyelitis (CFS/ME) symptoms in women. J Neuroimmunol 303:43–50
47. Irwin MR, Carrillo C, Olmstead R (2010) Sleep loss activates cellular markers of inflammation: sex differences. Brain Behav Immun 24(1):54–57
48. Mock V et al (1997) Effects of exercise on fatigue, physical functioning, and emotional distress during radiation therapy for breast cancer. Oncol Nurs Forum 24(6):991–1000
49. Payne JK et al (2008) Effect of exercise on biomarkers, fatigue, sleep disturbances, and depressive symptoms in older women with breast cancer receiving hormonal therapy. Oncol Nurs Forum 35(4):635
50. Yang CY et al (2010) Effects of a home-based walking program on perceived symptom and mood status in postoperative breast cancer women receiving adjuvant chemotherapy. J Adv Nurs 67(1):158–168
51. Carson JW et al (2009) Yoga of Awareness program for menopausal symptoms in breast cancer survivors: results from a randomized trial. Support Care Cancer 17:1301–1309
52. Bower JE et al (2012) Yoga for persistent fatigue in breast cancer survivors: a randomized controlled trial. Cancer 118(15):3766–3775
53. Chandwani KD et al (2010) Yoga improves quality of life and benefit finding in women undergoing radiotherapy for breast cancer. J Soc Integr Oncol 8(2):43–55
54. Chandwani KD et al (2014) Randomized, Controlled trial of yoga in women with breast cancer undergoing radiotherapy. J Clin Oncol 32(10):1058–1065
55. Chaoul A et al (2017) Randomized trial of Tibetan yoga in patients with breast cancer undergoing chemotherapy. Cancer 124(1):36–45
56. Chen Z et al (2013) Qigong improves quality of life in women undergoing radiotherapy for breast cancer. Cancer 119(9):1690–1698
57. Danhauer SC et al (2009) Restorative yoga for women with breast cancer: findings from a randomized pilot study. Psychooncology 18(4):360–368
58. Kiecolt-Glaser JK et al (2014) Yoga's impact on inflammation, mood, and fatigue in breast cancer survivors: a randomized controlled trial. J Clin Oncol 32(10):1040–1049
59. Roveda E et al (2017) Protective effect of aerobic physical activity on sleep behavior in breast cancer survivors. Integr Cancer Ther 16(1):21–31
60. Steindorf K et al (2017) Effects of exercise on sleep problems in breast cancer patients receiving radiotherapy: a randomized clinical trial. Breast Cancer Res Treat 163(3):489–499
61. Vardar Yağlı N et al (2015) 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 14(2):125–132

62. Vardar Yagli N, Ulger O (2015) The effects of yoga on the quality of life and depression in elderly breast cancer patients. Complement Ther Clin Pract 21(1):7–10
63. Vadiraja SH et al (2009) Effects of yoga on symptom management in breast cancer patients: a randomized controlled trial. Int J Yoga 2(2):73–79
64. Wang YJ et al (2011) Effects of a 6-week walking program on taiwanese women newly diagnosed with early-stage breast cancer. Cancer Nurs 34(2):E1–E13