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REVIEW

Impact of resistance training on fatigue among breast cancer patients undergoing chemotherapy: a systematic review and meta-analysis

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Abstract

Purpose The effects of aerobic exercise interventions for reducing fatigue after cancer treatment are well-established, and the effect of resistance training remains uncertain. Therefore, this systematic review and meta-analysis aim to analyze the effect of resistance training and combined resistance and endurance training on cancer-related fatigue (CRF) in breast cancer patients.

Methods A systematic search for randomized controlled trials (RCTs) was conducted on the PubMed, SPORTDiscus, Embase, and Cochrane databases, focusing on the effect of supervised resistance training and combined supervised resistance and endurance training on CRF. Random-effect models were employed for calculating the standardized mean difference (SMD). Risk of bias was assessed with risk of bias 2 (RoB2), and certainty of evidence was judged according to the GRADE approach.

Results A total of 9 RCTs with 1512 participants were included, and data from 866 participants in 8 RCTs were used for the meta-analysis. The risk of bias was deemed low in seven studies, while one study exhibited attrition bias, and one showed possible selection bias. Resistance training probably reduce the total fatigue (SMD= −0.30, 95% CI −0.52, −0.08, p=0.008), with individual studies showing small effects on physical and emotional CRF. A combined resistance and endurance training reduce total fatigue (SMD= −0.34, 95% CI −0.51, −0.17, p= 0.0001), with individual studies indicating moderate effects on physical fatigue, in daily life fatigue, and small effects on emotional and cognitive CRF.

Conclusion Both supervised resistance training and combined resistance and endurance training have a small effect on total CRF. There is a trend towards an influence of intensity, with higher intensity potentially resulting in lower total CRF.

Keywords Breast cancer · Cancer-related fatigue · Resistance training · Endurance training

Introduction

In the year 2022, 2.3 million people worldwide were diagnosed with breast carcinoma [1, 2]. The prognosis varies based on the cancer stage at the time of diagnosis, with a recurrence incidence after 5 years of less than 3% for patients in stage I and between 37 and 47% for those in stage III [3]. Treatment guidelines recommend a combination of surgery, chemotherapy, radiation therapy, and systemic adjuvant therapy [4]. These various medical interventions are associated with a multitude of adverse effects [5, 6]. One particularly burdensome side effect is cancer-related fatigue (CRF). CRF affects 56–95% patients with breast cancer during chemotherapy and is accompanied by impairments in daily life [7–9]. Moreover, CRF is characterized by excessive exhaustion unrelated to physical activity and disproportionate to prior efforts [10]. CRF combines physical symptoms with cognitive impairments, affecting concentration, attention, and daily motivation, while also encompassing emotional issues like exhaustion and mood swings [11, 12]. Forty percent of the patients continue to experience excessive fatigue after completion of therapy [8, 13]. The development of this side effect correlates with physical, psychological, social, cognitive, and behavioral factors [13]. Additionally, associations with physical activity have been identified, as well as links to mitochondrial dysfunction and dysregulation of the hypothalamus–pituitary–adrenal axis [8, 14–16].

Given these circumstances, the importance of physical activity during cancer treatment is increasingly emphasized.

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It could be demonstrated that higher levels of activity are associated with enhanced quality of life [17–20]. Resistance training, in particular, plays a significant role. It prevents the development or progression of sarcopenia [21] and triggers a transient change in sex hormones, insulin, inflammatory cytokines, and stress hormones [22]. Patients report on a personal level an improved subjective energy level and reduced stress [23]. Considering the current state of research, there is a clear endorsement of physical activity and training during chemotherapy, radiation therapy and even in cancer-survivorship [19, 20, 24]. This review focuses on chemotherapy, due to the extensive systematic side effects, especially on the muscular level [21], and the high prevalence rates of CRF. Patients undergoing chemotherapy often tend to reduce their physical activity, leading to a loss of muscle strength and alterations in the cross-sectional area of type I muscle fibers [15, 21]. Additionally, patients treated with anthracyclines exhibit lower strength and increased muscular fatigue, attributed to the mode of action causing muscle atrophy, a lower number of satellite cells, and a reduction in motor innervation [21, 25]. In the Cochrane review by Cramp and Byron-Daniel, while a reduction in fatigue was observed with aerobic training before and after cancer treatment, no clear statements regarding resistance training and its dosage were provided at that time [24]. A closer examination reveals that most studies on CRF interventions are conducted after the completion of medical treatment, despite the high prevalence during chemotherapy administration [7, 8, 14, 15, 26]. The aim of this work is to investigate the impact of resistance training and the combination of resistance and endurance training on the development or manifestation of CRF when the intervention is implemented during chemotherapy in breast cancer patients.

Methods

The execution and reporting of this systematic review adhere to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocol [27] and was registered in Prospero under the ID CRD42023444998.

Eligibility criteria

Randomized controlled trials (RCTs) investigating the impact of resistance training or combined resistance and endurance training on cancer-related fatigue (CRF) in breast cancer patients during chemotherapy are included. The study includes participants aged 18 to 85 undergoing neoadjuvant or adjuvant chemotherapy for breast cancer, across all stages, including metastases. Participants should have no contraindications for resistance training or the comparison intervention and must be physically and cognitively capable of following the supervising therapist. The intervention involves (a) supervised resistance training or (b) the combination of supervised resistance training and endurance training, with results compared with a control group. Exclusion criteria encompass participants under 18 or over 85 years, breast cancer survivors, other treatments (e.g., radiation or anti-hormone therapy, or combined chemotherapy and radiation), and any other cancer types (e.g., lung or colon cancer). Additionally, any intervention not involving supervised resistance training or the combination of resistance training with endurance training leads to exclusion. Non-RCT study formats and supervised endurance training only are excluded, as a meta-analysis by Medeiros Torres et al. has already covered the latter during chemotherapy [28]. All individual studies had received approval from their local ethics committees.

Search strategy

This systematic review includes studies published from 1994 until September 19, 2024. Systematic searches were conducted in PubMed/Medline, SPORTDiscus/EBSCO, Embase, and Cochrane databases until September 2024. No language limitations were applied. Reference lists of identified systematic reviews and meta-analyses were also examined for relevant RCTs [28, 40]. The search included all published studies from the inception of the database up until September 19, 2024.

Selection process

Two authors (OK, JL) independently conducted data searches and article selection according to inclusion criteria. Screening of titles was followed by abstract screening, removing irrelevant articles and duplicates. The authors then read the full text of pre-selected studies to assess whether inclusion criteria were met. Data from included studies were recorded in a spreadsheet. OK and JL independently extracted data from the included studies, and conflicts not attributable to extraction errors were resolved by KB.

Data extraction and analysis

During data collection, factors such as intervention groups, control groups, population characteristics divided in potential demographic moderators (including age, marital status) and potential clinical moderators (including weight or body mass index (BMI) and cancer stages), intervention factors (e.g., duration and intensity of the intervention), and fatigue scoring before and after the intervention were analyzed. Extracted information was used to create tables detailing the features of included studies and changes in CRF during interventions.

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Statistical analysis

For statistical analysis, data on CRF development for both intervention and control groups were extracted as the final mean at the end of the intervention, along with the corresponding standard deviation and the number of participants in each group. Studies not reporting data for the end of the intervention were not included in the meta-analysis, but individual values were reported narratively. The meta-analysis was performed using the RevMan Web program (The Cochrane Collaboration, 2022) [29]. The random effects model was utilized to calculate the standardized mean difference and the corresponding confidence interval, set at 95% CI. A significance level of $p < 0.05$ indicates a statistically significant difference. Heterogeneity was assessed using I^2, following Cochrane Handbook for Systematic Reviews categories, where I^2 values of 0%, 25%, 50%, and 75% represent no, low, moderate, and high heterogeneity, respectively. Results were pooled using the standardized mean difference (SMD) with a 95% confidence interval. An SMD of 0.2 represents a low effect, while an SMD of 0.5 indicates a moderate effect, and an SMD > 0.8 is considered large. If no effect size is reported in individual studies, the effect size is calculated using Cohen's d from the available data. Cohen's d is assessed similarly to the standardized mean differences. Studies using the Functional Assessment of Chronic Illness Therapy-Fatigue (FACIT-F) or the Functional Assessment of Cancer Therapy-Anemia (FACT-An) for assessment converted values to negative, as their scoring is inverse to the scoring of other assessments, where higher values indicate lower CRF.

Quality assessment

Methodological quality assessment is conducted using GRADE (Grading and Recommendations, Assessment, Development, and Evaluation). The following areas are evaluated: risk of bias (via RoB 2), indirectness, inconsistency, imprecision, reporting bias, effect size, dose–response relationship, and direction of residual confounding. Possible assessments include "very low," "low," "moderate," and "high."

Results

Study selection

The search resulted in a total of 769 articles across the specified databases. After removing duplicates, 388 studies remained for screening, where titles and abstracts were examined based on the defined inclusion and exclusion criteria. This led to the exclusion of 365 studies (see Fig. 1). After full-text screening, 9 RCTs were included in this systematic review [30–38] conducted in Canada (2007, 2013) [30, 31], Germany (2015, 2024) [32, 33, 37], Portugal [38], the Netherlands (2015) [34, 35], and Sweden (2018) [36]. All interventions were supervised.

Study characteristics

Overall, the review encompasses results from 1512 patients with an average age range of 49 to 56 years [30–38]. All studies assessed CRF values before, during and after ongoing chemotherapy. The meta-analysis includes data from 866 participants across 8 studies, as only the participants from the resistance training and control groups were included, reducing the total number of participants to 866 [30, 32–38]. Three studies also assessed fatigue levels after the end of chemotherapy [31, 35, 38]. The intervention periods ranged from 12 to 20 weeks [30, 32–34, 36, 37] or, in two studies, extended beyond the last chemotherapy cycle [31, 35].

Four studies examined resistance training [30, 32, 33, 37] compared with control groups, and five studies combined resistance training with endurance training [31, 34–36, 38]. Two studies implemented training education [35, 36]. Control groups received standard care [30, 33–35, 37, 38] or a combination of standard care with education [36]. One study used moderate endurance training as a control intervention [31]. Another study compared the effect of resistance training with muscle relaxation according to Jacobsen [32]. The characteristics of each study are presented in Table 1.

Outcome measurements

Different assessments were utilized in the included studies to analyze CRF. One study used the Fatigue Assessment Questionnaire [32]. The Multidimensional Fatigue Inventory (MFI) was used by three studies [33–35]. Two of the three author groups additionally used the Fatigue Quality List in conjunction with MFI [34, 35]. The remaining studies analyzed fatigue using the Functional Assessment of Cancer Therapy-Anemia Scale [30], Piper Fatigue Scale [36], Functional Assessment of Cancer Therapy, the European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire-Core 30 [37, 38], and the Trial Outcome Index-Fatigue [31]. Due to the diverse assessment methods, different fatigue values and domains are presented in the randomized studies. The authors captured values for total fatigue, physical fatigue, emotional/affective fatigue, and cognitive fatigue for this systematic review, as depicted in Tables 2 and 3. Due to the varied assessment methods, effect sizes are compared.

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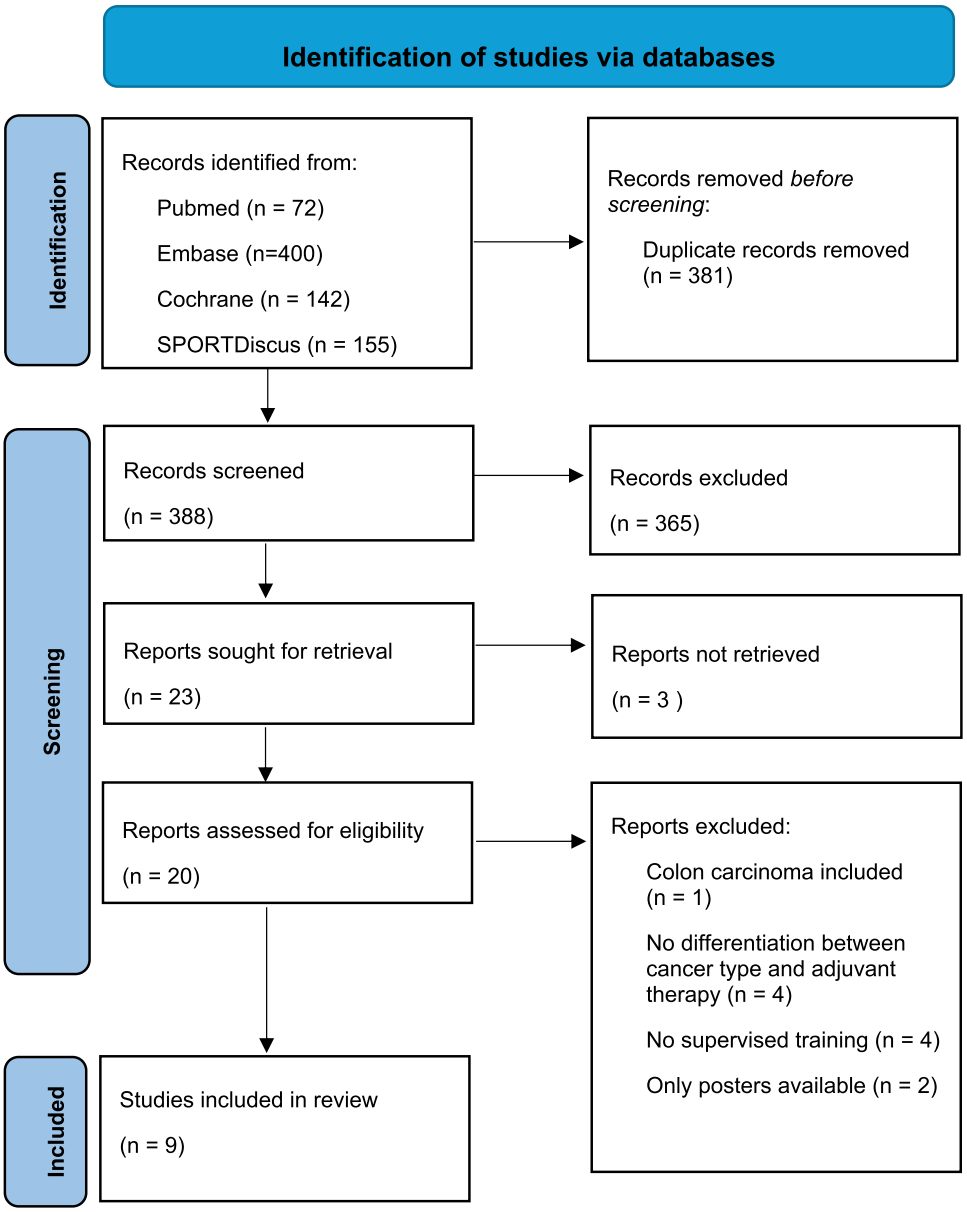
Fig. 1 Flowchart



Comparison of interventions

All studies differ in the dosage of resistance and endurance training (see Table 4). For example, Mijwel et al. employed higher-dose resistance training (70–80% of estimated one-repetition maximum (1 RM)) combined with 3 × 3 min high-intensity interval training (HIIT) at a rate of perceived exertion of 16–18 [36]. In contrast, Travier et al. used an intensity range of 45–75% of 1 RM combined with interval training changing in intensity below the ventilatory threshold [34]. Van Waart et al. implemented resistance training with 2 × 8 repetitions at 80% of 1 RM and 30 min of endurance training at 50–80% of maximum workload [35]. Courneya et al. dosed their combined resistance and endurance training with 2 sets of 10–12 repetitions at 60–75% of 1 RM and 75 min of aerobic endurance training per week [31]. The intensity of endurance training was not specified in this study [31]. In contrast to the others, Antunes et al. used the 12 repetition maximum for 3 sets in combination of an aerobic endurance training on 65 to 85% heart rate reserve [38]. In summary, two strategies were selected in the described studies [31, 34–36, 38]. On one hand, endurance training was conducted according to the HIIT (high-intensity interval training) principle with higher subjective exertion [36]. On the other hand, training at the aerobic threshold was chosen [31, 34, 35, 38]. Even in studies where resistance training alone was performed, the intensities varied, but they all fell within the hypertrophy and strength gain range [30, 32, 33]. Schmidt et al. conducted resistance training

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Table 1 Study characteristics

Study	Participants	Inclusion/exclusion	Demographic moderators	Clinical moderators	Intervention period	Study arms	Training parameters	In meta-analysis included
Gerland et al. 2024 [37]	40	- Women, ≥ 18 years - Operation within 6–12 weeks before inclusion - ECOG performance status < 2 - written informed consent - Ability to understand study protocol and questionnaires Excluded when: - Severe cardiac or cardiovascular disease - Severe chronic diseases prohibiting physical activity - Intense physical activity more than 2 h/week apart from intervention - Metastases - Substance abuse - No legal competence	Age, years (range) - IG 48.55 (28–68) - CG 47.35 (25–68)	BMI (kg/m^2) - IG 22.79 - CG 24.69 Breast cancer Stages 0 10% I 50% II 32.5% III 5% IV 2.5%	12 weeks	I CG	2×/week, 45–60 min 10-min warm-up, 7 exercises à 1 × 10–15 reps followed by 2 × 8–12 @ 70–80% h1RM	Yes

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Table 1 (continued)

Study	Participants	Inclusion/exclusion	Demographic moderators	Clinical moderators	Intervention period	Study arms	Training parameters	In meta-analysis included
Antunes et al. 2023 [38]	93	- Women ≥ 18 years old - Stage IA–IIIC breast cancer - Neoadjuvant or adjuvant chemotherapy - Follow-up at the Medical Oncology clinic at the CHVNG/E - Consent of the assistant oncologist for the practice of exercise - Able to provide informed consent - Acceptance of randomization to intervention group or control group Excluded when: - Contraindications to maximal exercise testing - Decompensated diabetes mellitus - Severe anemia (hemoglobin < 8 g/dL) uncorrectable with transfusion and/or iron and/or vitamin deficiency replacement - Pregnancy - Known significant heart disease (myocardial infarction, congestive heart failure, cardiomyopathy) - Usual medication containing beta-blockers	Age, years - I 49.66 ± 9.43 - UC 51.02 ± 9.54	BMI (kg/m^2) - I 26.94 ± 4.32 - UC 28.69 ± 6.82 Breast cancer stages I 15.1% II 50.5% III 34.4%	20 weeks after first assessment	I UC	5–10-min warm-up, combined resistance and endurance training, 5 min cool down Aerobic training: 20–30 min, adding 3 min every 2 w after 2 w with 20-min endurance training @ 65–85% of HRR Resistance training: 10 exercises, 2 × 10 @ lowest load increasing to 3 × 12 RM	yes

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Table 1 (continued)

Study	Participants	Inclusion/exclusion	Demographic moderators	Clinical moderators	Intervention period	Study arms	Training parameters	In meta-analysis included
Mijwel et al. 2018 [36]	240	- Women, 18–70 years old - I–IIIa breast cancer - Planned chemotherapy Excluded when: - Advanced diseases - Heart/lung disease, cognitive dysfunction - Not Swedish speaking	Age, years - RT-HIIT 52.7 ± 10.3 - AT-HIIT 54.4 ± 10.3 - UC 52.6 ± 10.2 Married or partnered RT-HIIT 60.6% AT-HIIT 59.7% UC 69.6% Tertiary education RT-HIIT 67.6% AT-HIIT 64.7% UC 66%	Weight, kg RT-HIIT 68.7 ± 11.3 AT-HIIT 67.7 ± 13.0 UC 69.1 ± 11.0 Breast cancer stages I–IIIa	16 weeks	AT-HIIT RT-HIIT UC + Education	RT-HIIT: 2×/week 60 min, 8 exercises à 2 × 8–12 Reps @ 70–80% 1 hRM + 3 × 3 min HIIT RPE 16–18, 1 min active or passive pause AT-HIIT: 20-min endurance training RPE 13–15, 3 × 3 min HIIT RPE 16–18, 1-min active or passive pause	yes
Van Waart et al. 2015 [35]	230	- Histologically confirmed primary breast cancer - Chemotherapy scheduled Excluded when: - Serious orthopedic, cardiovascular, cardiopulmonary conditions - Suffering from malnutrition—Serious psychiatric or cognitive problems- Not fluent in Dutch	Age, years 50.7 ± 9.1 Single/divorced/widow OnTrack 18% Onco-Move 17% UC 15% Married/living together OnTrack 58% Onco-Move 60% UC 62% Tertiary education OnTrack 61% Onco-Move 54% UC 50%	Breast cancer stages I 6% II 47% III 47%	Before to 3 weeks after the end of chemotherapy	- OnTrack - Onco-Move - UC	- OnTrack: 2×/W, 10 min 6 muscle groups à 2 × 8 reps @ 80% 1RM, + 30-min endurance training @ 50–80% workload (max) - Onco-Move: Home exercise, low Intensity, at least 30-min physical activity 5×/week	yes

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Table 1 (continued)

Study	Participants	Inclusion/exclusion	Demographic moderators	Clinical moderators	Intervention period	Study arms	Training parameters	In meta-analysis included
Travier et al. 2015 [34]	204	- Age 25–75 years - Breast cancer diagnosis < 6 weeks, stage M0 - Scheduled for chemotherapy - No treatment for any other cancer in the last 5 years - No contraindication for physical exercise - Dutch speaking - Karnofsky Performance Status ≥ 60	Age, years I 49.7 ± 8.2 UC 49.5 ± 7.9 Couple I 77.5% UC 74.5% Single I 19.6% UC 19.6% Tertiary education 40.6%	Weight, kg I 72.8 ± 13.2 UC 76.0 ± 15.4 BMI, kg/m^2 I 25.8 ± 4.4 UC 26.6 ± 5.2	18 weeks	- I - UC	- I: Endurance: 3 × 2 min—2 × 7 min or 3 × 4 min decreasing to 1 × 7 min HR under ventilatory threshold, 2 ×/week - I: resistance training: major muscle groups 2 × 10 Reps @ 65% 1 RM to 1 × 10 @ 75% 1RM + 1 × 20 @ 45% 1RM, 2 ×/week	yes
Courneya et al. 2013 [31]	301	- English/French-speaking non-pregnant women, Age ≥ 18 years - Breast cancer stage I–IIIc - Initiating adjuvant chemotherapy Excluded when: - Incomplete axillary surgery - Transabdominal rectus abdomens muscle reconstruction - Uncontrolled hypertension, cardiac or psychiatric illness	Age, years STAN 49.2 ± 8.4 HIGH 50.1 ± 8.8 COMB 50.5 ± 9.4 Married STAN 61.5% HIGH 63.4% COMB 68.3% tertiary education STAN 60.4% HIGH 67.3% COMB 66.3%	Weight, kg STAN 70.8 ± 15.2 HIGH 69.4 ± 13.2 COMB 75.2 ± 17.7 BMI, kg/m^2 STAN 26.5 ± 5.5 HIGH 26.0 ± 4.9 COMB 25.2 ± 4.5 Breast cancer stages I 33.6% IIa 34.2% IIb 21.9% IIIa 10.3%	1–2 weeks before until 3–4 weeks after chemotherapy	HIGH COMB STAN	STAN: 75 min/week on 3 days 55–75% VO2 peak - HIGH: 150 min/Week aerobic exercise 55–75% VO2 peak - COMB: 75 min/week endurance training, 9 exercises à 2 × 10–12 Reps @ 60–75% 1RM 25–30-min endurance training + 30–35-min resistance training	No

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Table 1 (continued)

Study	Participants	Inclusion/exclusion	Demographic moderators	Clinical moderators	Intervention period	Study arms	Training parameters	In meta-analysis included
Schmidt et al. 2015 [32]	95	- Histological confirmed primary breast cancer after lumpectomy/mastectomy - Age ≥ 18 years, BMI ≥ 18 kg/m^2 - Ability to understand and follow study protocol - Willingness to come to Heidelberg Excluded when: - Contraindication for resistance training with other concurrent malignant disease - Already participating in systematic intensive resistance or aerobic training (> 1 h twice/week)	Age, years EX 52.2 ± 9.9 RC 53.5 ± 10.2	BMI (kg/m^2) EX 25.7 ± 4.6 RC 26.3 ± 4.9 Breast cancer stages I 38.9% II 43.2% III 15.5% IV 2.1%	12 weeks	EX RC	- EX: 2×/week, 60 min, 8 exercises à 3 × 8–12 reps @ 60–80% 1RM - RC: 2×/week, 60-min relaxation exercises	yes
Schmidt et al. 2015 [33]	67	- Primary moderate- or high risk- breast cancer - Initiating chemotherapy without taxane and Herceptin - Age 18–70 years - Physician clearance to exercise Excluded when: - Acute infectious disease, NYHA III, myocardial infection < 3 months, pulmonary or renal insufficiency, neurological disorders - < 10,000 platelets, < 8 g/dl hemoglobin - Radiation therapy	Age, years RT 53 ± 12.55 ET 56 ± 10.15 SC 54 ± 11.19	Weight RT 74.8 ± 15.83 ET 72.1 ± 12.35 SC 76.3 ± 15.40	12 weeks	RT ET SC	- RT: 2×/week, 60-min 10 exercises à 20 Reps @ 50% h1RM - ET: 2×/week, 45 min, stationary bike, 10-min warm-up, 25–30 min Borg 11–14, 5-min cool down	yes

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Table 1 (continued)

Study	Participants	Inclusion/exclusion	Demographic moderators	Clinical moderators	Intervention period	Study arms	Training parameters	In meta-analysis included
Courneya et al. 2007 [30]	242	- English-/French-speaking non-pregnant women, Age ≥ 18 years - Breast cancer stage I–IIIa - Beginning of first-line adjuvant chemotherapy Excluded when: - Incomplete axillary surgery - Transabdominal rectus abdominal muscle reconstruction - Uncontrolled hypertension, cardiac, or psychiatric illness	Age, years - 49.2 (range 25–78) Married STAN 63.6% RET 57.3% AET 71.8% Tertiary education STAN 64.6% RET 62.2% AET 65.4%	Weight (kg) - 70.6 ± 14.3 BMI (kg/m^2) - 26.6 ± 5.5 Breast cancer stages I 24.8% II a 40.9% II b 19.8% III a 14.5%	17 weeks ± 4 (95% CI, 9 to 24)	- AET - RET - UC	- AET: 3 ×/week endurance training @ 60% VO2max week 1–6, 70% week 7–12, 80% after week 12 Start 15 min, increase by 5 min every 3 weeks up to 45 min in week 18 - RET: 3 ×/week, 9 exercises à 2 × 8–12 reps @ 60–70% 1 RM	yes

W, weeks; *d*, days; *reps*, repetitions; *1 RM*, one-repetition maximum; *ES*, effect size; *RPE*, rate of perceived exertion; *HF*, heart rate; *EX*, exercise group; *RC*, relaxation group; *RET*, resistance training; *AET*, endurance training; *UC*, usual care; *RT-HIIT*, resistance training combined with high-intensity interval training; *AT-HIIT*, endurance training combined with high-intensity interval training; *I*, intervention group; *STAN*, moderate intensity endurance training; *HIGH*, high-intensity endurance training; *COMB*, combined endurance and resistance training; *RT*, resistance training; *ET*, endurance training; *UC*, usual care; *HRR*, heart rate reserve

with 3 sets of 8–12 repetitions at 60–80% of 1 RM [32]. Schmidt, Weisser et al. investigated the intervention with a load of 10 exercises, each with 20 repetitions at 50% of hypothetical 1 RM [33]. Courneya et al. dosed their resistance training with 2 sets of 8–12 repetitions at 60–70% of estimated 1 RM [31], and Gerland et al. used an intensity of one set of 10 to 15 reps followed by 2 sets of 8–12 reps at 70 to 80% h1RM [37].

Comparison of effect sizes

Overall, six studies reported effect sizes for the conducted interventions [30–32, 34–36]. One study only presents outcome numbers of the Multidimensional Fatigue Inventory (MFI) pre- and post-testing [31]. Another study presented only the post-test results of the EORTC QLQ-C30 without any effect size [37, 38]. Regarding the comparison of effect sizes, the included studies were divided into two groups: the first analysis group comprises studies with resistance training as the conducted intervention [30, 32, 33, 37], and the second analysis group includes all randomized studies that conducted a combination of resistance and endurance training [31, 34–36, 38].

Effects of resistance training

In total, four out of the nine studies implemented resistance training [30, 32, 33, 37], of which three studies determined the adjusted mean change for total fatigue [30, 32, 37], and one study assessed physical, emotional/affective, and cognitive fatigue [32]. While one study achieved a small effect (ES = 0.45) regarding total fatigue [32], the effect of the second study was very small (ES = 0.12) [30]. The third study did not report any effect size [37]. In the intergroup comparison, the three studies did not show significant differences. Combining the effect sizes for total fatigue results in an overall effect of ES = − 0.30 (95% CI − 0.52 to − 0.08) (see Fig. 2). Examining the individual effect of resistance training on physical fatigue revealed a significant difference ($p = 0.05$) between the intervention group and the control group, with a small effect on physical fatigue (ES = 0.45). However, very small effects (ES = 0.3 and ES = 0.08) and no statistical significance ($p = 0.41$ and $p > 0.99$) were reported for emotional/affective fatigue and cognitive fatigue, respectively [32] (see Table 2). Due to insufficient data, no meta-analysis was conducted for these domains.

Effects of combined resistance and endurance training

In total, five studies implemented a combined intervention of resistance and endurance training [31, 34–36, 38]. Each of the five studies investigated total fatigue, while

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Table 2 Effects of resistance exercise

Study	Outcome	Assessment				Total fatigue Mean ± SD					
						Baseline	Postintervention				Adjusted mean difference Mean 95% CI, p, ES
Gerland et al. 2024 [37]	CRF	- EORTC.-QLQC30			IG CG		−8.8 ± 26.6 3.5 ± 32.9				$p = 0.214$
Schmidt et al. 2015 [32]	CRF	- Fatigue Assessment Questionnaire			EX RC	36.4 ± 19.2 41.0 ± 21.1	36.1 ± 20.6 44.8 ± 21.0				EX vs RC − 5.8 (− 12.6 to 1.1) $p = 0.098$, ES = 0.45
Schmidt et al. 2015 [33]	CRF	- Multidimensional Fatigue Inventory			RT ET SC	9.25 ± 3.09 8.76 ± 4.31 9.54 ± 3.35	10.55 ± 3.22 12.35 ± 4.37 12.38 ± 3.50				
Courneya et al. 2007 [30]	CRF	- Functional Assessment of Cancer Therapy-Anemia Scale			RET AET UC	34.3 ± 10.1 35.3 ± 12,1 34.6 ± 11.1	36.3 ± 9.4 36.8 ± 10.4 34.9 ± 12.5				RET vs UC 1.7 (− 1.8 to 5.2) $p = 0.338$, ES = 0.12
		Physical fatigue Mean ± SD			Emotional/affective fatigue Mean ± SD			Cognitive fatigue Mean ± SD			
		Baseline	Postintervention	Adjusted mean difference Mean, 95% CI, p, ES	Baseline	Postintervention	Adjusted mean difference Mean 95% CI, p, ES	Baseline	Postintervention	Adjusted mean difference Mean 95% CI, p, ES	
Gerland et al. 2024 [37]											
Schmidt et al. 2015 [32]	EX	40.4 ± 24.5	39.9 ± 25.0	EX vs RC − 8.1 (− 16.3 to 0.1) $p = 0.052$, ES = 0.45	29.2 ± 21.9	26.8 ± 23.5	EX vs RC − 3.0 (− 10.2 to 4.2) $p = 0.41$, ES = 0.3	30.2 ± 25.3	34.9 ± 25.1	EX vs RC 0.0 (− 9.7 to 9.7), $p \geq 0.99$, ES = 0.08	
	RC	42.9 ± 23.8	49.4 ± 22.7		40.0 ± 28.0	37.9 ± 27.1		34.8 ± 28.1	37.0 ± 27.6		
Schmidt et al. 2015 [33]											
Courneya et al. 2007 [30]	RET										
	AET										
	UC										

CRF, cancer-related fatigue; *EORTC-QLQ 30*, European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire-Core 30; *SD*, standard deviation; *ES*, effect size; *EX*, exercise group; *RC*, relaxation group; *RET*, resistance training; *AET*, endurance training; *UC*, usual care; *RT*, resistance training; *ET*, endurance training

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Table 3 Effects of a combined resistance and endurance training

Study	Outcome	Assessment		Total fatigue Mean ± SD			Physical fatigue Mean ± SD		
				Baseline	Postintervention	Adjusted mean difference Mean 95% CI, *p*, ES	Baseline	Postintervention	Adjusted mean difference Mean, 95% CI, *p*, ES
Antunes et al. 2023 [38]	CRF	- EORTC-QLQC30	I	24.34 ± 18.18	30.30 ± 21.87	I vs UC − 20.19 (− 29.74 to − 10.63), $p < 0.001$			
			UC	17.77 ± 18.41	43.63 ± 25.01				
Mijwel et al. 2018 [36]	CRF	- Piper Fatigue Scale	RT-HIIT	3.09 ± 3.17	3.16 ± 2.92	RT-HIIT vs UC − 1.17 (− 2.18 to − 0.16), $p = 0.02$, ES = − 0.51	3.24 ± 3.23	3.31 ± 3.07	RT-HIIT vs UC − 1.22 (− 2.33 to − 0.11), $p = 0.03$, ES = − 0.48
			AT-HIIT	2.10 ± 2.63	3.16 ± 2.61	AT-HIIT vs UC − 0.72 (− 1.73 to 0.30), $p = 0.02$, ES = − 0.26	2.27 ± 2.87	3.48 ± 2.96	AT-HIIT vs UC − 0.64 (− 1.76 to 0.49), $p = 0.03$, ES = − 0.13
			UC	2.30 ± 2.81	3.94 ± 2.95		2.64 ± 3.15	4.25 ± 3.21	
Van Waart et al. 2015 [35]	CRF	- Multidimensional Fatigue Inventory—Fatigue Quality List	OnTrack	10.6 ± 4.1	13.1 ± 3.9	OnTrack vs UC − 1.3 (− 2.5 to − 0.1), $p = 0.041$, ES = 0.29 Onco-Move vs UC − 0.7 (− 1.8 to 0.5), $p = 0.25$, ES = 0.17	10.0 ± 4.0	11.7 ± 4.2	OnTrack vs UC − 2.7 (− 4.0 to − 1.4), $p \leq 0.001$, ES = 0.63
			Onko-Move	10.6 ± 3.8	13.7 ± 3.9		9.9 ± 3.5	13.3 ± 4.7	Onco-Move vs UC − 1.1 (− 2.4 to 0.2), $p = 0.10$, ES = 0.28
			UC	11.7 ± 4,4	14.7 ± 4.2		11.1 ± 4.5	14.7 ± 4.4	
Travier et al. 2015 [34]	CRF	- Multidimensional Fatigue Inventory - Fatigue Quality List	I	10.1 ± 4.3		I vs UC − 1.0 (− 2.1 to 0.1), ES = − 0.23	9.9 ± 4.3		I vs UC -1.3 (− 2.5 to − 0.1), ES = − 0.30
			UC	10.6 ± 4.1			10.6 ± 4.1		
Courneya et al. 2013 [31]	CRF	- Functional Assessment of Cancer Therapy	STAN	40.4 ± 9.3		COMB vs STAN + 0.8 (− 1.3 to 3.0), $p = 0.44$			
			HIGH	40.6 ± 9.4		HIGH vs COMB + 1.0 (− 1.2 to 3.1) $p = 0.36$			
			COMB	40.7 ± 10.2					
		- Trial outcome index-fatigue	STAN	82.8 ± 14.9		COMB vs STAN + 0.4 (-3.5 to 4.2), $p = 0.84$			
			HIGH	82.8 ± 17.8		HIGH vs COMB + 3.0 (-0.8 to 6.8), $p = 0.12$			
			COMB	83.7 ± 18.5					
Study		Behavior/ daily life fatigue Mean ± SD				Emotional/affective fatigue Mean ± SD		Cognitive fatigue Mean ± SD	

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Table 3 (continued)

		Baseline	Postintervention	Adjusted mean difference Mean 95% CI, *p*, ES	Baseline	Postintervention	Adjusted mean difference Mean, 95% CI, *p*, ES	Baseline	Postintervention	Adjusted mean difference Mean 95% CI, *p*, ES
Mijwel et al. 2018 [36]	RT-HIIT AT-HIIT UC	3.10 ± 3.39 1.87 ± 2.57 2.04 ± 2.79	3.07 ± 3.20 2.99 ± 2.74 3.98 ± 3.19	RT-HIIT vs UC − 1.46 (− 2.55 to − 0.37), $p < 0.01$, ES = − 0.62 AT-HIIT vs UC 0.96 (-2.05 to 0.14) $p < 0.0$, ES = − 0.30	3.28 ± 3.43 2.37 ± 2.98 2.45 ± 3.01	3.48 ± 3.21 3.72 ± 3.04 4.21 ± 3.11	RT-HIIT vs UC − 1.10 (− 2.26 to 0.06), $p = 0.07$, ES = -0.46 AT-HIIT vs UC − 0.49 (− 1.66 to 0.68), $p = 0.07$, ES = 0.13	2.79 ± 2.95 1.88 ± 2.51 2.15 ± 2.70	2.85 ± 2.74 2.60 ± 2.25 3.41 ± 2.78	RT-HIIT vs UC − 0.89 (− 1.81 to 0.03), $p = 0.05$, ES = − 0.42 AT-HIIT vs UC − 0.70 (− 1.63 to 0.23), $p = 0.05$, ES = − 0.08
Van Waart et al. 2015 [35]	OnTrack Onko-Move UC							9.3 ± 4.3 9.7 ± 4.0 10.8 ± 4.9	10.5 ± 4.0 11.3 ± 4.6 11.8 ± 4.8	OnTrack vs UC − 0.4 (− 1.6 to 0.7), $p = 0.44$, ES = 0.10 Onco-Move vs UC 0.0 (− 1.2 to 1.2), $p = 0.95$, ES = 0.01
Travier et al. 2015 [34]	I UC							9.8 ± 4.0 10.2 ± 4.1		I vs UC 0.0 (− 1.2 to 1.2) ES = 0.01
Courneya et al. 2013 [31]	STAN HIGH COMB									

CRF, cancer-related fatigue; *SD*, standard deviation; *ES*, effect size; *RT-HIIT*, resistance training combined with high-intensity interval training; *AT-HIIT*, endurance training combined with high-intensity interval training; *UC*, usual care; *I*, intervention group; *STAN*, moderate intensity endurance training; *HIGH*, high-intensity endurance training; *COMB*, combined endurance and resistance training; *EORTC-QLQ 30*, European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire-Core 30*Intervention*

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Table 4 Intervention characteristics

Study		Frequency	Duration	Intensity	Number of exercise
Gerland et al. 2024 [37]	RT	2×/week	45-60 min	10-min warm-up 1×10 – 15 reps followed by 2×8–12 @ 70–80% h1RM	7
Antunes et al. 2023 [38]	RT + AT	3×/week	Unknown	5–10-min warm-up, 5-min cool down 20–30 min, @ 65–85% of HRR + 2×10 @ lowest load increasing to 3×12RM	10 + AT
Mijwel et al. 2018 [36]	RT + AT	2×/week	1 h	2×8–12 reps @ 70– 80% h1RM + 3×3 min HIIT RPE 16–18	8 + HIIT
Van Waart et al. 2015 [35]	RT + AT	2×/week	40 min	2×8 reps @ 80% h1RM + 40 min endurance @ 50–80% max workload	6 + AT
Travier et al. 2015 [34]	RT + AT	2×/week	Unknown	2×10 reps @65% up to 1×10 @ 75% 1 RM and1×20 @ 45% 1 RM + HR over (3×2 min to2×7 min) and under (3×4 min to 1×7) ventilatory threshold	Major muscle groups + endurance training
Schmidt et al. 2015 [32]	RT	2×/week	1 h	3×8–12 reps @ 60–80% 1 RM	8
Schmidt et al. 2015 [33]	RT	2×/week	1 h	20 reps @ 50% h1RM	10
Courneya et al. 2013 [31]	RT + AT	75 min AT/week	approx. 60 min	2×10–12 reps @ 60—75% 1 RM + 25–30-min aerobic training at 55–75% VO2 peak	9
Courneya et al. 2007 [30]	RT	3×/week	Unknown	2×8–12 reps @ 60–70% h1RM	9

Reps, repetitions; *h1RM*, hypothetical one repetition maximum; *min*, minutes; *HIIT*, high-intensity interval training; *RPE*, rate of perceived exertion; *RT*, resistance training; *AT*, aerobic training; *VO2peak*, peak oxygen uptake

three studies additionally examined physical and cognitive fatigue [31, 34–36, 38]. Furthermore, one of the five included studies analyzed daily life or behavior-related and emotional/affective fatigue [36]. Regarding total fatigue, one study only provides baseline values before the intervention, making it impossible to calculate effect size and therefore could not be included in the meta-analysis [31]. Combining the effects for total fatigue yields an effect size of ES = − 0.34 (95% CI − 0.51 to − 0.17) (see Fig. 3). Comparing the effect sizes of the combined resistance and endurance training interventions of the other three studies with control groups reveals an effect size range from ES = − 0.23 [34] to ES = − 0.51 [36].

Two studies analyzed the effect of combined resistance and endurance training on physical fatigue [35, 36] (see Table 3). Statistically significant changes were achieved with small (ES = − 0.48; $p = 0.03$) to moderate effects (ES = 0.63, $p < 0.001$) [35, 36]. Regarding daily life-related or behavior-related fatigue, a moderate effect with ES = − 0.62 ($p < 0.01$) was achieved. When considering emotional/affective fatigue, the effect was lower (ES = − 0.46; $p = 0.07$), as was the effect on cognitive fatigue (ES = − 0.42; $p = 0.05$ and ES = 0.1; $p = 0.44$) [34, 35] (see Table 3). Due to the limited amount of data and studies investigating physical, emotional, and cognitive fatigue, no meta-analysis was conducted for these subgroups.

Side effects of the intervention

Four studies reported no unwanted effects during training [31, 32, 35, 36]. In four studies, no information regarding unwanted side effects could be extracted [33, 34, 37, 38]. In Courneya et al.'s study, participants reported various side effects, including dizziness, hypotension, nausea, weakness, and mild diarrhea, from which they quickly recovered [30]. They were all able to continue the study after the symptoms had subsided [30].

Certainty and risk of *bias*

For the GRADE assessment, a total of nine studies were included, divided into a resistance training group [30, 32, 33, 37] and a combined resistance and endurance training group [31, 34–36, 38]. Limitations were imposed due to a wide confidence interval and a low to moderate participant count (see Table 5). The risk of bias was not considered severe. Due to the nature of training interventions, blinding of participants or intervention-conducting personnel is not possible. In seven

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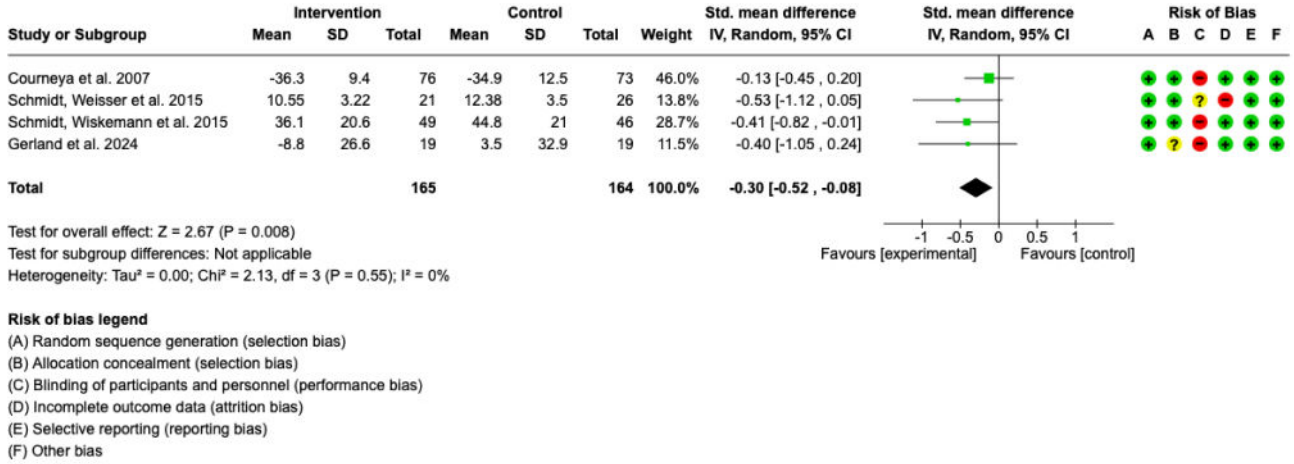

Fig. 2 Effects of resistance training on total fatigue

out of nine studies, an intention-to-treat analysis was planned despite a high dropout rate [30–32, 34–36, 38], with two studies lacking this information [33, 37]. Due to the conducted education in two studies, a potential educational bias can be suspected, which could bias the results in a positive direction [35, 36]. Overall, the certainty was judged as low.

Discussion

Our meta-analysis of 8 included studies, comprising a total of 866 breast cancer patients, revealed a low effect on the development and severity of overall cancer-related fatigue (CRF) compared with control groups. Importantly, there seems to be little difference between supervised resistance training and supervised combined resistance and endurance training. These findings align with results from other systematic reviews and meta-analyses. For instance, the systematic review by van Vulpen et al. in 2016, which analyzed the effects of resistance training and/or endurance training similar to our review, showed a significant low effect size of SMD = − 0.22 (95% CI, − 0.38 to − 0.05) [39]. Their review included 5 clinical studies with 784 participants [39]. Similarly, Furmaniak et al. achieved a comparable outcome in their review in 2016, encompassing 19 studies with 1698 women performing resistance and/or endurance training, calculating an effect size of ES = − 0.28 (95% CI, − 0.41 to − 0.16; $p < 0.00001$) [40]. On the contrary, Medeiros Torres et al. demonstrated in their systematic review in 2022 a slightly higher effect for supervised resistance training

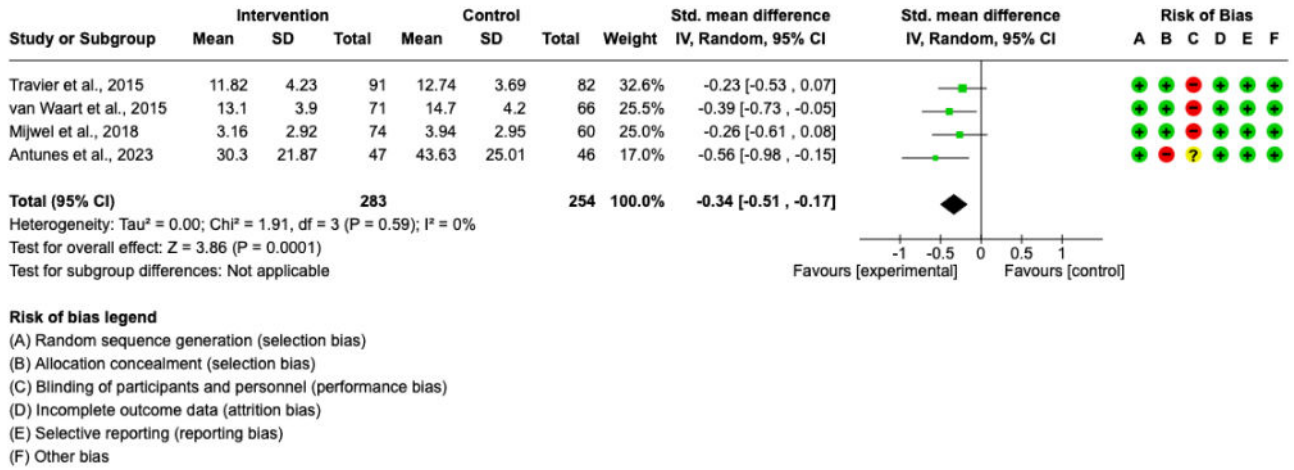

Fig. 3 Effects of combined resistance and endurance training on total fatigue

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Table 5 Study quality

Certainty assessment							№ of participants		Effect	Certainty
№ studies	Study-design	Risk of bias	Inkonsistency	Indirectness	Imprecision	Other	Particpant intervention	Controlgroup	Absolut (95% CI)	
Combined resistance and endurance training										
5	RCT	No serious risk of bias	No serious inconsistency	Serious[a]	Serious[a]	none	387	350	SMD **0.34 SD less** (0.51 less to 0.17 less)	⨁⨁◯◯ low
Resistance training										
4	RCT	No serious risk of bias	No serious inconsistency	Serious[b]	serious[b]	none	165	164	SMD **0.30 SD less** (0.52 less to 0.08 less)	⨁⨁◯◯ low

CI confidence interval, *SMD* standardized mean difference. Explanations: [a]Wide confidence interval, moderate sample size. [b]Wide confidence interval, low sample size

(SMD = − 0.30, 95% CI, − 0.46 to − 0.15, $p = 0.000$) and a much larger effect for combined resistance and endurance training (SMD = − 1.13, 95% CI − 2.09 to − 0.17, $p = 0.021$) on fatigue [28]. It is noteworthy that Medeiros Torres et al. included both chemotherapy and radiation therapy in the analysis of supervised resistance training and combined the effect of resistance and endurance training with mind–body exercises. Consequently, their meta-analysis comprises a larger number of included studies ($n = 20$) and participants ($n = 1793$) [28], differing from our meta-analysis, where we focused on supervised resistance training or the combination of supervised resistance and endurance training during chemotherapy, resulting in a more homogeneous number of participants and studies. The presented effects primarily pertain to total fatigue, as the limited available data did not allow for a meta-analysis regarding physical, emotional, cognitive, or daily life-related fatigue. However, upon examining the effects of individual studies, supervised combined resistance and endurance training seems to outperform supervised resistance training alone. The intervention group in the study by van Waart et al. exhibited a lower increase in fatigue with a moderate effect (ES = − 0.63, $p < 0.001$) on physical fatigue [35]. Mijwel et al. also demonstrated a modest effect (ES = − 0.42, $p = 0.05$) on cognitive fatigue [36]. The intensity of training appears to play a crucial role in the manifestation of symptoms, as highlighted by several studies. In the randomized controlled trial (RCT) by Travier et al., the data analysis revealed a comparatively lower effect, likely due to the lower intensity of the intervention applied [34]. This resulted in a modest reduction in physical fatigue (effect size [ES] = 0.3) and no significant effect on cognitive fatigue (ES = 0.01) [34]. In contrast, van Waart et al. and Mijwel et al. employed higher-intensity training regimens in their interventions, which demonstrated more substantial improvements in fatigue outcomes [35, 36]. This supports the notion that higher training intensity may lead to more pronounced benefits, as further evidenced by the RCT conducted by Demmelmaier et al., where participants experienced reduced physical fatigue with increased training intensity during (neo-)adjuvant therapies [41]. When comparing resistance training alone to a combination of resistance and endurance training during chemotherapy, no significant differences were found. However, combining both types of training seems to mitigate cancer-related fatigue (CRF) more effectively, addressing multiple contributing factors and resulting in a milder manifestation of symptoms.

The strength of our meta-analysis lies in the rigorous inclusion and exclusion criteria, enabling the isolated analysis of the effects of resistance training or combined resistance and endurance training during chemotherapy. Previous analyses pooled effects for both chemotherapy and radiation simultaneously. However, we showed that during chemotherapy, whether solely resistance training or a combination

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of resistance and endurance training is performed, it appears to yield similar effects. Our strict inclusion and exclusion criteria facilitated the calculation of very high homogeneity ($I^2 = 1\%$ and $I^2 = 0\%$), allowing for a robust extrapolation of the results to other breast cancer patients undergoing chemotherapy. Furthermore, we conducted initial comparisons regarding intensity, suggesting that higher or more intense resistance training, as well as high-intensity interval training (HIIT), might have a stronger effect on milder CRF manifestation. Possible differences may arise due to the varying mechanisms of action of training at different intensities. It is assumed that HIIT (high-intensity interval training) exerts anti-inflammatory effects through the downward regulation of pro-inflammatory cytokines and the upward regulation of anti-inflammatory mediators [42]. Resistance training builds muscle strength, helping cancer patients regain lost muscle mass and strength due to treatment (e.g., chemotherapy, radiation), which often contributes to fatigue [21, 25]. Given the close alignment of the effect of resistance training and combined resistance training and endurance training facilitates shared decision-making for the patient [43], enabling an active role in therapy, leading to improved treatment adherence, higher patient satisfaction, and a better understanding of the disease and treatment [44–48]. In contrast to other meta-analyses, our analysis exhibits very high homogeneity both in the analysis of resistance training and in the analysis of combined resistance and endurance training, enhancing reproducibility for patients with breast cancer.

A significant limitation is the smaller number of included studies and participants due to highly restrictive inclusion criteria. While high homogeneity proves to be an advantage, it also limits the generalizability of our systematic review's findings to other cancer entities or other treatments. Consequently, our results cannot be extrapolated to other cancer conditions. A separate meta-analysis would be necessary for such an extension. Another weakness is the large 95% CI implying low certainty. The interpretability of the conducted meta-analyses is correspondingly limited, indicating a favorable trend of training interventions during chemotherapy, both in the form of resistance training and combined resistance and endurance training. To make more precise conclusions, additional data need to be collected, analyzed, and published.

Conclusion

Both resistance training and combined resistance and endurance training can positively impact the development of CRF. We also observed a tentative influence of training intensity, suggesting that higher intensity might have a more positive effect in terms of milder CRF manifestation. More high-quality RCT are needed.

Consent for publication

Not applicable.

Author contribution JL conceived the idea for this article and was one of the independent reviewers through all the stages of this systematic review.

OK and KB served as the third independent reviewer, resolving discrepancies not attributable to extraction errors, and, together with JL, conducted the methodological assessment of the included studies and critically revised the article.

All authors read and approved the final manuscript.

Data availability The datasets and materials used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Consent to participate Not applicable.

Competing interest The authors declare no competing interests.

References

1. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F (2021) Global Cancer Statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 71(3):209–49. https://doi.org/10.3322/caac.21660
2. WHO (2023) Breast Cancer (Fact Sheet) Available from: https://www.who.int/news-room/fact-sheets/detail/breast-cancer. Accessed 26th Oct 2023
3. Mariotto AB, Etzioni R, Taylor RJ, Cho H, Wolfe CJ, Feuer EJ (2023) Prediction of risk of metastatic recurrence for female breast cancer patients in the presence of competing causes of death. Cancer Epidemiol Biomarkers Prev 32(12):1683–9. https://doi.org/10.1158/1055-9965.Epi-23-0544
4. AWMF (2021) Leitlinienprogramm Onkologie (Deutsche Krebsgesellschaft, Deutsche Krebshilfe, AWMF) S3-Leitlinie Früherkennung, Diagnose, Therapie und Nachsorge des Mammakarzinoms, Version 4.4. AWMF Registernummer: 032–045OL. Available from: http://www.leitlinienprogramm-onkologie.de/leitlinien/mammakarzinom/. Accessed 4th Dec 2022
5. Schmidt ME, Scherer S, Wiskemann J, Steindorf K (2019) Return to work after breast cancer: the role of treatment-related side effects and potential impact on quality of life. Eur J Cancer Care (Engl) 28(4):e13051. https://doi.org/10.1111/ecc.13051
6. Wang K, Yee C, Tam S, Drost L, Chan S, Zaki P et al (2018) Prevalence of pain in patients with breast cancer post-treatment: a systematic review. Breast 42:113–27. https://doi.org/10.1016/j.breast.2018.08.105
7. de Jong N, Candel MJJM, Schouten HC, Abu-Saad HH, Courtens AM (2004) Prevalence and course of fatigue in breast cancer patients receiving adjuvant chemotherapy. Ann Oncol 15(6):896–905. https://doi.org/10.1093/annonc/mdh229
8. Hiensch AE, Bolam KA, Mijwel S, Nolte K, Wengström Y, Rundqvist H (2021) Inflammation mediates exercise effects on fatigue in patients with breast cancer. Med Sci Sports Exerc 53(3):496–504. https://doi.org/10.1249/mss.0000000000002490

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9. Manir KS, Bhadra K, Misra S, Roy S, Saha K, Banerjee S (2012) Fatigue in breast cancer patients on adjuvant treatment: course and prevalence. Indian J Palliat Care 18(2):109–16. https://doi.org/10.4103/0973-1075.100826
10 Berger AM, Gerber LH, Mayer DK (2012) Cancer-related fatigue: implications for breast cancer survivors. Cancer 118(8 Suppl):2261–9. https://doi.org/10.1002/cncr.27475
11 Bower JE (2014) Cancer-related fatigue—mechanisms, risk factors, and treatments. Nat Rev Clin Oncol 11(10):597–609. https://doi.org/10.1038/nrclinonc.2014.127
12 Weis J (2011) Cancer-related fatigue: prevalence, assessment, and treatment strategies. Expert Rev Pharmacoecon Outcomes Res 11(4):441–6. https://doi.org/10.1586/erp.11.44
13. Álvarez-Bustos A, de Pedro CG, Romero-Elías M, Madurga R, Mateo-Montoya A, Provencio M et al (2021) Prevalence and correlates of cancer-related fatigue in breast cancer survivors. Support Care Cancer 29(11):6523–34. https://doi.org/10.1007/s00520-021-06218-5
14 GarabeliCavalliKluthcovsky AC, Urbanetz AA, Lima TR (2012) Fatigue after treatment in breast cancer survivors: prevalence, determinants, and impact on health-related quality of life. Supp Care Cancer 20(8):1901–9. https://doi.org/10.1007/s00520-011-1293-7
15. Buffart LM, Sweegers MG, May AM, Chinapaw MJM, van Vulpen JK, Newton RU et al (2020) Muscle contractile properties of cancer patients receiving chemotherapy: assessment of feasibility and exercise effects. Scand J Med Sci Sports 30(10):1918–29. https://doi.org/10.1111/sms.13758
16. Rasa S, Nora-Krukle Z, Henning N, Eliassen E, Shikova E, Harrer T et al (2018) Chronic viral infections in myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS). J Transl Med 16(1):268. https://doi.org/10.1186/s12967-018-1644-y
17. Vallance JK, Friedenreich CM, Wang Q, Matthews CE, Yang L, McNeely ML et al (2023) Depression, happiness, and satisfaction with life in women newly diagnosed with breast cancer: associations with device-measured physical activity and sedentary time. Psychooncology 32(8):1268–78. https://doi.org/10.1002/pon.6180
18. Antunes P, Joaquim A, Sampaio F, Nunes C, Ascensão A, Vilela E et al (2024) Exercise training benefits health-related quality of life and functional capacity during breast cancer chemotherapy: a randomized controlled trial. Med Sci Sports Exerc 56(4):600–11. https://doi.org/10.1249/mss.0000000000003341
19 Schmid D, Leitzmann MF (2014) Association between physical activity and mortality among breast cancer and colorectal cancer survivors: a systematic review and meta-analysis. Ann Oncol 25(7):1293–311. https://doi.org/10.1093/annonc/mdu012
20 McTiernan A, Friedenreich CM, Katzmarzyk PT, Powell KE, Macko RF, Buchner D et al (2019) Physical activity in cancer prevention and survival: a systematic review. Med Sci Sports Exerc 51(6):1252–61. https://doi.org/10.1249/mss.0000000000001937
21. Klassen O, Schmidt ME, Ulrich CM, Schneeweiss A, Potthoff K, Steindorf K et al (2017) Muscle strength in breast cancer patients receiving different treatment regimes. J Cachexia Sarcopenia Muscle 8(2):305–316
22. Strasser B, Steindorf K, Wiskemann J, Ulrich CM (2013) Impact of resistance training in cancer survivors: a meta-analysis. Med Sci Sports Exerc 45(11):2080–2090
23. Johnsson A, Broberg P, Norrbom J, Gustafsson T, Elander A (2019) A single exercise session improves side-effects of chemotherapy in women with breast cancer: an observational study. BMC Cancer 19(1):1073
24 Cramp F, Byron-Daniel J (2012) Exercise for the management of cancer-related fatigue in adults. Cochrane Database Syst Rev 11(11):Cd006145
25. Mijwel S, Cardinale DA, Norrbom J, Chapman M, Ivarsson N, Wengström Y et al (2018) Exercise training during chemotherapy preserves skeletal muscle fiber area, capillarization, and mitochondrial content in patients with breast cancer. FASEB J 32(10):5495–5505
26. Meneses-Echávez JF, González-Jiménez E, Ramírez-Vélez R (2015) Effects of supervised exercise on cancer-related fatigue in breast cancer survivors: a systematic review and meta-analysis. BMC Cancer 15:77
27. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Int J Surg 88:105906
28. Medeiros Torres DR, Koifman J, da Silva SS (2022) Impact on fatigue of different types of physical exercise during adjuvant chemotherapy and radiotherapy in breast cancer: systematic review and meta-analysis. Support Care Cancer 30(6):4651–4662
29. The Cochrane Collaboration (2024) Review Manager (RevMan) [Computer program]. Version 7.2.0. Available from: www.revman.cochrane.org. Accessed 20 Sept 2024
30. Courneya KS, Mackey JR, Bell GJ, Jones LW, Field CJ, Fairey AS (2007) Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: a multicenter randomized controlled trial. J Clin Oncol 25(28):4396–4404
31. Courneya KS, Segal RJ, Mackey JR, Gelmon K, Reid RD, Friedenreich CM et al (2013) Effects of exercise dose and type during breast cancer chemotherapy: multicenter randomized trial. J Natl Cancer Inst 105(23):1821–1832
32. Schmidt ME, Wiskemann J, Ulrich CM, Schneeweiss A, Potthoff K, Steindorf K (2015) Effects of resistance exercise on fatigue and quality of life in breast cancer patients undergoing adjuvant chemotherapy: a randomized controlled trial. Int J Cancer 137(2):471–480
33. Schmidt T, Weisser B, Durek C, Böckelmann I (2015) Comparing endurance and resistance training with standard care during chemotherapy for patients with primary breast cancer. Anticancer Res 35(10):5623–5629
34. Travier N, Velthuis MJ, Steins Bisschop CN, van den Buijs BJ, Monninkhof EM, Backx FJ et al (2015) Effects of an 18-week exercise programme started early during breast cancer treatment: a randomised controlled trial. BMC Med 13:121
35. van Waart H, Stuiver MM, van Harten WH, Geleijn E, Kieffer JM, Buffart LM et al (2015) Effect of low-intensity physical activity and moderate- to high-intensity physical exercise during adjuvant chemotherapy on physical fitness, fatigue, and chemotherapy completion rates: results of the PACES randomized clinical trial. J Clin Oncol 33(17):1918–1927
36. Mijwel S, Backman M, Bolam KA, Jervaeus A, Sundberg CJ, Margolin S et al (2018) Adding high-intensity interval training to conventional training modalities: optimizing health-related outcomes during chemotherapy for breast cancer: the OptiTrain randomized controlled trial. Breast Cancer Res Treat 168(1):79–93
37. Gerland L, Harbeck N, Frisse S, Bloch W, Malter W, Kates R, Baumann FT (2024) Evaluation of the impact of adaptive progressive supervised resistance training on strength and quality of life in patients with breast cancer during chemotherapy: the VALESCO study. Oncol Res Treat 47(9):387–400. https://doi.org/10.1159/000539087
38. Antunes P, Joaquim A, Sampaio F, Nunes C, Ascensão A, Vilela E et al (2024) Exercise training benefits health-related quality of life and functional capacity during breast cancer chemotherapy: a randomized controlled trial. Med Sci Sports Exerc 56(4):600–11. https://doi.org/10.1249/mss.0000000000003341
39. van Vulpen JK, Peeters PH, Velthuis MJ, van der Wall E, May AM (2016) Effects of physical exercise during adjuvant breast cancer treatment on physical and psychosocial dimensions of cancer-related fatigue: a meta-analysis. Maturitas 85:104–111
40 Furmaniak AC, Menig M, Markes MH (2016) Exercise for women receiving adjuvant therapy for breast cancer. Cochrane Database Syst Rev 9(9):Cd005001

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41. Demmelmaier I, Johansson S, Melloh M, Ljungman L, Andersson S, Beckman L et al (2021) Does exercise intensity matter for fatigue during (neo-)adjuvant cancer treatment? The Phys-Can randomized clinical trial. Scand J Med Sci Sports 31(5):1144–1159
42. Chen X, Shi X, Yu Z, Ma X (2023) High-intensity interval training in breast cancer patients: a systematic review and meta-analysis. Cancer Med 12(17):17692–17705
43. Stiggelbout AM, Pieterse AH, De Haes JC (2015) Shared decision making: concepts, evidence, and practice. Patient Educ Couns 98(10):1172–1179
44. Barry MJ, Edgman-Levitan S (2012) Shared decision making—pinnacle of patient-centered care. N Engl J Med 366(9):780–781
45. Stacey D, Légaré F, Lewis K, Barry MJ, Bennett CL, Eden KB et al (2017) Decision aids for people facing health treatment or screening decisions. Cochrane Database Syst Rev 4(4):Cd001431
46. Joosten EA, DeFuentes-Merillas L, de Weert GH, Sensky T, van der Staak CP, de Jong CA (2008) Systematic review of the effects of shared decision-making on patient satisfaction, treatment adherence and health status. Psychother Psychosom 77(4):219–226
47. Légaré F, Ratté S, Gravel K, Graham ID (2008) Barriers and facilitators to implementing shared decision-making in clinical practice: update of a systematic review of health professionals' perceptions. Patient Educ Couns 73(3):526–535
48. Elwyn G, Edwards A, Wensing M, Hood K, Atwell C, Grol R (2004) Achieving involvement: process outcomes from a cluster randomized trial of shared decision making skill development and use of risk communication aids in general practice. Fam Pract 21(4):337–346

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