©Journal of Sports Science and Medicine (2024) **23,** 366-395
http://www.jssm.org DOI: https://doi.org/10.52082/jssm.2024.366

Review article

Combined Aerobic and Resistance Training Improves Body Composition, Alters Cardiometabolic Risk, and Ameliorates Cancer-Related Indicators in Breast Cancer Patients and Survivors with Overweight/Obesity: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Sameer Badri Al-Mhanna [1,2], Alexios Batrakoulis [3,4]✉, Norhayati Mohd Noor [5], Mahaneem Mohamed [2], Clemens Drenowatz [6], Ahmad Adebayo Irekeola [7], Hafeez Abiola Afolabi [8], Mehmet Gülü [9], Nouf H. Alkhamees [10] and Wan Syaheedah Wan Ghazali [2]✉

[1] Center for Global Health Research, Saveetha Medical College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India; [2] Department of Physiology, School of Medical Sciences, University Sains Malaysia, Kubang Kerian, Kelantan, Malaysia; [3] Department of Physical Education and Sport Science, School of Physical Education, Sport Science and Dietetics, University of Thessaly, Karies, Trikala, Greece; [4] Department of Physical Education and Sport Science, School of Physical Education and Sport Science, Democritus University of Thrace, Komotini, Greece; [5] Department of Family Medicine, School of Medical Sciences, Kubang Keria, Malaysia; [6] Division of Sport, Physical Activity and Health, University of Teacher Education Upper Austria, Linz, Austria; [7] Department of Medical Microbiology and Parasitology, School of Medical Sciences, University Sains Malaysia, Kubang Kerian, Kelantan, Malaysia; [8] Department of General Surgery, School of Medical Sciences, Hospital University Sains Malaysia, University Sains Malaysia, Kubang Kerian, Kelantan, Malaysia; [9] Department of Sports Management, Faculty of Sport Sciences, Kirikkale University, Kirikkale, Turkey; [10] Department of Rehabilitation, College of Health and Rehabilitation Sciences Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia

Abstract

Breast cancer survivors with obesity are at a high risk of cancer recurrence, comorbidity, and mortality. This review aims to systematically evaluate the effects of combined aerobic and resistance training (CART) on body composition, lipid homeostasis, inflammation, adipokines, cancer-related fatigue, sleep, and quality of life in breast cancer patients and survivors with overweight/obesity. An electronic search was conducted in PubMed, Web of Science, Scopus, Science Direct, Cochrane, and Google Scholar databases from inception up to January 8, 2024. Randomized controlled trials (RCTs) meeting the inclusion criteria were selected for the analysis. The Cochrane risk of bias tool was used to assess eligible studies, and the GRADE method to evaluate the quality of evidence. A random-effects model was used, and data were analyzed using mean (MD) and standardized mean differences (SMD) for continuous variables with 95% confidence intervals (CI). We assessed the data for risk of bias, heterogeneity, sensitivity, reporting bias, and quality of evidence. A total of 17 randomized controlled trials were included in the systematic review involving 1,148 female patients and survivors (mean age: 54.0 ± 3.4 years). The primary outcomes showed significant improvements in body mass index (SMD -0.57 kg/m^2, p = 0.04), body fat (SMD -0.50%, p = 0.02), fat mass (SMD -0.63 kg, p = 0.04), hip circumference (MD -3.14 cm, p = 0.02), and fat-free mass (SMD 1.03 kg, p < 0.001). The secondary outcomes indicated significant increases in high-density lipoprotein cholesterol (MD -0.05 mmol/L, p = 0.008), natural killer cells (SMD 0.42%, p = 0.04), reductions in triglycerides (MD -81.90 mg/dL, p < 0.01), total cholesterol (SMD -0.95 mmol/L, p < 0.01), tumor necrosis factor α (SMD -0.89 pg/mL, p = 0.03), and leptin (SMD -0.63 ng/mL, p = 0.03). Also, beneficial alterations were found in cancer-related fatigue (SMD -0.98, p = 0.03), sleep (SMD -1.17, p < 0.001), and quality of life (SMD 2.94, p = 0.02) scores. There was very low to low confidence in the estimated effect of most of the outcomes. The present findings reveal that CART could be considered an adjunct therapy in supporting the conventional clinical approach observed following exercise. However, further high-quality research is needed to evaluate whether CART would be a valuable intervention to lower aggressive pharmacologic use in breast cancer patients with overweight/obesity.

Key words: Oncology, muscle strengthening, cardiorespiratory exercise, cardiovascular disease, inflammation, adipokines, fatigue, sleep, quality of life.

Introduction

Cancer is a critical global health concern since it is the world's most common non-communicable disease and the second major cause of death (Afolabi et al., 2022b; Meneses-Echávez et al., 2015). More specifically, breast cancer (BC) is the most frequent type of cancer in women, and 25% of BC cases are due to excessive weight and sedentary lifestyle risk factors (Siegel et al., 2020). Thus, obesity affects one out of every three BC survivors (Greenlee et al., 2016), raising the chance of cancer recurrence, comorbidity, and mortality (Feliciano et al., 2019; Hwangbo et al., 2018; Lohmann et al., 2021; Petrelli et al., 2021). Given that fat tissue is an endocrine organ that secretes various inflammatory factors and adipokines (Afolabi et al., 2022a), a significant association between BC and numerous impaired cardiometabolic health-related indices has been documented in women (Chowdhury et al., 2021; Guo et al., 2013; Wu et al., 2009). BC survivors are at a high risk of developing comorbidities, such as hyperlipidemia, sarcopenia, and osteoporosis (Ording et al., 2013), which affect individuals' quality of life (QoL), cardiorespiratory fitness, physical function, and bone health while increasing cancer-related pain and fatigue (Al-Mhanna et al., 2022; Ganz, 2006; Stanton, 2006). Also,

Received: 09 January 2024 / Accepted: 11 April 2024 / Published (online): 01 June 2024

excess adiposity is linked to early recurrence on breast cancer survivors after treatment, showing that the management of obesity may be a critical health factor for this cohort (Acevedo et al., 2022; Elreda et al., 2022).

Regular exercise has been reported as a vital tool for reducing the most common and impairing symptoms in BC patients before, during, and after treatment (Mortimer et al., 2010; Mutalub et al., 2022). In BC patients and survivors, exercise is considered an effective non-pharmacologic method for lowering pro-inflammatory biomarkers and cardiovascular disease (CVD) risk factors as well as mental health, and physical function (Campbell et al., 2019; Speck et al., 2010; Van Alsten et al., 2020). However, exercise oncology has not been yet established as an emerging trend among practitioners in the health and fitness community (Newsome et al., 2024). In terms of the mechanism behind the positive role of exercise in BC, exercise-induced reductions in hyperlipidemia and chronic inflammation are believed to inhibit tumor growth by lowering serum cholesterol levels and reducing the exposure of tumor cells to cholesterol, increasing antitumor immunity, and regulating tumor vasculature (Betof et al., 2013). In addition, exercise can reduce blood lipid levels by improving skeletal muscle's ability to use lipids instead of glycogen or increasing lecithin-cholesterol acyltransferase and lipoprotein lipase activity (Al-Mhanna et al., 2024a; Al-Mhanna et al., 2024b; Mann et al., 2014). Also, exercise may counteract the pro-tumor impact of hyperlipidemia by reducing chronic inflammation, lowering serum lipids, improving the immune system's ability to identify and destroy tumor cells, and stabilizing the tumor's vascular network (Gonzalo-Encabo et al., 2022).

Although many trials show that exercise may improve body composition in BC patients (Almstedt et al., 2016; Dieli-Conwright and Orozco 2015), there is a lack of evidence synthesis and pooled outcomes via meta-analysis that evaluated the effectiveness of combined aerobic and resistance training (CART) among BC patients with overweight/obesity (Dieli-Conwright et al., 2022; Jones and Courneya, 2002; Milne et al., 2008a). Furthermore, the long-term implications of CART in women with BC remain unclear (de Paulo et al., 2018), indicating that more research is required, aiming to investigate the effects of CART on body composition and several cardiometabolic health aspects as previously reported (de Paulo et al., 2018).. Thus, the present review aimed to assess the effects of CART on anthropometrics, body composition, lipid metabolism, inflammation, adipokines, QoL, sleep quality, and fatigue among women with BC and overweight/obesity.

Methods

Registration

This systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement guidelines (Page et al., 2021). The study protocol was registered in the International Prospective Register of Systematic Reviews (ID: CRD42022308214).

Literature search strategy

Articles were retrieved from PubMed, Web of Science, Scopus, Science Direct, Cochrane Library, and Google Scholar after a systematic electronic search. Four authors (S.A., B.K., A.B., and H.A.) employed a combination of keywords and Boolean operators, specifically "OR" and "AND" in conducting an electronic search of literature up to January 8, 2024. The keywords utilized were ("Breast Cancer" OR "Breast Neoplasm") AND "(Overweight" OR "Obese") AND "(Exercise" OR "Training") to retrieve pertinent material (Table S1). The PICOS was used to formulate the research questions for systematic reviews and meta-analyses as follows: (P) Population: BC patients with overweight or obesity; (I) Intervention: CART; (C) Comparator: standard treatment (ST) (patients who did not perform any exercise); (O) Outcomes: [primary: body weight (BW), body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), body fat (BF), fat mass (FM), fat-free mass (FFM); secondary: total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), C–reactive protein (CRP), Tumor necrosis factor α (TNF-α), interleukin-6 (IL-6), interleukin-6 (IL-8), natural killer (NK) cells, adiponectin (ADPN), leptin (LEP), cancer-related fatigue (FA), sleep quality (SQ), and QoL]; and (S) Study type: randomized controlled trials (RCTs). The reference lists of included articles were searched for articles that met the inclusion criteria as well as the reference lists of all relevant systematic reviews.

Eligibility criteria

Studies were considered eligible for inclusion if the following criteria were met: (i) participants were BC patients with overweight (BMI 25 - 29.9 kg/m^2) or obesity (BMI ≥30 kg/m^2); (ii) no specified age limit for participants; (iii) the intervention used in the studies was CART; (iv) articles provided full-text accessibility and were published in a refereed journal from inception up to 8 January 2024**;** (v) no language restrictions; and (vi) studies were RCTs. The following were excluded: (i) studies involving a mixed sample of individuals (e.g., underweight or normoweight BC patients or overweight/obese people without BC); (ii) articles where the effects of CART cannot be isolated because exercise training was involved as part of a multicomponent intervention (e.g., diet and exercise intervention); (iii) studies where the control group performed exercise; (iv) articles that did not assess the outcome measures of interest; (v) studies that used an acute exercise intervention (e.g., single bout or duration ≤2 weeks); and (vi) review articles, case reports, studies lacking a control group, and ambiguous or unclear data.

Study selection

The screening process was conducted collaboratively among four authors (S.B.A.L., B.K., A.B., and H.A.), who independently evaluated publications based on titles, abstracts, and full texts (in instances of uncertainty). In cases of conflicts or uncertainties, a fifth author (A.A.I.) was involved in the resolution. While the screening was not conducted in duplicate, it involved thorough evaluation by Multiple authors to ensure robust inclusion and exclusion

criteria were applied consistently. Additionally, literature management software (EndNote X9, Clarivate Analytics, Philadelphia, PA, USA) was utilized to manage the records of the literature search.

Data Extraction

Two authors (S.B.A.L. and A.A.I.) independently sampled and extracted data from the relevant studies after reading the full text. The included investigations generated a significant amount of data that was retrieved and published, consisting of the first author, population, publication year, gender, sample size, and exercise intervention details (frequency, intensity, time, and type), study duration, and outcome measures.

Risk of bias assessment

Two authors (S.B.A.L. and A.B.) independently assessed the risk of bias from individual studies according to the Cochrane Handbook for Systematic Reviews of Interventions [35]. The overall risk of bias assessment for each eligible study was judged considering the following factors: (i) random sequence generation; (ii) allocation concealment; (iii) blinding of participants and personnel; (iv) blinding of outcome assessors; (v) completeness of outcome data; (vi) selectivity of outcome reporting; and (vii) other biases as outlined in the Cochrane Handbook for Systematic Reviews of Interventions (Table S2). Eligible studies were classified into three levels of risk of bias (e.g., high, some concerns, and low) by the number of factors for which high, unclear, or low risk of bias potentially existed.

Data analysis

We performed the meta-analyses using Review Manager 5.4 software (Cochrane Collaboration, https://revman.cochrane.org/info) and reported the results of the random-effects model. Thresholds for the interpretation of the I^2 statistic can be misleading since the importance of inconsistency depends on several factors. We used the guide to the interpretation of heterogeneity as outlined: 0–40% might not be important; 30 - 60% may represent moderate heterogeneity; 50 - 90% may represent substantial heterogeneity; and 75 - 100% would be considerable heterogeneity (Higgins and Green, 2008). Mean differences (MD) or standardized mean differences (SMD) and 95% confidence intervals (CI) were applied to calculate the effect size. MD was used when the outcome measures were comparable across studies and were measured on the same scale, while SMD was used when the outcome measures were measured on different scales or were using different units across studies. The preference between MD and SMD was dependent on the nature of the outcome measure and the heterogeneity of the included studies.

The choice between fixed effects and random effects models depends on the assumption about the homogeneity of the study populations and protocols. The fixed effects model assumes one study population and protocol, generalizable to them; while the random effects model assumes various populations and protocols, generalizable to the entire universe of studies. In this study, we did not use the fixed effects model because it includes studies from various populations, making the results generalizable to the entire universe of studies. A two-sided $p < 0.05$ was considered to indicate statistical significance.

Grading quality of evidence

Two authors (S.B.A.L. and A.B.) independently assessed the quality of evidence for primary and secondary outcomes according to GRADE methodology (GRADEpro, 2014) for risk of bias, inconsistency, indirectness, imprecision, and publication bias; classified as very low, low, moderate, or high. In cases of conflicts or uncertainties, a third author (N.H.A.) was involved in the resolution. Evidence may be upgraded based on factors such as large effect size, dose-response gradient, or when all plausible confounding would reduce a demonstrated effect or suggest a spurious effect when results show no effect. Downgrading factors may include risk of bias, inconsistency of results, indirectness of evidence, imprecision, and publication bias (Table 2).

Subgroup analysis

We conducted a subgroup analysis when the I^2 statistic was more than 50%. Subgroup analysis was done on the duration of the intervention on the studies investigated the effect of CART on BMI, whether the studies were conducted for ≤16 weeks or >16 weeks.

Sensitivity analysis

We performed a sensitivity analysis to investigate the impact of the risk of bias for performance bias and detection bias.

Results

Literature search and selection

From the specified databases, PubMed, Web of Science, Scopus, Science Direct, Cochrane Library, and Google Scholar (Figure 1), a total of 21,751 studies were obtained. After removing duplicate articles, the number of studies eligible for further evaluation was reduced to 20,684. Through a review of the titles and abstracts based on predetermined inclusion and exclusion criteria, 20,643 studies were excluded. Subsequently, the full text of the remaining 41 articles was carefully examined, excluding 18 articles with reasons (Table S3). Therefore, 23 records were included in this study. However, six records were subsequent studies of eligible trials included in this review (Table S4). Hence, 17 studies (RCTs) were finally included in this review, and data were extracted from 1,148 patients who met the eligibility criteria.

Literature characteristics

Sixteen out of the 17 RCTs were from high-income countries (Battaglini et al., 2007; Brown et al., 2021; Dieli-Conwright et al., 2018; Dieli-Conwright et al., 2022; Dieli-Conwright et al., 2019; Hutnick et al., 2005; Jones et al., 2020; Lee et al., 2019; Ligibel et al., 2008; Ligibel et al., 2019; Mutrie et al., 2007; Nieman et al., 1995; Rogers et al., 2013; Rogers et al., 2014; Saxton et al., 2014; Scott et al., 2013), and one trial from upper-middle income country (Ergun et al., 2013). Thirteen out of the 17 trials recruited their respondents from hospital settings (Battaglini et al.,

2007; Dieli-Conwright et al., 2018; Dieli-Conwright et al., 2022; Dieli-Conwright et al., 2019; Ergun et al., 2013; Lee et al., 2019; Ligibel et al., 2008; Ligibel et al., 2019; Mutrie et al., 2007; Rogers et al., 2013; Rogers et al., 2014; Saxton et al., 2014; Scott et al., 2013). Participants in one trial were recruited using a variety of active and passive outreach methods (Brown et al., 2021). In two trials, participants were recruited through advertisements placed in local newspapers (Hutnick et al., 2005; Jones et al., 2020). Meanwhile, in one trial, information regarding the recruitment of participants was not provided (Nieman et al., 1995). Eight out of the 17 trials performed the exercise intervention at health care sites (Battaglini et al., 2007; Dieli-Conwright et al., 2018; Dieli-Conwright et al., 2019; Ergun et al., 2013; Jones et al., 2020; Lee et al., 2019; Saxton et al., 2014; Scott et al., 2013), while nine trials conducted the exercise intervention at both a healthcare site and participants' home (Brown et al., 2021; Dieli-Conwright et al., 2022; Hutnick et al., 2005; Ligibel et al., 2008; Ligibel et al., 2019; Mutrie et al., 2007; Nieman et al., 1995; Rogers et al., 2013; Rogers et al., 2014). The length of the exercise intervention ranged from 8 to 52 weeks (8–12 weeks: 35%; 16–52 weeks: 65%). Table 1 shows the characteristics of the included trials.

Risk of bias assessments results

The summary of the risk of bias assessment is shown in Figure 2. Details of the risk of bias judgment per domain for each study are provided in Figure S1. In the majority of the trials across most domains, the risk of bias was low or unclear. There was no indication of selective reporting bias. The lack of sufficient random sequence generation in the original study might cause treatment effect bias in both the original studies and the following review findings. The risk of performance bias was presented in seven trials, which was unclear in three trials owing to a lack of details concerning the blinding of the participants, while in four trials the participants were not blinded and hence considered as a high-performance bias. Table S2 details the risk of bias assessment.

The certainty of findings for the outcomes ranged from very low to low, with the downgrading of evidence primarily due to several factors. These included small sample sizes in both control and intervention groups across the included studies, a high risk of bias, as well as moderate, considerable, and substantial heterogeneities. Table 2 details the summary of quality assessment findings.

Primary outcomes

Anthropometrics

BW and BMI were reported in five and six trials involving 455 and 429 participants, respectively. No difference was found in BW between CART and ST (Figure S2 and Table 2), while CART reduced BMI (SMD -0.57 kg/m^2, 95% CI -1.12 to -0.02; $I^2 = 84\%$; $p = 0.04$) compared to ST, showing very low certainty. A subgroup analysis showed that short- [≤16 weeks; (four studies, n = 368);

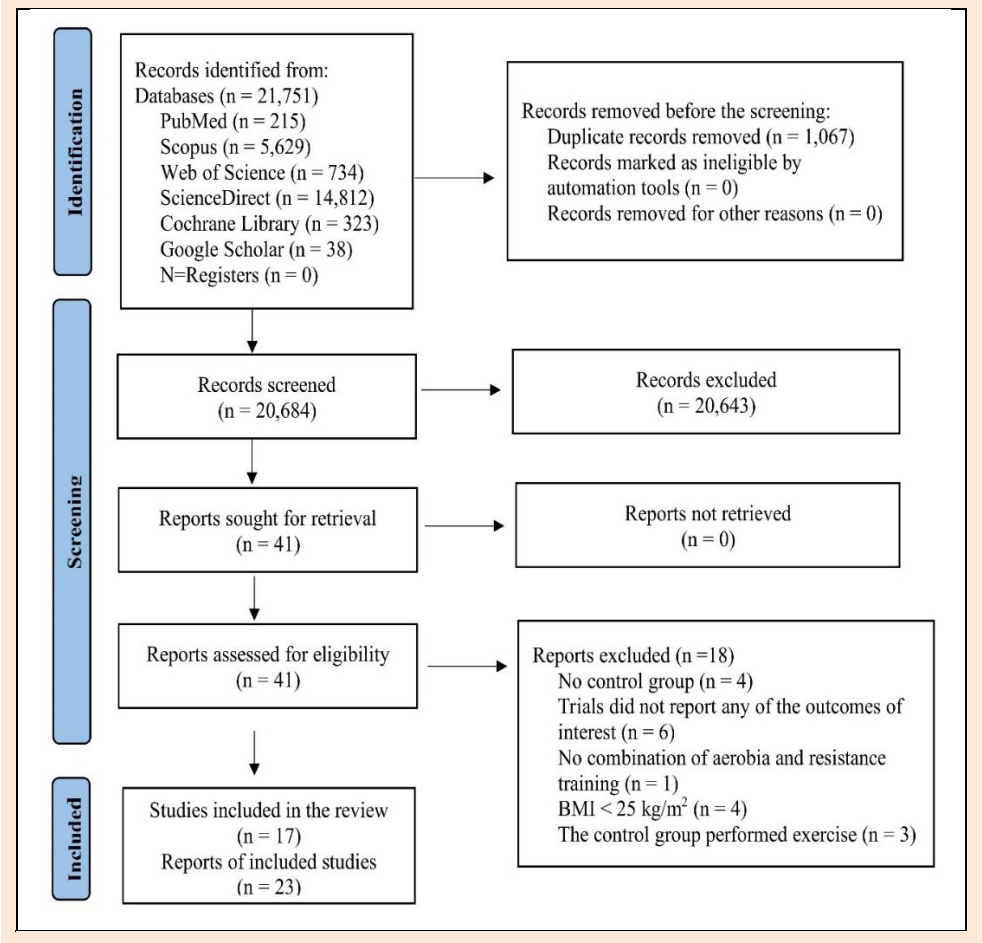

Figure 1. PRISMA flow diagram for the recruiting studies.

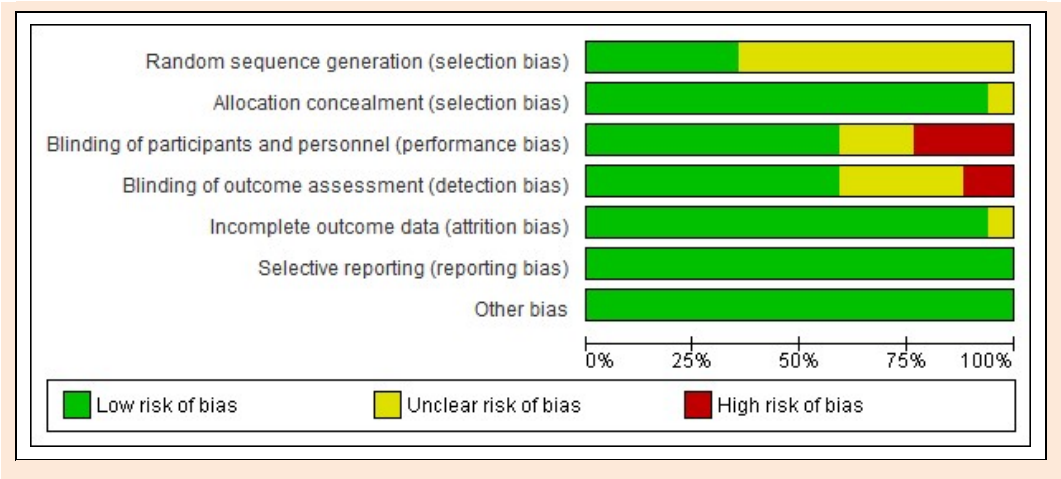

Figure 2. Summary of the risk of bias assessment.

SMD -0.21 kg/m^2, 95% CI -0.42 to -0.00; I^2 = 0%; p = 0.04], but not long-term [>16 weeks; (two studies, n = 61)] interventions exhibited more favorable effects on BMI than ST (Figure S3 and Table 2). Subgroup analysis is done for BMI. The substantial heterogeneity could not be explained by subgroup analysis according to the duration of the intervention. WC and HC were reported in two trials involving 191 patients. CART induced a significant improvement in HC (Figure S4 and Table 2), demonstrating low certainty (MD -3.14 cm, 95% CI -4.77 to -1.52; I^2 = 0%; p = 0.02), but not in WC (Figure S5). WHR was reported in (two studies, n = 122) with no meaningful changes between CART and ST (Figure S6). There were no significant changes in the effect estimate after the sensitivity analysis for Mutrie et al. (2007) was done on the BW, BMI, FA, and QoL parameters. There were no significant changes in the effect estimate after the sensitivity analysis for Hutnick et al. (2005) was done on BW, BMI, BF, and IL-6. However, Sensitivity analysis for WHR outcome in Ligibel et al. (2008) shows changes in the effect estimate (MD - 1.10, 95% CI -0.16 to -0.04, I^2 statistics = 0%, p = 0.02).

Body composition

BF, FM, and FFM were assessed in (six studies, n=305), (four studies, n = 347), and (two studies, n = 111) trials, respectively. CART induced favorable reductions in BF (SMD -0.50%, 95% CI -0.93 to -0.07; I^2 = 68%; p = 0.02; very low certainty) (Figure S7 and Table 2) and FM (SMD -0.63 kg, 95% CI -1.23 to -0.04; I^2=83%; p = 0.04; low certainty) compared to ST (Figure S8 and Table 2). In FFM, ST showed a greater increase (SMD 1.03 kg, 95% CI 0.63 to 1.43; I^2 = 0%; p < 0.001; low certainty) than CART (Figure S9 and Table 2). There were no significant changes in the effect estimate after the sensitivity analysis for Battaglini et al. (2007) was done on FFM.

Secondary outcomes

Lipid metabolism

TC, HDL-C, LDL-C, and TG were evaluated in (two studies, n = 170), (three studies, n = 261), (two studies, n = 111), and (one study, n = 91) trials, respectively. CART exhibited significant improvements in TC (SMD -0.95 mmol/L, 95% CI -1.37 to -0.52; I^2 = 43%; P < 0.01; moderate certainty), HDL-C (MD -0.05 mmol/L, 95% CI -0.15 to 0.04; I^2 = 99%; p = 0.008; very low certainty) (Figure S10 and Table 2) and TG (MD -81.90 mg/dL, 95% CI -91.21 to -72.59; p < 0.01; very low certainty) (Figure S11 and Table 2), but not in LDL-C (Figure S12 and Table 2).

Inflammation

IL-6, IL-8, TNF-α, and CRP were investigated in (six studies, n = 340), (three studies, n = 171), (four, n = 256), and (three, n = 218) trials, respectively. No significant changes were found in IL-6, IL-8, and CRP between CART and ST, but CART showed a greater reduction in TNF-α (SMD -0.89 pg/mL, 95% CI -1.70 to -0.08; I^2 = 89%; p = 0.03; low certainty) than ST (Figures S13-S16 and Table 2). There were no significant changes in the effect estimate after the sensitivity analysis for Ergun et al. (2013) was done on IL-6, IL-8, and TNF-α. There were no significant changes in the effect estimate after the sensitivity analysis for Ligibel et al. (2008) was done on IL-6, IL-8, TNF-α, CRP, WC, BF,HC, BW and LEP.

Adipokines

ADPN and LEP were reported in (two studies, n = 120) and (four studies, n=236) trials, respectively. CART induced beneficial alterations in LEP (SMD -0.63 ng/mL, 95% CI -1.20 to -0.06; I^2 = 74%; p = 0.03; low certainty), but not in ADPN compared to ST (Figures S17-S18 and Table 2). There were no significant changes in the effect estimate after the sensitivity analysis for Dieli-Conwright et al. (2022) was done on LEP.

Cancer-related indicators

NK cells, FA, SQ, and QoL were assessed in (two studies, n = 97), (four studies, n = 348), (four studies, n = 348) and (four studies, n = 356), respectively. CART more favorable changes in NK cells (SMD 0.42%, 95% CI 0.01 to 0.82; I^2 = 0%; p = 0.04; moderate certainty). Also, beneficial alterations were found in FA (SMD -0.98, 95% CI -1.85 to -0.11; I^2 = 92%; p = 0.03; very low certainty), SQ (SMD -1.40, 95% CI -2.50 to -0.30; I^2 = 87%; p = 0.01; low certainty), and QoL (SMD 2.94, 95% CI 0.46 to 5.41; I^2 = 98%; p = 0.02; very low certainty) scores compared to ST (Figure S19-22 and Table 2).

Table 1. Characteristics of included studies.

References	Patients' Status / Treatment Stage	Sample Size	Age (yrs) / Country	CART Intervention (training parameters)	Length (wks)	Setting / Cancer Stage	BMI ± SD (kg/m^2)	Outcome Measures
(Dieli-Conwright et al., 2018)	BC survivors After treatment	N: 91 EX: 46 C: 45	EX: 52.8 ± 10.6 CO: 53.6 ± 10.1 United States	AE: 2–3 d/wk, 150 min, 40%–50% HRR; RT: 3 d/wk, 40%–50% 1-RM	16	Supervised / Stage: I, II, III	EX: 33.1 ± 5.7 C: 33.4 ± 5.2	HDL-C, TC, TG, CRP, TNF-α, IL-6, LEP, BM, BF, FM, FFM, WC, HC, QoL, FA
(Dieli-Conwright et al., 2018) Cont.	BC survivors After treatment	N: 20 EX: 10 C: 10	EX: 53.0 ± 10.0 CO: 55.0 ± 4.5 United States			Supervised / Stage: I, III	EX: 33.5 ± 5.7 C: 33.3 ± 8.7	BF, ADPN, IL-8, LDL
(Dieli-Conwright et al., 2018) Cont.	BC survivors After treatment	N: 100 EX: 50 C: 50	Total: 52 ± 10.4 United States	AE: 2 d/wk, 80 min, 65%–80% HRmax; RT: 2–3 d/wk, 60% 1-RM	16	Supervised / stage: 0, III	Total BMI: 33.5 ± 5.5	SQ
(Dieli-Conwright et al., 2019)	BC survivors After treatment	N: 56 EX: 29 C: 27	EX: 46.9 ± 10.2 C: 46.7 ± 10.0 United States	AE: 2–3 d/wk, 150 min, 40% –50% HRR; RT: 2–3 d/wk, 80% 1-RM	16	Supervised / Stage: I, II, III	EX: 35.1 ± 6.1 C: 34.7 ± 6.4	BM, WC, HC, BF, FM, FFM, SBP, DBP, FG, FI, TC, HDL-C, LDL-C, TG, CRP, QoL
(Dieli-Conwright et al., 2022)	BC survivors After treatment	N: 25 EX: 13 C: 12	EX: 59.5 ± 6.5 C: 54.1 ± 10.6 United States	AE+RT, 150 m/wk plus home-based AE 970 min/wk)	24	Supervised & home-based / Stage: I, III	EX: 29.5 ± 3.6 C: 36.4 ± 6.1	BMI, LEP
(Brown et al., 2021)	BC survivors After treatment	N: 177 EX: 87 C: 90	EX: 59.1 ± 8.1 C: 59.0 ± 8.5 United States	AE: 3–6 d/wk, 180 min/wk, 50%–70% HRmax; RT: 2 d/wk, 2–3 sets x 10 reps.	52	Supervised & home-based / Stage: I, III	EX: 34.0 ± 6.2 C: 34.0 ± 5.7	BM, FM, BMD
(Ergun et al., 2013)	BC survivors After treatment	N: 40 EX: 20 C: 20	EX: 49.7 ± 8.35 C: 50.3 ± 10.4 Turkey	AE + RT: for 45 min/D for 3d/wk and brisk walking for 30 min/D for 3 d/wk	12	Supervised / Stage: N/A	EX: 26.6 ± 4.4 C: 28.6 ± 5.2	FA, IL-6, IL-8, TNF-α, QoL, DEP
(Rogers et al., 2013)	BC survivors After treatment	N: 28 EX: 15 C: 13	EX: 58.0 ± 6.1 C: 53.7 ± 13.9 United States	AE: 150 min/wk; RT: 2 d/wk, 60%–70% 1-RM	12	Supervised & home-based / Stage: I, II, III	EX: 33.9 ± 7.4 C: 30.3 ±7.11	BMI, BF, FM, WHR, FA, IL-1β, IL-6, IL-8, IL-10, TNF-α, LEP
(Rogers et al., 2014)	BC survivors After treatment	N: 42 EX: 20 C: 22	EX: 57.2 ± 5.5 C: 55.2 ± 9.1 United States	AE: 160 min/wk; RT: 2 d/wk, 60%–70% 1-RM	12	Supervised & home-based / Stage: I, III	EX: 29.8 ± 4.8 C: 32.6 ± 6.6	FA, BMI, BF, IL-6, IL-8, IL-10, TNF-α, SQ
(Hutnick et al., 2005)	BC survivors After treatment	N: 36 EX: 21 C: 15	EX: 48.5 ± 10.6 C: 52.3 ± 9.2 United States	AE+RT (40–90 min), 3 d/wk, 60%–75% HRmax/1-RM	24	Supervised & home-based / Stage: I, II, III	EX: 26.7 ± 5.45 C: 26.7 ± 4.5	BM, BMI, BF, CRF, IL-6
(Battaglini et al., 2007)	BC patients During treatment	N: 20 EX:10 C: 10	EX 57.5 ± 23.0 C: 56.6 ± 16.0 United States	AE+RT (60 min), 2 d/wk, 40%–60% HRR/1-RM	21	Supervised / Stage: N/A	EX: 77.5 ± 27.3 C: 82.2 ± 25.0	FFM, Muscular Strength

ADPN: Adiponectin, AE: Aerobic Exercise, BC: Breast Cancer, BF: Body Fat, BM: Body Mass, BMI: Body Mass Index, BMD: Bone Mineral Density, C: Control Group, CART: Combined Aerobic and Resistance Training, CRF: Cardiorespiratory Fitness, CRP: C-Reactive Protein, DBP: Diastolic Blood Pressure, DEP: Depression, EX: Exercise Group, FA: Cancer-related Fatigue, FFM: Fat-Free Mass, FG: Fasting Glucose, FI: Fasting Insulin, FM: Fat Mass, HC: hip circumference, HDL-C: High-Density Lipoprotein Cholesterol, HRmax: Maximum Heart Rate, HRR: Heart Rate Reserve, IL: Interleukin, LEP: Leptin, LDL: Low-Density Lipoprotein Cholesterol, NK: Natural Killer, RT: Resistance Training, SBP: Systolic Blood Pressure, SQ: Sleep Quality, TC: Total Cholesterol, TG: Triglycerides, TNF-α: Tumor Necrosis Factor α, QoL: Quality of Life, WC: Waist circumference, WHR: Waist-to-Hip Ratio, 1-RM: Repetition Maximum.

Table 1. Continue ….

References	Patients' Status / Treatment Stage	Sample Size	Age (yrs) / Country	CART Intervention (training parameters)	Length (wks)	Setting / Cancer Stage	BMI ± SD (kg/m^2)	Outcome Measures
(Mutrie et al., 2007)	BC patients. During treatment	N: 181 EX: 82 C: 95	EX: 51.3 ± 10.3 C: 51.8 ± 8.7 United Kingdom	AE+RT (45 min), 2 d/wk, 50%–75% HRR/1-RM	12	Supervised & home-based / Stage: 0, III	EX: 27.3 ± 5.2 C: 27.5 ± 6.0	BMI, QoL, FA, DEP, Physical Function
(Nieman et al., 1995)	BC survivors After treatment	N: 12 EX: 6 C: 6	EX: 60.8 ± 4.0 C: 51.2 ± 4.7 United States	AE+RT, (60 min), 3 d/wk, 75% HRR/1-RM	8	Supervised / Stage: N/A	EX: 67.6 ± 3.7 C: 75.5 ± 9.8	CRF
(Ligibel et al., 2008)	BC survivors After treatment	N: 82 EX: 40 C: 42	EX: 52.0 ± 9.0 C: 53.0 ± 9.0 United States	AE: 90 min/wk, 2 d/wk; RT: 50 min/wk, 2 d/wk	16	Supervised & home-based / Stage: I, II, III	EX: 30.3 ± 5.9 C: 31.4 ± 6.8	BM, BMI, WC, HC, WHR, BF, LEP, ADPN
(Ligibel et al., 2019)	BC patients Before treatment	N: 48 EX: 26 C: 22	EX: 52.3 ± 9.6 C: 53.1 ± 7.9 United States	AE: 180 min/wk; 60%–70% HRmax; RT: 40 min/wk, 60%–70% 1-RM	16	Supervised & home-based / Stage: I, II, III	EX: 30.7 ± 6.1 C: 29.1 ± 7.4	LEP, CRP, IL-6
(Jones et al., 2020)	BC survivors After treatment	N: 51 EX: 26 C: 25	EX: 55.8 ± 7.2 C: 55.9 ± 7.1 New Zealand	AE+RT (60 min), 2 d/wk	12	Supervised / Stage: I, II, III	EX: 27.8 ± 5.5 C: 27.5 ± 4.8	BM, BMI, FM, BF, SBP, DBP, CRF
(Lee et al., 2019)	BC survivors After treatment	N: 91 EX: 46 C: 45	Total: 53.5 ±10.4 United States	AE: ≥150 min, 2–3 d/wk, 65%–80% HRmax; RT: 2–3 d/wk	16	Supervised / Stage: I, III	BM1 ≥25.0 or BF ≥30%	TC, LDL-C, HDL-C, TG
(Saxton et al., 2014)	BC survivors After treatment	N:85 EX: 44 C: 41	EX: 55.8 ± 10.0 C: 55.3 ± 8.8 United Kingdom	AE: 30 min, 65%–85% HRmax, 3 d/wk; RT: 10–15 min, 2–3 d/wk	24	Supervised / Stage I, III	EX: 29.7±3.5 C: 31.1 ± 5.7	IL-6, TNF-α, NK cell
(Scott et al., 2013)	BC survivors After treatment	N: 83 EX: 43 C: 40	EX: 55.6 ± 10.2 C: 55.9 ± 8.9 United Kingdom	AE: 30 min, 65%–85% HRmax, 3 d/wk; RT: 10–15 min, 2–3 d/wk	24	Supervised / Stage: I, III	EX: 29.6 ± 3.5 C: 31.1 ± 5.6	CRF, SBP, DBP, FG, CRP, TC, HDL-C, LDL-C, QoL, LEP

ADPN: Adiponectin, AE: Aerobic Exercise, BC: Breast Cancer, BF: Body Fat, BM: Body Mass, BMI: Body Mass Index, BMD: Bone Mineral Density, C: Control Group, CART: Combined Aerobic and Resistance Training, CRF: Cardiorespiratory Fitness, CRP: C-Reactive Protein, DBP: Diastolic Blood Pressure, DEP: Depression, EX: Exercise Group, FA: Cancer-related Fatigue, FFM: Fat-Free Mass, FG: Fasting Glucose, FI: Fasting Insulin, FM: Fat Mass, HC: hip circumference, HDL-C: High-Density Lipoprotein Cholesterol, HRmax: Maximum Heart Rate, HRR: Heart Rate Reserve, IL: Interleukin, LEP: Leptin, LDL: Low-Density Lipoprotein Cholesterol, NK: Natural Killer, RT: Resistance Training, SBP: Systolic Blood Pressure, SQ: Sleep Quality, TC: Total Cholesterol, TG: Triglycerides, TNF-α: Tumor Necrosis Factor α, QoL: Quality of Life, WC: Waist circumference, WHR: Waist-to-Hip Ratio, 1-RM: Repetition Maximum.

Discussion

In the present review, for the first time to the best of our knowledge, evidence about the efficacy of CART on cardiometabolic risk factors and cancer-related indicators is provided. The main findings reveal that CART induces beneficial alterations in anthropometric characteristics, body composition, lipid metabolism, inflammation, adipokines, and cancer-related outcomes, such as fatigue, sleep, and quality of life in BC patients with overweight/obesity. Given that aerobic and resistance training alone have been documented as effective exercise modalities for provoking positive results in cardiometabolic health-related outcomes among people with excessive weight (Batrakoulis et al., 2022) and/or cancer (Kudiarasu et al., 2023; Yang et al., 2023), our findings suggest that CART may be considered as an effective exercise solution for women with BC and concurrent overweight/obesity commonly present with impaired cardiometabolic health (Simon et al., 2021). However, the present results should be taken into account with caution due to the small number of studies with small participant numbers and low-GRADE ratings included in the current meta-analysis.

Table 2. **Summary of quality assessment findings (GRADE).**

Outcome	Certainty assessment							№ of patients			Effect	Certainty
	№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	CART	ST	*p*-value	Absolute (95% CI)	
BW (kg)	5	RCT	not serious	not serious	not serious	serious[b]	none	231	224	0.95	SMD 0.04 lower (1.23 lower to 1.15 higher)	⊕⊕⊕◯ Moderate
BMI (kg/m^2)	6	RCT	serious[e]	serious[c]	not serious	serious[b]	none	213	216	0.04	SMD 0.57 lower (1.12 lower to 0.02 lower)	⊕◯◯◯ Very low
BMI (≤16 wks)	4	RCT	serious[e]	not serious	not serious	serious[b]	none	179	189	0.04	SMD 0.21 lower (0.42 lower to 0)	⊕⊕◯◯ Low
BMI (>16 wks)	2	RCT	serious[e]	very serious[a]	not serious	serious[b]	none	34	27	0.27	SMD 2.49 lower (6.91 lower to 1.93 higher)	⊕◯◯◯ Very low
HC (cm)	2	RCT	serious[d]	not serious	not serious	serious[b]	none	97	94	0.02	MD 3.14 lower (4.77 lower to 1.52 lower)	⊕⊕◯◯ Low
WC (cm)	2	RCT	serious[d]	not serious	not serious	serious[b]	none	97	94	0.19	MD 3.63 lower (9.02 lower to 1.77 higher)	⊕⊕◯◯ Low
WHR	2	RCT	serious[d]	serious[c]	not serious	serious[b]	none	60	62	0.34	MD 0.05 lower (0.15 lower to 0.05 higher)	⊕◯◯◯ Very low
BF (%)	6	RCT	serious[d]	serious[c]	not serious	serious[b]	none	157	148	0.02	SMD 0.5 lower (0.93 lower to 0.07 lower)	⊕◯◯◯ Very low
FM (kg)	4	RCT	not serious	serious[c]	not serious	serious[b]	none	174	173	0.04	SMD 0.76 lower (1.44 lower to 0.08 lower)	⊕⊕◯◯ Low
FFM (kg)	2	RCT	serious[d]	not serious	not serious	serious[b]	none	56	55	<0.01	SMD 1.03 higher (0.63 higher to 1.43 higher)	⊕⊕◯◯ Low
TC (mmol/L)	2	RCT	not serious	not serious	not serious	serious[b]	none	87	83	<0.01	SMD 0.95 lower (1.37 lower to 0.52 lower)	⊕⊕⊕◯ Moderate
HDL-C (mmol/L)	3	RCT	not serious	very serious[a]	not serious	serious[b]	none	133	128	0.008	MD 8 higher (2.05 higher to 13.94 higher)	⊕◯◯◯ Very low
LDL-C (mmol/L)	2	RCT	not serious	very serious[a]	not serious	serious[b]	none	56	55	<0.01	SMD 1.4 lower (5.22 lower to 2.41 higher)	⊕◯◯◯ Very low
TG (mg/Dl)	1	RCT	not serious[a]	very serious[a]	not serious	serious[b]	none	46	45	<0.01	MD 81.9 lower (91.21 lower to 72.59 lower)	⊕◯◯◯ Very low
IL-6 (pg/mL)	6	RCT	not serious	not serious	not serious	serious[b]	none	177	163	0.33	SMD 0.11 lower (0.32 lower to 0.11 higher)	⊕⊕⊕◯ Moderate
IL-8 (pg/mL)	3	RCT	not serious	very serious[a]	not serious	serious[b]	none	86	85	0.20	SMD 1.32 lower (3.33 lower to 0.7 higher)	⊕◯◯◯ Very low

ADPN: Adiponectin, AE: Aerobic Exercise, BC: Breast Cancer, BF: Body Fat, BM: Body Weight, BMI: Body Mass Index, BMD: Bone Mineral Density, C: Control Group, CART: Combined Aerobic and Resistance Training, CI: confidence intervals, CRF: Cardiorespiratory Fitness, CRP: C-Reactive Protein, DBP: Diastolic Blood Pressure, DEP: Depression, EX: Exercise Group, FA: Cancer-related Fatigue, FFM: Fat-Free Mass, FG: Fasting Glucose, FI: Fasting Insulin, FM: Fat Mass, HC: hip circumference, HDL-C: High-Density Lipoprotein Cholesterol, HRmax: Maximum Heart Rate, HRR: Heart Rate Reserve, IL: Interleukin, LEP: Leptin, LDL: Low-Density Lipoprotein Cholesterol, MD: mean difference, NK: Natural Killer, RCT: randomized control trial, RT: Resistance Training, SBP: Systolic Blood Pressure, SMD: standardized mean difference, ST: standard treatment, SQ: Sleep Quality, TC: Total Cholesterol, TG: Triglycerides, TNF-α: Tumor Necrosis Factor α, QoL: Quality of Life, WC: Waist circumference, WHR: Waist-to-Hip Ratio, 1-RM: Repetition Maximum, a: there is considerable heterogeneity in the study's outcome, b: the included studies recorded a small sample size for both the control and intervention group, c: there is substantial heterogeneity in the studies, d: The assessor was not blinding, e: participants were aware of all exercise procedures, f: there is moderate heterogeneity in the involved studies.

Table 2. Continue…

Outcome	Certainty assessment							№ of patients			Effect	Certainty
	№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	CART	ST	*p*-value	Absolute (95% CI)	
TNF-α (pg/mL)	4	RCT	not serious	serious[c]	not serious	serious[b]	none	130	126	0.03	SMD 0.89 lower (1.7 lower to 0.08 lower)	⊕⊕◯◯ Low
CRP (mg/dL)	3	RCT	not serious	very serious[a]	not serious	serious[b]	none	113	105	0.23	SMD 1.69 lower (4.42 lower to 1.05 higher)	⊕◯◯◯ Very low
ADPN (ug/mL)	2	RCT	serious[d]	very serious[a]	not serious	serious[b]	none	61	59	0.36	MD 5.06 higher (5.82 lower to 15.93 higher)	⊕◯◯◯ Very low
LEP (ng/mL)	4	RCT	not serious	serious[c]	not serious	serious[b]	none	122	114	0.03	SMD 0.63 lower (1.2 lower to 0.06 lower)	⊕⊕◯◯ Low
NK cells (%)	2	RCT	not serious	not serious	not serious	serious[b]	none	50	47	0.04	SMD 0.42 higher (0.01 higher to 0.82 higher)	⊕⊕⊕◯ Moderate
FA (score)	4	RCT	serious[e]	very serious[a]	not serious	serious[b]	none	168	180	0.03	SMD 0.98 lower (1.85 lower to 0.11 lower)	⊕◯◯◯ Very low
SQ (score)	2	RCT	not serious	serious[f]	not serious	serious[b]	none	70	72	0.01	SMD 1.17 lower (1.76 lower to 0.57 lower)	⊕⊕◯◯ Low
QoL (score)	4	RCT	serious[e]	very serious[a]	not serious	serious[b]	none	174	182	0.02	SMD 2.94 higher (0.46 higher to 5.41 higher)	⊕◯◯◯ Very low

ADPN: Adiponectin, AE: Aerobic Exercise, BC: Breast Cancer, BF: Body Fat, BM: Body Weight, BMI: Body Mass Index, BMD: Bone Mineral Density, C: Control Group, CART: Combined Aerobic and Resistance Training, CI: confidence intervals, CRF: Cardiorespiratory Fitness, CRP: C-Reactive Protein, DBP: Diastolic Blood Pressure, DEP: Depression, EX: Exercise Group, FA: Cancer-related Fatigue, FFM: Fat-Free Mass, FG: Fasting Glucose, FI: Fasting Insulin, FM: Fat Mass, HC: hip circumference, HDL-C: High-Density Lipoprotein Cholesterol, HRmax: Maximum Heart Rate, HRR: Heart Rate Reserve, IL: Interleukin, LEP: Leptin, LDL: Low-Density Lipoprotein Cholesterol, MD: mean difference, NK: Natural Killer, RCT: randomized control trial, RT: Resistance Training, SBP: Systolic Blood Pressure, SMD: standardized mean difference, ST: standard treatment, SQ: Sleep Quality, TC: Total Cholesterol, TG: Triglycerides, TNF-α: Tumor Necrosis Factor α, QoL: Quality of Life, WC: Waist circumference, WHR: Waist-to-Hip Ratio, 1-RM: Repetition Maximum, a: there is considerable heterogeneity in the study's outcome, b: the included studies recorded a small sample size for both the control and intervention group, c: there is substantial heterogeneity in the studies, d: The assessor was not blinding, e: participants were aware of all exercise procedures, f: there is moderate heterogeneity in the involved studies.

Anthropometrics and body composition

The present meta-analysis provides insights into the positive role of CART on specific anthropometric characteristics, such as BMI and HC, but not BM, WC, and WHR in women with BC and concurrent overweight/obesity. However, visceral fat was not assessed and this also is an important category of variables that should be examined further in the future, given that this type of fat adversely affects metabolic health and promotes comorbidity among BC patients and survivors with excessive weight (Anwar et al., 2021). Interestingly, CART as a component of a multimodal lifestyle intervention promotes weight loss in BC survivors (Lake et al., 2022), which is not aligned with our results, given that no meaningful change was reported in BM. However, since women with BC and concurrent excess weight prone to have abdominal obesity linked to glucose metabolism dysregulation (Moore and Shah, 2020), further investigation is needed in this area to determine whether CART alone can induce a significant reduction in BM.

Our results also show considerable improvements in critical body composition markers, such as BF, FM, and FFM, which are in line with CART-induced adaptations reported in people with obesity, but without cancer (Batrakoulis et al., 2022). This is a vital outcome, considering the key role of the obesity epidemic in BC recurrence among those who successfully completed treatment (Acevedo et al., 2022). Likewise, previous research showed similar effects of CART on various anthropometric and body composition indices among BC patients and survivors (Joaquim et al., 2022). Ultimately, exercise training is more beneficial than usual care for increasing FFM in women with BC, both during and after treatment (Fraser et al., 2022). Taking this into account, the present findings corroborate the current evidence underlining the vital role of regular exercise training, with particular emphasis on muscle strengthening activities, regarding the physiological and functional importance of FFM in this cohort (Fraser et al., 2022). However, further high-quality trials are warranted to identify whether CART can elicit favorable changes in visceral adiposity that is associated with lower morbidity and mortality risks (Mulligan et al., 2019).

Lipid metabolism

BC patients and survivors with concurrent overweight/obesity tend to demonstrate lipid metabolism impairments, enhancing the risk of developing CVD (Raychaudhuri et al., 2022). Thus, the relationship between lipid profile and obesity among BC survivors has been widely investigated (de Jesus et al., 2022; Okekunle et al., 2022; Vasseur and Guillaumond, 2022). According to the American Cancer Society guidelines, it is vital for cancer prevention and treatment to maintain a normal lipid profile, aiming to lower the likelihood of comorbidities (Rock et al., 2020). Importantly, the key role of lipid metabolism in promoting BC growth and progression has been documented, showing the strong relationship between obesity and BC (Blucher and Stadler, 2017). In this meta-analysis, CART elicited significant improvements in TC, HDL-C, and TG, but not in LDL-C. The present results support the current findings regarding the beneficial role of CART in improving blood lipids in BC patients (Kong and Gao, 2022). Such a remark cannot be explained here; however, the occurrence of obesity in conjunction with cancer may play some role in the simultaneous management of glucose and lipid homeostasis due to the presence of systemic inflammation (Roxburgh and McMillan, 2014). Noticeably, CART seems to be the optimal exercise solution for inducing favorable effects in lipid metabolism among people with BC and obesity (Kong and Gao, 2022), or obesity alone (Batrakoulis et al., 2022). Also, various traditional and alternative exercise modes appear effective for improving blood lipids in populations with impaired metabolic health and concurrent overweight/obesity (Al-Mhanna et al., 2023; Batrakoulis, 2022a; Batrakoulis, 2022b; Batrakoulis et al., 2021); however, additional studies examining these outcome measures among BC patients and survivors with overweight/obesity are necessary.

Inflammation

Obesity is associated with BC due to chronic adipose tissue inflammation, and thus BC patients with excess weight are likely to demonstrate high inflammatory markers (Kolb and Zhang, 2020). Interestingly, CART has been reported as an effective exercise training modality for improving the inflammatory profile in BC survivors (de Jesus Leite et al., 2018). In the present study, we detected significant CART-induced improvements in TNF-α, but not in IL-6, IL-8, and CRP. Such a substantial reduction in TNF-α is important, given that BC patients and survivors with overweight/obesity commonly present with several cardiometabolic health impairments linked to raised oxidative stress, diminished antioxidant capacity, and insulin dysregulation due to inflamed adipose tissue, altering the immune system (Roxburgh and McMillan, 2014; Simon et al., 2021). However, other inflammatory markers included in this meta-analysis did not exhibit significant changes following CART among BC patients and survivors with overweight/obesity. Hence, our results cannot provide clear evidence regarding the impact of CART on chronic inflammation in this cohort, and therefore further research in this area would be beneficial. Collectively, exercise training appears as a powerful non-pharmacological intervention for lowering circulating cytokines and inhibiting cancer recurrence in BC survivors (Zhou et al., 2022).

Adipokines

Considering that high circulating LEP levels increase the risk of tumor progression in cancer patients, while LEP resistance is common among individuals with obesity, exercise-induced reductions in LEP may be beneficial for BC patients and survivors with obesity (Perego et al., 2021). According to our results, CART showed a substantial reduction in LEP compared to ST. In general, data regarding the effects of CART on LEP among people with cancer and obesity are currently limited. However, a 6-month CART intervention improved various cardiometabolic health-related markers, including adipokines such as LEP and ADPN in middle-aged men with obesity (Brunelli et al., 2015). As for other exercise modes and their impact on LEP, conflicting results are present in the current literature regarding the effectiveness of long-term aerobic exercise. More specifically, aerobic exercise suggests dose-response favorable effects on LEP in premenopausal women at risk for BC (Sturgeon et al., 2016), but a 6-month aerobic-based training protocol did not exhibit a meaningful reduction in LEP among postmenopausal women at risk for BC (Khosravi et al., 2018). In summary, LEP has been documented as a vital mediator for the linkage between obesity and BC, promoting tumor initiation, development growth, and metastasis. That being said, future research on the potential role of CART interventions in circulating LEP levels may be necessary, since LEP is considered a key player in the novel therapeutic strategies for BC treatment (Atoum et al., 2020).

Given that ADPN is involved in glucose and energy homeostasis while being inversely associated with FM, individuals with obesity are commonly presented with low ADPN levels (Kadowaki and Yamauchi, 2005). Taking this into consideration, significant exercise-induced increases in ADPN levels may be critical for BC patients and survivors with a high BMI, since such favorable changes may improve body composition, affecting the risk of developing metastases (Perego et al., 2021). In this meta-analysis, CART did not suggest advantageous changes in ADPN relative to usual care. To date, relevant RCTs examining the role of ADPN in women with BC and obesity are scarce. However, a 4-week CART-like protocol showed positive alterations in ADPN among women with obesity, but without BC (Rejeki et al., 2023). Also, long-term aerobic exercise alone evokes a favorable elevation in ADPN levels while reducing BF in premenopausal women at risk for BC. Noticeably, these beneficial aerobic exercise-induced increases in ADPN were dependent on BF changes in this cohort (Sturgeon et al., 2016). Ultimately, ADPN is vital in both obesity and cancer, and thus exercise interventions suggesting significant increases in ADPN may considered as an important component of a multimodal treatment approach for BC patients and survivors with obesity (Perego et al., 2021).

Cancer-related indicators

Cancer-related FA has been reported as a very common

side effect of BC caused by treatment affecting hormones related to fatigue and pain. Therefore, BC patients and survivors demonstrate a likelihood of developing various major mental health complications, such as anxiety, depression, and distress, resulting in reduced sleep and QoL (Cho and Hwang, 2021). Generally, there is a relationship among cancer-related FA, SQ, and QoL among BC patients and survivors. Interestingly, six in 10 of BC patients demonstrate major sleep problems linked to significant reductions in QoL and mood (Fortner et al., 2002). On the other hand, regular involvement in physical activity and exercise may help individuals with obesity improve all these health-related indicators (Bardwell and Ancoli-Israel, 2008; Mendelson et al., 2016). In the present review, CART exhibited significant improvements in cancer-related FA, SQ, and QoL relative to usual care, indicating that such a training modality may be a valuable adjunct therapy option in women with BC and excessive weight. Such beneficial alterations in critical cancer-related indices may also play an important role in adherence and behavioral regulation to exercise during and after treatment, since supervised exercise delivered in a real-world clinical setting should be a priority for patients, clinicians, and practitioners (Kirkham et al., 2018). However, it has been well documented that people with obesity are very likely to show mental health impairments due to body dissatisfaction (Gilyana et al., 2023) linked to sedentarism (Chekroud et al., 2018), resulting in high dropout rates when participating in regular structured exercise (Burgess et al., 2017). Collectively, exercise training seems to be a powerful weapon against poor QoL among BC patients and survivors, and therefore exercise prescription to this particular cohort may be effective for lowering FA, improving SQ, and increasing QoL (Chen et al., 2023). Given that both cancer and obesity adversely affect SQ (Chang and Chang, 2020) and QoL (Heidary et al., 2023; Taylor et al., 2013), the effectiveness of various exercise modes, including CART, is vital for women with BC and excess weight, since CART-induced adaptations and responses may mitigate potential depressive and anxiety symptoms, as well as sleep disturbances frequently present in this cohort before, during, and after treatment without reducing compliance rates compared to usual care. (Wang et al., 2023).

Implications for future research

Considering that the combination of aerobic-based and muscle-strengthening activities is highly recommended for cancer patients and survivors (Campbell et al., 2019) as well as individuals with overweight/obesity (American College of Sports Medicine et al., 2021), further studies are urgently needed to investigate the optimal amount and intensity of CART for this cohort. Future trials should focus on the mechanisms behind the effectiveness of CART on cardiometabolic health and cancer-related indices as well as the association between CART and tumor growth. Also, studies examining the effects of CART on additional cardiovascular disease risk factors (e.g., glucose metabolism, blood pressure, and functional aerobic capacity) and mental health indicators (e.g., depression, anxiety, psychological distress, and mood) would support the current evidence. Furthermore, CART-like protocols should be investigated not only through supervised interventions conducted in a lab-based environment but also under real-world conditions, aiming to evaluate the practicability of CART among BC patients and survivors with overweight/obesity. Lastly, the potential role of CART in immunity among BC cancer patients and survivors also needs to be studied. Such a future approach may comprehend the relationship between CART and immune function as well as the connection between these immunological indicators and clinical benefits in this cohort.

Limitations

The present review has several limitations and thus the findings should be taken into consideration with caution. Eligible studies exhibited inconsistency with regard to the training parameters implemented during the CART interventions, resulting in significant heterogeneity among the included trials. Our study demonstrates that beneficial CART-induced adaptations are existent principally among middle-aged (mean age: 54.0 ± 3.4 years) women. Hence, current outcomes cannot be generalized to men, other age and BMI groups among BC patients and survivors. Considering the outcome measures included in the present study, the role of CART in a wide spectrum of cardiometabolic health still remains unclear due to the lack of data in terms of glucose homeostasis, resting cardiovascular function, oxidative stress, and physical function. Moreover, we discovered substantial heterogeneity in some outcomes in our analysis, but we were unable to explain this due to limited trials. Despite conducting a sensitivity analysis to explore the influence of performance bias and detection bias on the outcomes, in the majority of cases, there were no changes in the estimated effects. This may be attributed to inadequate sample size and biases associated with performance and detection.

Conclusion

The present systematic review and meta-analysis delivers critical outcomes regarding the implementation of CART for BC patients and survivors with concurrent overweight/obesity as an adjunct component of a comprehensive therapy plan. The findings reveal clear evidence that CART has a favorable effect on cardiometabolic health and cancer-related indicators, such as anthropometric characteristics, body composition, lipid homeostasis, inflammation, adipokines, fatigue, sleep, and QoL in BC patients and survivors with concurrent overweight/obesity during and after treatment. More trials with robust methodological design are needed to investigate the dose-response relationship, training parameters configuration, and mechanisms behind these beneficial alterations. This meta-analysis also highlights the rationale for further high-quality RCTs to examine additional outcome measures related to cardiometabolic and mental health, aiming to support the present CART-induced effects for BC patients and survivors with concurrent overweight/obesity.

Acknowledgements

The authors declare that there are no conflicts of interest. The experiments comply with the current laws of the country where they were performed. The data that support the findings of this study are available on request from the corresponding author.

References

Acevedo, F., Walbaum, B., Muniz, S., Petric, M., Martinez, R., Guerra, C., Navarro, M., Cordova-Delgado, M., Pinto, M.P. and Sanchez, C. (2022) Obesity is associated with early recurrence on breast cancer patients that achieved pathological complete response to neoadjuvant chemotherapy. *Scientific Reports* **12**, 21145. https://doi.org/10.1038/s41598-022-25043-2

Afolabi, H., Salleh, S.M., Zakaria, Z., Ch'ng, E.S., Mohd Nafi, S.N., Abdul Aziz, A.A.B., Al-Mhanna, S.B., Wada, Y. and Abdulrahman, A.S. (2022a) The Prediction of Survival Outcome and Prognosis Factor in Association with Comorbidity Status in Patients with Colorectal Cancer: A Research-Based Study. *Healthcare* **10**, 1693. https://doi.org/10.3390/healthcare10091693

Afolabi, H.A., Salleh, S.M., Zakaria, Z., Ch'ng, E.S., Mohd Nafi, S.N., Abdul Aziz, A.A.B., Irekeola, A.A., Wada, Y. and Al-Mhanna, S.B. (2022b) A GNAS gene mutation's independent expression in the growth of colorectal cancer: a systematic review and meta-analysis. *Cancers* **14**, 5480. https://doi.org/10.3390/cancers14225480

Al-Mhanna, S.B., Ghazali, W.S.W., Mohamed, M., Rabaan, A.A., Santali, E.Y., Alestad, J.H., Santali, E.Y., Arshad, S., Ahmed, N. and Afolabi, H.A. (2022) Effectiveness of physical activity on immunity markers and quality of life in cancer patients: a systematic review. *PeerJ* **10**, e13664. https://doi.org/10.7717/peerj.13664

Al-Mhanna, S.B., Leão, C., Wan Ghazali, W.S., Mohamed, M., Batrakoulis, A., Afolabi, H.A., Abubakar, B.D., Aldhahi, M.I., Gülü, M., Yagin, F.H. and Nikolaidis, P.T. (2024a) Impact of Exercise on High-Density Lipoprotein Cholesterol in Adults with Overweight and Obesity: A Narrative Review. *Annals of Applied Sport Science* **12**.

Al-Mhanna, S.B., Rocha-Rodriguesc, S., Mohamed, M., Batrakoulis, A., Aldhahi, M.I., Afolabi, H.A., Yagin, F.H., Alhussain, M.H., Gulu, M., Abubakar, B.D., Ghazali, W.S.W., Alghannam, A.F. and Badicu, G. (2023) Effects of combined aerobic exercise and diet on cardiometabolic health in patients with obesity and type 2 diabetes: a systematic review and meta-analysis. *BMC Sports Science Medicine and Rehabilitation* **15**, 165. https://doi.org/10.1186/s13102-023-00766-5

Al-Mhanna, S.B., Wan Ghazali, W.S., Batrakoulis, A., Alkhamees, N.H., Drenowatz, C., Mohamed, M., Gülü, M., Afolabi, H.A. and Badicu, G. (2024b) Impact of Various Types of Exercise on Lipid Metabolism in Patients with Type 2 Diabetes and Concurrent Overweight/Obesity: A Narrative Review. *Annals of Applied Sport Science* **12**.

Almstedt, H.C., Grote, S., Korte, J.R., Beaudion, S.P., Shoepe, T.C., Strand, S. and Tarleton, H.P. (2016) Combined aerobic and resistance training improves bone health of female cancer survivors. *Breast Cancer* **5**, 274-279. https://doi.org/10.1016/j.bonr.2016.09.003

American College of Sports Medicine, Liguori, G., Feito, Y., Fountaine, C. and Roy, B.A. (2021) *ACSM's guidelines for exercise testing and prescription*. 11th ed. Philadelphia, PA: Wolters Kluwer Health.

Anwar, S.L., Cahyono, R., Prabowo, D., Avanti, W.S., Choridah, L., Dwianingsih, E.K., Harahap, W.A. and Aryandono, T. (2021) Metabolic comorbidities and the association with risks of recurrent metastatic disease in breast cancer survivors. *BMC Cancer* **21**, 590. https://doi.org/10.1186/s12885-021-08343-0

Atoum, M.F., Alzoughool, F. and Al-Hourani, H. (2020) Linkage Between Obesity Leptin and Breast Cancer. *Breast Cancer (Auckl)* **14**, 1178223419898458. https://doi.org/10.1177/1178223419898458

Bardwell, W.A. and Ancoli-Israel, S. (2008) Breast Cancer and Fatigue. *Sleep Medicine Clinics* **3**, 61-71. https://doi.org/10.1016/j.jsmc.2007.10.011

Batrakoulis, A. (2022a) Psychophysiological Adaptations to Pilates Training in Overweight and Obese Individuals: A Topical Review. *Diseases* **10**. https://doi.org/10.3390/diseases10040071

Batrakoulis, A. (2022b) Psychophysiological Adaptations to Yoga Practice in Overweight and Obese Individuals: A Topical Review. *Diseases* **10**. https://doi.org/10.3390/diseases10040107

Batrakoulis, A., Jamurtas, A.Z. and Fatouros, I.G. (2021) High-Intensity Interval Training in Metabolic Diseases: Physiological Adaptations. *ACSM's Health & Fitness Journal* **25**, 54-59. https://doi.org/10.1249/FIT.0000000000000703

Batrakoulis, A., Jamurtas, A.Z., Metsios, G.S., Perivoliotis, K., Liguori, G., Feito, Y., Riebe, D., Thompson, W.R., Angelopoulos, T.J., Krustrup, P., Mohr, M., Draganidis, D., Poulios, A. and Fatouros, I.G. (2022) Comparative Efficacy of 5 Exercise Types on Cardiometabolic Health in Overweight and Obese Adults: A Systematic Review and Network Meta-Analysis of 81 Randomized Controlled Trials. *Circulation: Cardiovascular Quality and Outcomes* **15**, e008243. https://doi.org/10.1161/CIRCOUTCOMES.121.008243

Battaglini, C., Bottaro, M., Dennehy, C., Rae, L., Shields, E., Kirk, D. and Hackney, A. (2007) The effects of an individualized exercise intervention on body composition in breast cancer patients undergoing treatment. *Sao Paulo Medical Journal* **125**, 22-28. https://doi.org/10.1590/S1516-31802007000100005

Betof, A.S., Dewhirst, M.W. and Jones, L.W. (2013) Effects and potential mechanisms of exercise training on cancer progression: a translational perspective. *Brain, Behavior, and Immunity* **30**, 75-87. https://doi.org/10.1016/j.bbi.2012.05.001

Bloomquist, K., Adamsen, L., Hayes, S.C., Lillelund, C., Andersen, C., Christensen, K.B., Oturai, P., Ejlertsen, B., Tuxen, M.K. and Møller, T. (2019) Heavy-load resistance exercise during chemotherapy in physically inactive breast cancer survivors at risk for lymphedema: a randomized trial. Acta Oncologica **58(12)**, 1667-1675. https://doi.org/10.1080/0284186X.2019.1643916

Blucher, C. and Stadler, S.C. (2017) Obesity and Breast Cancer: Current Insights on the Role of Fatty Acids and Lipid Metabolism in Promoting Breast Cancer Growth and Progression. *Frontiers in Endocrinology* **8**, 293. https://doi.org/10.3389/fendo.2017.00293

Brown, J.C., Sarwer, D.B., Troxel, A.B., Sturgeon, K., DeMichele, A.M., Denlinger, C.S. and Schmitz, K.H. (2021) A randomized trial of exercise and diet on body composition in survivors of breast cancer with overweight or obesity. *Breast Cancer Research and Treatment* **189**, 145-154. https://doi.org/10.1007/s10549-021-06284-7

Brunelli, D.T., Chacon-Mikahil, M.P.T., Gaspari, A.F., Lopes, W.A., Bonganha, V., Bonfante, I.L., Bellotto, M.L., Libardi, C.A. and Cavaglieri, C.R. (2015) Combined Training Reduces Subclinical Inflammation in Obese Middle-Age Men. *Medicine & Science in Sports & Exercise* **47**, 2207-2215. https://doi.org/10.1249/MSS.0000000000000658

Burgess, E., Hassmen, P., Welvaert, M. and Pumpa, K.L. (2017) Behavioural treatment strategies improve adherence to lifestyle intervention programmes in adults with obesity: a systematic review and meta-analysis. *Clinical Obesity* **7**, 105-114. https://doi.org/10.1111/cob.12180

Campbell, K.L., Winters-Stone, K.M., Wiskemann, J., May, A.M., Schwartz, A.L., Courneya, K.S., Zucker, D.S., Matthews, C.E., Ligibel, J.A., Gerber, L.H., Morris, G.S., Patel, A.V., Hue, T.F., Perna, F.M. and Schmitz, K.H. (2019) Exercise Guidelines for Cancer Survivors: Consensus Statement from International Multidisciplinary Roundtable. *Medicine & Science in Sports & Exercise* **51**, 2375-2390. https://doi.org/10.1249/MSS.0000000000002116

Chang, W.P. and Chang, Y.P. (2020) Meta-Analysis of Changes in Sleep Quality of Women with Breast Cancer before and after Therapy. *Breast Care* **15**, 227-235. https://doi.org/10.1159/000502943

Chekroud, S.R., Gueorguieva, R., Zheutlin, A.B., Paulus, M., Krumholz, H.M., Krystal, J.H. and Chekroud, A.M. (2018) Association between physical exercise and mental health in 1.2 million individuals in the USA between 2011 and 2015: a cross-sectional study. *Lancet Psychiatry* **5**, 739-746. https://doi.org/10.1016/S2215-0366(18)30227-X

Chen, L., Peng, P., Xu, Z. and Ding, X. (2023) The effects of exercise on the quality of life of patients with breast cancer: a systematic review and meta-analysis based on the QLQ-C30 quality of life scale. *Gland Surgery* **12**, 633-650. https://doi.org/10.21037/gs-23-126

Cho, O.H. and Hwang, K.H. (2021) Association between sleep quality, anxiety and depression among Korean breast cancer survivors. *Nursing Open* **8**, 1030-1037. https://doi.org/10.1002/nop2.710

Chowdhury, F.A., Islam, M.F., Prova, M.T., Khatun, M., Sharmin, I., Islam, K.M., Hassan, M.K., Khan, M.A.S. and Rahman, M.M. (2021) Association of hyperlipidemia with breast cancer in Bangladeshi women. *Lipids in Health and Disease* **20**, 1-9. https://doi.org/10.1186/s12944-021-01480-2

Courneya, K.S., McKenzie, D.C., Mackey, J.R., Gelmon, K., Friedenreich, C.M., Yasui, Y., Reid, R.D., Vallerand, J.R., Adams, S.C.,

Proulx, C., Dolan, L.B., Wooding, E. and Segal, R.J. (2014) Subgroup effects in a randomised trial of different types and doses of exercise during breast cancer chemotherapy. *British Journal of Cancer* **111(9)**, 1718-1725. https://doi.org/10.1038/bjc.2014.466

Courneya, K.S., Segal, R.J., Mackey, J.R., Gelmon, K., Friedenreich, C.M., Yasui, Y., Reid, R.D., Jespersen, D., Cook, D., Proulx, C., Trinh, L., Dolan, L.B., Wooding, E., Forbes, C.C. and McKenzie, D.C. (2014) Effects of exercise dose and type on sleep quality in breast cancer patients receiving chemotherapy: a multicenter randomized trial. *Breast Cancer Research and Treatment* **144(2)**, 361-369. https://doi.org/10.1007/s10549-014-2883-0

de Jesus Leite, M.A.F., Puga, G.M., Arantes, F.J., Oliveira, C.J.F., Cunha, L.M., Bortolini, M.J.S. and Penha-Silva, N. (2018) Effects of combined and resistance training on the inflammatory profile in breast cancer survivors: A systematic review. *Complementary Therapies in Medicine* **36**, 73-81. https://doi.org/10.1016/j.ctim.2017.11.023

de Jesus, M., Mohammed, T., Singh, M., Tiu, J.G. and Kim, A.S. (2022) Etiology and Management of Dyslipidemia in Patients With Cancer. *Frontiers in Cardiovascular Medicine* **9**, 892335. https://doi.org/10.3389/fcvm.2022.892335

de Jesus Leite, M.A.F., Mariano, I.M., Dechichi, J.G.C., Giolo, J.S., Gonçalves, Á.C. and Puga, G.M. (2021) Exercise training and detraining effects on body composition, muscle strength and lipid, inflammatory and oxidative markers in breast cancer survivors under tamoxifen treatment. *Life Sciences* **284**, 119924. https://doi.org/10.1016/j.lfs.2021.119924

de Paulo, T.R., Winters-Stone, K.M., Viezel, J., Rossi, F.E., Simões, R.R., Tosello, G. and Junior, I.F.F. (2018) Effects of resistance plus aerobic training on body composition and metabolic markers in older breast cancer survivors undergoing aromatase inhibitor therapy. *Experimental Gerontology* **111**, 210-217. https://doi.org/10.1016/j.exger.2018.07.022

Dieli-Conwright, C.M., Courneya, K.S., Demark-Wahnefried, W., Sami, N., Lee, K., Buchanan, T.A., Spicer, D.V., Tripathy, D., Bernstein, L. and Mortimer, J.E. (2018) Effects of aerobic and resistance exercise on metabolic syndrome, sarcopenic obesity, and circulating biomarkers in overweight or obese survivors of breast cancer: a randomized controlled trial. *Journal of Clinical Oncology* **36**, 875. https://doi.org/10.1200/JCO.2017.75.7526

Dieli-Conwright, C.M., Harrigan, M., Cartmel, B., Chagpar, A., Bai, Y., Li, F.-y., Rimm, D.L., Pusztai, L., Lu, L. and Sanft, T. (2022) Impact of a randomized weight loss trial on breast tissue markers in breast cancer survivors. *NPJ Breast Cancer* **8**, 1-7. https://doi.org/10.1038/s41523-022-00396-z

Dieli-Conwright, C.M. and Orozco, B.Z. (2015) Exercise after breast cancer treatment: current perspectives. *Breast Cancer: Targets and Therapy* **7**, 353. https://doi.org/10.2147/BCTT.S82039

Dieli-Conwright, C.M., Sweeney, F.C., Courneya, K.S., Tripathy, D., Sami, N., Lee, K., Buchanan, T.A., Spicer, D., Bernstein, L. and Mortimer, J.E. (2019) Hispanic ethnicity as a moderator of the effects of aerobic and resistance exercise in survivors of breast cancer. *Cancer* **125**, 910-920. https://doi.org/10.1002/cncr.31879

Elreda, L., Kim, A. and Malik, M. (2022) Mitigating Breast Cancer Disparities by Addressing the Obesity Epidemic. *Current Breast Cancer Reports* **14**, 168-173. https://doi.org/10.1007/s12609-022-00460-4

Ergun, M., Eyigor, S., Karaca, B., Kisim, A. and Uslu, R. (2013) Effects of exercise on angiogenesis and apoptosis-related molecules, quality of life, fatigue and depression in breast cancer patients. *European Journal of Cancer Care* **22**, 626-637. https://doi.org/10.1111/ecc.12068

Feliciano, E.M.C., Chen, W.Y., Bradshaw, P.T., Prado, C.M., Alexeeff, S., Albers, K.B., Castillo, A.L. and Caan, B.J. (2019) Adipose tissue distribution and cardiovascular disease risk among breast cancer survivors. *Journal of Clinical Oncology* **37**, 2528. https://doi.org/10.1200/JCO.19.00286

Fernández-Lao, C., Cantarero-Villanueva, I., Fernández-de-Las-Peñas, C., del Moral-Ávila, R., Castro-Sánchez, A.M. and Arroyo-Morales, M. (2012) Effectiveness of a multidimensional physical therapy program on pain, pressure hypersensitivity, and trigger points in breast cancer survivors: a randomized controlled clinical trial. *The Clinical Journal of Pain* **28(2)**, 113-121. https://doi.org/10.1097/AJP.0b013e318225dc02

Fortner, B.V., Stepanski, E.J., Wang, S.C., Kasprowicz, S. and Durrence, H.H. (2002) Sleep and quality of life in breast cancer patients. *Journal of Pain and Symptom Management* **24**, 471-480. https://doi.org/10.1016/S0885-3924(02)00500-6

Fraser, S.F., Gardner, J.R., Dalla Via, J. and Daly, R.M. (2022) The Effect of Exercise Training on Lean Body Mass in Breast Cancer Patients: A Systematic Review and Meta-analysis. *Medicine & Science in Sports & Exercise* **54**, 211-219. https://doi.org/10.1249/MSS.0000000000002792

Ganz, P.A. (2006) Monitoring the physical health of cancer survivors: a survivorship-focused medical history. *Journal of Clinical Oncology* **24**, 5105-5111. https://doi.org/10.1200/JCO.2006.06.0541

Gilyana, M., Batrakoulis, A. and Zisi, V. (2023) Physical Activity, Body Image, and Emotional Intelligence Differences in Adults with Overweight and Obesity. *Diseases* **11**. https://doi.org/10.3390/diseases11020071

Gómez, A.M., Martínez, C., Fiuza-Luces, C., Herrero, F., Pérez, M., Madero, L., Ruiz, J.R., Lucia, A. and Ramírez, M. (2011) Exercise training and cytokines in breast cancer survivors. *International Journal of Sports Medicine* **32(6)**, 461-467. https://doi.org/10.1055/s-0031-1271697

Gonzalo-Encabo, P., Christopher, C.N., Lee, K., Normann, A.J., Yunker, A.G., Norris, M.K., Wang, E. and Dieli-Conwright, C.M. (2022) High Intensity Interval Training Improves Metabolic Syndrome in Women with Breast Cancer Receiving Anthracyclines. *Scandinavian Journal of Medicine & Science in Sports* **33(4)**, 475-484. https://doi.org/10.1111/sms.14280

GRADEpro, G. (2014) Computer program on www.gradepro.org. Version [July, 2016]. McMaster University.

Greenlee, H., Shi, Z., Molmenti, C.L.S., Rundle, A. and Tsai, W.Y. (2016) Trends in obesity prevalence in adults with a history of cancer: results from the US National Health Interview Survey, 1997 to 2014. *Journal of Clinical Oncology* **34**, 3133. https://doi.org/10.1200/JCO.2016.66.4391

Guo, Y.-Z., Pan, L., Du, C.-J., Ren, D.-Q. and Xie, X.-M. (2013) Association between C-reactive protein and risk of cancer: a meta-analysis of prospective cohort studies. *Asia Pacific Journal of Clinical Oncology* **14**, 243-248. https://doi.org/10.7314/APJCP.2013.14.1.243

Harvie, M., Pegington, M., McMullan, D., Bundred, N., Livingstone, K., Campbell, A., Wolstenholme, J., Lovato, E., Campbell, H., Adams, J., Speed, S., Morris, J., Howell, S. and Howell, A. (2019) The effectiveness of home versus community-based weight control programmes initiated soon after breast cancer diagnosis: a randomised controlled trial. *British Journal of Cancer* **121(6)**, 443-454. https://doi.org/10.1038/s41416-019-0522-6

Heidary, Z., Ghaemi, M., Hossein Rashidi, B., Kohandel Gargari, O. and Montazeri, A. (2023) Quality of Life in Breast Cancer Patients: A Systematic Review of the Qualitative Studies. *Cancer Control* **30**, 10732748231168318. https://doi.org/10.1177/10732748231168318

Higgins, J.P. and Green, S. (2008) Cochrane handbook for systematic reviews of interventions. https://doi.org/10.1002/9780470712184

Hutnick, N.A., Williams, N.I., Kraemer, W.J., Orsega-Smith, E., Dixon, R.H., Bleznak, A.D. and Mastro, A.M. (2005) Exercise and lymphocyte activation following chemotherapy for breast cancer. *Medicine and Science in Sports and Exercise* **37**, 1827. https://doi.org/10.1249/01.mss.0000175857.84936.1a

Hwangbo, Y., Kang, D., Kang, M., Kim, S., Lee, E.K., Kim, Y.A., Chang, Y.J., Choi, K.S., Jung, S.-Y. and Woo, S.M. (2018) Incidence of diabetes after cancer development: a Korean national cohort study. *Journal of Diabetes* **4**, 1099-1105. https://doi.org/10.1001/jamaoncol.2018.1684

Joaquim, A., Leao, I., Antunes, P., Capela, A., Viamonte, S., Alves, A.J., Helguero, L.A. and Macedo, A. (2022) Impact of physical exercise programs in breast cancer survivors on health-related quality of life, physical fitness, and body composition: Evidence from systematic reviews and meta-analyses. *Frontiers in Oncology* **12**, 955505. https://doi.org/10.3389/fonc.2022.955505

Jones, L.M., Stoner, L., Baldi, J.C. and McLaren, B. (2020) Circuit resistance training and cardiovascular health in breast cancer survivors. *European Journal of Cancer Care* **29**, e13231. https://doi.org/10.1111/ecc.13231

Jones, L.W. and Courneya, K.S. (2002) Exercise counseling and programming preferences of cancer survivors. *Cancer Practice* **10**, 208-215. https://doi.org/10.1046/j.1523-5394.2002.104003.x

Kadowaki, T. and Yamauchi, T. (2005) Adiponectin and adiponectin receptors. *Endocrine Reviews* **26**, 439-451. https://doi.org/10.1210/er.2005-0005

Khosravi, N., Eskandari, Z., Farajivafa, V., Hanson, E.D., Agha-Alinejad, H., Abdollah-Pour, A. and Haghighat, S. (2018) Effect of 6 months of aerobic training on adipokines as breast cancer risk factors in postmenopausal women: A randomized controlled trial. *Journal of Cancer Research and Therapeutics* **14**, 1336-1340. https://doi.org/10.4103/jcrt.JCRT_684_16

Kim, T.H., Chang, J.S., Park, K.S., Park, J., Kim, N., Lee, J.I. and Kong, I.D. (2017) Effects of exercise training on circulating levels of Dickkpof-1 and secreted frizzled-related protein-1 in breast cancer survivors: A pilot single-blind randomized controlled trial. *Plos One* **12(2)**, e0171771. https://doi.org/10.1371/journal.pone.0171771

Kirkham, A.A., Bonsignore, A., Bland, K.A., McKenzie, D.C., Gelmon, K.A., Van Patten, C.L. and Campbell, K.L. (2018) Exercise Prescription and Adherence for Breast Cancer: One Size Does Not FITT All. *Medicine & Science in Sports & Exercise* **50**, 177-186. https://doi.org/10.1249/MSS.0000000000001446

Kolb, R. and Zhang, W. (2020) Obesity and Breast Cancer: A Case of Inflamed Adipose Tissue. *Cancers* **12**. https://doi.org/10.3390/cancers12061686

Kong, L. and Gao, R. (2022) Aerobic exercise combined with resistance exercise training improves cardiopulmonary function and blood lipid of patients with breast cancer: A systematic review and meta-analysis. Medicine (Baltimore) **101**, e32391. https://doi.org/10.1097/MD.0000000000032391

Kudiarasu, C., Lopez, P., Galvao, D.A., Newton, R.U., Taaffe, D.R., Mansell, L., Fleay, B., Saunders, C., Fox-Harding, C. and Singh, F. (2023) What are the most effective exercise, physical activity, and dietary interventions to improve body composition in women diagnosed with or at high-risk of breast cancer? A systematic review and network meta-analysis. *Cancer* **129**, 3697-3712. https://doi.org/10.1002/cncr.35043

Lake, B., Damery, S. and Jolly, K. (2022) Effectiveness of weight loss interventions in breast cancer survivors: a systematic review of reviews. *British Journal of Sports Medicine Open* **12**, e062288. https://doi.org/10.1136/bmjopen-2022-062288

Lee, K., Tripathy, D., Demark-Wahnefried, W., Courneya, K.S., Sami, N., Bernstein, L., Spicer, D., Buchanan, T.A., Mortimer, J.E. and Dieli-Conwright, C.M. (2019) Effect of aerobic and resistance exercise intervention on cardiovascular disease risk in women with early-stage breast cancer: a randomized clinical trial. *JAMA Oncology* **5**, 710-714. https://doi.org/10.1001/jamaoncol.2019.0038

Ligibel, J.A., Campbell, N., Partridge, A., Chen, W.Y., Salinardi, T., Chen, H., Adloff, K., Keshaviah, A. and Winer, E.P. (2008) Impact of a mixed strength and endurance exercise intervention on insulin levels in breast cancer survivors. *Journal of Clinical Oncology* **26**, 907-912. https://doi.org/10.1200/JCO.2007.12.7357.

Ligibel, J.A., Dillon, D., Giobbie-Hurder, A., McTiernan, A., Frank, E., Cornwell, M., Pun, M., Campbell, N., Dowling, R.J. and Chang, M.C. (2019) Impact of a Pre-Operative Exercise Intervention on Breast Cancer Proliferation and Gene Expression: Results from the Pre-Operative Health and Body (PreHAB) Study Exercise Window Trial in Newly Diagnosed Breast Cancer. *Clinical Cancer Research* **25**, 5398-5406. https://doi.org/10.1158/1078-0432.CCR-18-3143

Lohmann, A.E., Soldera, S.V., Pimentel, I., Ribnikar, D., Ennis, M., Amir, E. and Goodwin, P.J. (2021) Association of obesity with breast cancer outcome in relation to cancer subtypes: a meta-analysis. *Journal of the National Cancer Institute* 113(11), 1465-1475. https://doi.org/10.1093/jnci/djab023

Mann, S., Beedie, C. and Jimenez, A. (2014) Differential effects of aerobic exercise, resistance training, and combined exercise modalities on cholesterol and the lipid profile: review, synthesis, and recommendations. *Sports Medicine* **44**, 211-221. https://doi.org/10.1007/s40279-013-0110-5

May, A.M., Van Weert, E., Korstjens, I., Hoekstra-Weebers, J.E., Van Der Schans, C.P., Zonderland, M.L., Mesters, I., Van Den Borne, B. and Ros, W.D. (2008) Improved physical fitness of cancer survivors: a randomised controlled trial comparing physical training with physical and cognitive-behavioural training. *Acta Oncologica* **47(5)**, 825-834. https://doi.org/10.1080/02841860701666063

Mendelson, M., Borowik, A., Michallet, A.S., Perrin, C., Monneret, D., Faure, P., Levy, P., Pepin, J.L., Wuyam, B. and Flore, P. (2016) Sleep quality, sleep duration, and physical activity in obese adolescents: effects of exercise training. *Pediatric Obesity* **11**, 26-32. https://doi.org/10.1111/ijpo.12015

Meneses-Echávez, J.F., González-Jiménez, E. and 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**, 1-13. https://doi.org/10.1186/s12885-015-1069-4

Milne, H.M., Wallman, K.E., Gordon, S. and Courneya, K.S. (2008a) Effects of a combined aerobic and resistance exercise program in breast cancer survivors: a randomized controlled trial. *Breast Cancer Research and Treatment* **108**, 279-288. https://doi.org/10.1007/s10549-007-9602-z

Milne, H.M., Wallman, K.E., Gordon, S. and Courneya, K.S. (2008b) Impact of a combined resistance and aerobic exercise program on motivational variables in breast cancer survivors: a randomized controlled trial. *Annals of Behavioral Medicine* **36(2)**, 158-166. https://doi.org/10.1007/s12160-008-9059-2

Moore, K.J. and Shah, R. (2020) Introduction to the obesity, metabolic syndrome, and CVD compendium. Circulation Research, 126, 1475-1476. https://doi.org/10.1161/CIRCRESAHA.120.317240

Mortimer, J.E., Barsevick, A.M., Bennett, C.L., Berger, A.M., Cleeland, C., DeVader, S.R., Escalante, C., Gilreath, J., Hurria, A. and Mendoza, T.R. (2010) Studying cancer-related fatigue: report of the NCCN scientific research committee. *Journal of the National Comprehensive Cancer Network* **8**, 1331-1339. https://doi.org/10.6004/jnccn.2010.0101

Mulligan, A.A., Lentjes, M.A.H., Luben, R.N., Wareham, N.J. and Khaw, K.T. (2019) Changes in waist circumference and risk of all-cause and CVD mortality: results from the European Prospective Investigation into Cancer in Norfolk (EPIC-Norfolk) cohort study. *BMC Cardiovascular Disorders* **19**, 238. https://doi.org/10.1186/s12872-019-1223-z

Mutalub, Y.B., Abdulwahab, M., Mohammed, A., Yahkub, A.M., Al-Mhanna, S.B., Yusof, W., Tang, S.P., Rasool, A.H.G. and Mokhtar, S.S. (2022) Gut microbiota modulation as a novel therapeutic strategy in cardiometabolic diseases. *Foods* **11**, 2575. https://doi.org/10.3390/foods11172575

Mutrie, N., Campbell, A.M., Whyte, F., McConnachie, A., Emslie, C., Lee, L., Kearney, N., Walker, A. and Ritchie, D. (2007) Benefits of supervised group exercise programme for women being treated for early stage breast cancer: pragmatic randomised controlled trial. *British Journal of Sports Medicine* **334**, 517. https://doi.org/10.1136/bmj.39094.648553.AE

Newsome, A.M., Reed, R., Sansone, J., Batrakoulis, A., McAvoy, C. and Parrott, M.W. (2024) 2024 ACSM Worldwide Fitness Trends: Future Directions of the Health and Fitness Industry. *ACSM's Health & Fitness Journal* **28**, 14-26. https://doi.org/10.1249/FIT.0000000000000933

Nieman, D., Cook, V., Henson, D., Suttles, J., Rejeski, W., Ribisl, P., Fagoaga, O. and Nehlsen-Cannarella, S. (1995) Moderate exercise training and natural killer cell cytotoxic activity in breast cancer patients. *International Journal of Sports Medicine* **16**, 334-337. https://doi.org/10.1055/s-2007-973015

Okekunle, A.P., Yie, G.E., Song, S., Kim, Z., Youn, H.J., Cho, J., Min, J.W., Kim, Y.S. and Lee, J.E. (2022) Association of lipid profile with obesity among breast cancer survivors: a cross-sectional study. *Lipids in Health and Disease* **21**, 66. https://doi.org/10.1186/s12944-022-01674-2

Ording, A.G., Garne, J.P., Nyström, P.M.W., Frøslev, T., Sørensen, H.T. and Lash, T.L. (2013) Comorbid diseases interact with breast cancer to affect mortality in the first year after diagnosis—a Danish nationwide matched cohort study. *Plos One* **8**, e76013. https://doi.org/10.1371/journal.pone.0076013

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hrobjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P. and Moher, D. (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *British Journal of Sports Medicine* **372**, 71. https://doi.org/10.1136/bmj.n71

Paulo, T.R.S., Rossi, F.E., Viezel, J., Tosello, G.T., Seidinger, S.C., Simões, R.R., de Freitas, R. Jr. and Freitas, I.F. Jr (2019) The impact of an exercise program on quality of life in older breast

cancer survivors undergoing aromatase inhibitor therapy: a randomized controlled trial. *Health and Quality of Life Outcomes* **17(1)**, 17. https://doi.org/10.1186/s12955-019-1090-4

Perego, S., Sansoni, V., Ziemann, E. and Lombardi, G. (2021) Another Weapon against Cancer and Metastasis: Physical-Activity-Dependent Effects on Adiposity and Adipokines. *International Journal of Molecular Sciences* **22**. https://doi.org/10.3390/ijms22042005

Petrelli, F., Cortellini, A., Indini, A., Tomasello, G., Ghidini, M., Nigro, O., Salati, M., Dottorini, L., Iaculli, A. and Varricchio, A. (2021) Association of obesity with survival outcomes in patients with cancer: a systematic review and meta-analysis. *Journal of Nutrition* **4**, e213520. https://doi.org/10.1001/jamanetworkopen.2021.3520

Raychaudhuri, S., Dieli-Conwright, C.M., Cheng, R.K., Barac, A., Reding, K.W., Vasbinder, A., Cook, K.L., Nair, V., Desai, P. and Simon, M.S. (2022) A review of research on the intersection between breast cancer and cardiovascular research in the Women's Health Initiative (WHI). *Frontiers in Oncology* **12**, 1039246. https://doi.org/10.3389/fonc.2022.1039246

Rejeki, P.S., Pranoto, A., Rahmanto, I., Izzatunnisa, N., Yosika, G.F., Hernaningsih, Y., Wungu, C.D.K. and Halim, S. (2023) The Positive Effect of Four-Week Combined Aerobic-Resistance Training on Body Composition and Adipokine Levels in Obese Females. *Sports (Basel)* **11**. https://doi.org/10.3390/sports11040090

Rock, C.L., Thomson, C., Gansler, T., Gapstur, S.M., McCullough, M.L., Patel, A.V., Andrews, K.S., Bandera, E.V., Spees, C.K., Robien, K., Hartman, S., Sullivan, K., Grant, B.L., Hamilton, K.K., Kushi, L.H., Caan, B.J., Kibbe, D., Black, J.D., Wiedt, T.L., McMahon, C., Sloan, K. and Doyle, C. (2020) American Cancer Society guideline for diet and physical activity for cancer prevention. *Cancer Journal for Clinicians* **70**, 245-271. https://doi.org/10.3322/caac.21591

Rogers, L.Q., Fogleman, A., Trammell, R., Hopkins-Price, P., Vicari, S., Rao, K., Edson, B., Verhulst, S., Courneya, K.S. and Hoelzer, K. (2013) Effects of a physical activity behavior change intervention on inflammation and related health outcomes in breast cancer survivors: pilot randomized trial. *Integrative Cancer Therapies* **12**, 323-335. https://doi.org/10.1177/1534735412449687

Rogers, L.Q., Fogleman, A., Trammell, R., Hopkins-Price, P., Spenner, A., Vicari, S., Rao, K., Courneya, K.S., Hoelzer, K., Robbs, R. and Verhulst, S. (2015) Inflammation and psychosocial factors mediate exercise effects on sleep quality in breast cancer survivors: pilot randomized controlled trial. *Psychooncology* **24(3)**, 302-310. https://doi.org/10.1002/pon.3594

Rogers, L.Q., Vicari, S., Trammell, R., Hopkins-Price, P., Fogleman, A., Spenner, A., Rao, K., Courneya, K.S., Hoelzer, K.S. and Robbs, R. (2014) Biobehavioral factors mediate exercise effects on fatigue in breast cancer survivors. *Medicine and Science in Sports and Exercise* **46**, 1077. https://doi.org/10.1249/MSS.0000000000000210

Roxburgh, C.S. and McMillan, D.C. (2014) Cancer and systemic inflammation: treat the tumour and treat the host. *British Journal of Cancer* **110**, 1409-1412. https://doi.org/10.1038/bjc.2014.90

Saxton, J.M., Scott, E.J., Daley, A.J., Woodroofe, M.N., Mutrie, N., Crank, H., Powers, H.J. and Coleman, R.E. (2014) Effects of an exercise and hypocaloric healthy eating intervention on indices of psychological health status, hypothalamic-pituitary-adrenal axis regulation, and immune function after early-stage breast cancer: a randomised controlled trial. *Breast Cancer Research* **16**, 1-10. https://doi.org/10.1186/bcr3643

Schmitz, K.H., Troxel, A.B., Dean, L.T., DeMichele, A., Brown, J.C., Sturgeon, K., Zhang, Z., Evangelisti, M., Spinelli, B., Kallan, M.J., Denlinger, C., Cheville, A., Winkels, R.M., Chodosh, L. and Sarwer, D.B. (2019) Effect of home-based exercise and weight loss programs on breast cancer-related lymphedema outcomes among overweight breast cancer survivors: The WISER Survivor randomized clinical trial. *JAMA Oncology* **5(11)**, 1605-1613. https://doi.org/10.1001/jamaoncol.2019.2109

Schwartz, A.L., Winters-Stone, K. and Gallucci, B. (2007) Exercise effects on bone mineral density in women with breast cancer receiving adjuvant chemotherapy. *Oncology Nursing Forum* **34(3)**, 627-633. https://doi.org/10.1188/07.ONF.627-633

Scott, E., Daley, A., Doll, H., Woodroofe, N., Coleman, R., Mutrie, N., Crank, H., Powers, H. and Saxton, J. (2013) Effects of an exercise and hypocaloric healthy eating program on biomarkers associated with longterm prognosis after early-stage breast cancer: a randomized controlled trial. *Cancer Causes & Control* **24**, 181-191. https://doi.org/10.1007/s10552-012-0104-x

Siegel, R.L., Miller, K.D. and Jemal, A. (2020) Cancer statistics, 2020. *Cancer Journal for Clinicians* **70**, 7-30. https://doi.org/10.3322/caac.21590

Simon, M.S., Hastert, T.A., Barac, A., Banack, H.R., Caan, B.J., Chlebowski, R.T., Foraker, R., Hovsepyan, G., Liu, S., Luo, J., Manson, J.E., Neuhouser, M.L., Okwuosa, T.M., Pan, K., Qi, L., Ruterbusch, J.J., Shadyab, A.H., Thomson, C.A., Wactawski-Wende, J., Waheed, N. and Beebe-Dimmer, J.L. (2021) Cardiometabolic risk factors and survival after cancer in the Women's Health Initiative. *Cancer* **127**, 598-608. https://doi.org/10.1002/cncr.33295

Speck, R.M., Courneya, K.S., Mâsse, L.C., Duval, S. and Schmitz, K.H. (2010) An update of controlled physical activity trials in cancer survivors: a systematic review and meta-analysis. *Journal of Cancer Survivorship* **4**, 87-100. https://doi.org/10.1007/s11764-009-0110-5

Stanton, A.L. (2006) Psychosocial concerns and interventions for cancer survivors. *Journal of Clinical Oncology* **24**, 5132-5137. https://doi.org/10.1200/JCO.2006.06.8775

Sturgeon, K., Digiovanni, L., Good, J., Salvatore, D., Fenderson, D., Domchek, S., Stopfer, J., Galantino, M.L., Bryan, C., Hwang, W.T. and Schmitz, K. (2016) Exercise-Induced Dose-Response Alterations in Adiponectin and Leptin Levels Are Dependent on Body Fat Changes in Women at Risk for Breast Cancer. *Cancer Epidemiology Biomarkers & Prevention* **25**, 1195-2000. https://doi.org/10.1158/1055-9965.EPI-15-1087

Sweeney, F.C., Demark-Wahnefried, W., Courneya, K.S., Sami, N., Lee, K., Tripathy, D., Yamada, K., Buchanan, T.A., Spicer, D.V., Bernstein, L., Mortimer, J.E. and Dieli-Conwright, C.M. (2019) Aerobic and resistance exercise improves shoulder function in women who are overweight or obese and have breast cancer: A randomized controlled trial. *Physical Therapy* **99(10)**, 1334-1345. https://doi.org/10.1093/ptj/pzz096

Taylor, V.H., Forhan, M., Vigod, S.N., McIntyre, R.S. and Morrison, K.M. (2013) The impact of obesity on quality of life. *Best Practice & Research Clinical Endocrinology & Metabolism* **27**, 139-146. https://doi.org/10.1016/j.beem.2013.04.004

Travier, N., Fonseca-Nunes, A., Javierre, C., Guillamo, E., Arribas, L., Peiró, I., Buckland, G., Moreno, F., Urruticoechea, A., Oviedo, G.R., Roca, A., Hurtós, L., Ortega, V., Muñoz, M., Garrigós, L., Cirauqui, B., Del Barco, S., Arcusa, A., Seguí, M.A., Borràs, J.M., Gonzalez, C.A. and Agudo, A. (2014) Effect of a diet and physical activity intervention on body weight and nutritional patterns in overweight and obese breast cancer survivors. *Medical Oncology* **31(1)**, 783. https://doi.org/10.1007/s12032-013-0783-5

Van Alsten, S.C., Rabkin, C.S., Sawada, N., Shimazu, T., Charvat, H., Yamaji, T., Inoue, M., Kemp, T.J., Pinto, L.A. and Camargo, M.C. (2020) Metabolic syndrome, physical activity, and inflammation: a cross-sectional analysis of 110 circulating biomarkers in Japanese adults. *Cancer Epidemiology, Biomarkers & Prevention* **29**, 1639-1646. https://doi.org/10.1158/1055-9965.EPI-19-1513

Vasseur, S. and Guillaumond, F. (2022) Lipids in cancer: a global view of the contribution of lipid pathways to metastatic formation and treatment resistance. *Oncogenesis* **11**, 46. https://doi.org/10.1038/s41389-022-00420-8

Wang, T.C., Chen, P.L., Liao, W.C. and Tsai, I.C. (2023) Differential Impact of Exercises on Quality-of-Life Improvement in Breast Cancer Survivors: A Network Meta-Analysis of Randomized Controlled Trials. *Cancers* **15**. https://doi.org/10.3390/cancers15133380

Wu, M., Chou, Y., Chou, W., Hsu, G., Chu, C., Yu, C., Yu, J. and Sun, C. (2009) Circulating levels of leptin, adiposity, and breast cancer risk. *British Journal of Cancer* **100**, 578-582. https://doi.org/10.1038/sj.bjc.6604913

Yang, H., Liu, L. and Zhang, X. (2023) Exercise interventions on body composition and quality of life of overweight/obese breast cancer survivors: a meta-analysis. *BMC Women's Health* **23**, 484. https://doi.org/10.1186/s12905-023-02627-2

Zhou, Y., Jia, N., Ding, M. and Yuan, K. (2022) Effects of exercise on inflammatory factors and IGF system in breast cancer survivors:

a meta-analysis. *BMC Women's Health* **22**, 507. https://doi.org/10.1186/s12905-022-02058-5

Key points

- Combined aerobic and resistance training exert beneficial changes in anthropometrics, body composition, and lipid metabolism.
- Combined aerobic and resistance training reveals advantageous alterations in various cancer-related indicators, such as fatigue, sleep, and quality of life.
- Combined aerobic and resistance training may be considered a valuable piece of a multicomponent therapy puzzle in supporting women with breast cancer and concurrent overweight/obesity.
- Further research is needed in this area through large-scale randomized controlled trials and higher methodological quality.

✉ **Alexios Batrakoulis**
Department of Physical Education and Sport Science, School of Physical Education, Sport Science and Dietetics, University of Thessaly, Karies, Trikala, Greece

✉ **Wan Syaheedah Wan Ghazali**
Department of Physiology, School of Medical Sciences, University Sains Malaysia, Kubang Kerian, Kelantan, Malaysia

AUTHOR BIOGRAPHY

Sameer Badri AL-MHANNA
Employment
Department of Exercise Physiology, School of Medical Sciences, Universiti Sains Malaysia, Malaysia
Degree
PhD
Research interests
Clinical Exercise Physiology, Cancer, Obesity, Diabetes Mellitus
E-mail: sameerbadri9@gmail.com

Alexios BATRAKOULIS
Employment
Department of Physical Education and Sport Science, School of Physical Education and Sport Science, Democritus University of Thrace, Greece
Degree
PhD
Research interests
Clinical Exercise Physiology, Obesity, High-Intensity Interval Training, Strength and Conditioning, Health and Fitness Trends
E-mail: abatrako@phyed.duth.gr

Mohd Noor NORHAYATI
Employment
Department of Family Medicine, School of Medical Sciences, Universiti Sains Malaysia, Malaysia
Degree
PhD
Research interests
Maternal Health, Complementary Medicine
E-mail: hayatikk@usm.my

Mahaneem MOHAMED
Employment
Department of Physiology, School of Medical Sciences, Universiti Sains Malaysia, Malaysia
Degree
PhD
Research interests
Obesity, Diabetes Mellitus
E-mail: mahaneem@usm.my

Clemens DRENOWATZ
Employment
Division of Sport, Physical Activity and Health, University of Education Upper Austria, Austria
Degree
PhD
Research interests
Motor Competence, Exercise, Weight Management
E-mail: Clemens.drenowatz@ph-ooe.at

Ahmad Adebayo IREKEOLA
Employment
Depart. of Medical Microbiology and Parasitology, School of Medical Sciences, Univ. Sains Malaysia, Malaysia
Degree
PhD
Research interests
Viral Infectious Diseases
E-mail: profahmad007@yahoo.com

Hafeez Abiola AFOLABI
Employment
Department of General Surgery, School of Medical Sciences, Hospital University Sains Malaysia, Malaysia
Degree
PhD
Research interests
General Surgery, Cancer, Obesity, Diabetes Mellitus
E-mail: afolabihafeez68@gmail.com

Mehmet GÜLÜ
Employment
Department of Sports Management, Faculty of Sport Sciences, Kirikkale University, Kirikkale, Turkey
Degree
PhD
Research interests
Sports Medicine, Obesity, Physical Activity
E-mail: mehmetgulu@kku.edu.tr

Nouf H. ALKHAMEES
Employment
Department of Rehabilitation, College of Health and Rehabilitation Sciences, Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia
Degree
PhD
Research interests
Orthopedic Rehabilitation, Holistic Care
E-mail: nhalkhamees@pnu.edu.sa

Wan Syaheedah WAN GHAZALI
Employment
Department of Physiology, School of Medical Sciences, Universiti Sains Malaysia, Malaysia
Degree
PhD
Research interests
Obesity, Diabetes Mellitus
E-mail: syaheeda@usm.my

SUPPLEMANTARY MATERIALS

Table S1. Search strategy.

#	Database	Algorithm
1	PubMed	((("Breast cancer" [Title/Abstract]) OR ("Breast Neoplasm" [Title/Abstract])) AND (("Overweight" [Title/Abstract]) OR ("Obese" [Title/Abstract]))) AND (("Exercise" [Title/Abstract]) OR ("Training" [Title/Abstract]))
2	Scopus	TITLE- ABS("Breast cancer" OR "Breast Neoplasm") AND TITLE- ABS("Overweight" OR "Obese") AND TITLE- ABS("Exercise" OR "Training")
3	Google Scholar	allintitle("Breast cancer" OR "Breast Neoplasm") ("Overweight" OR "Obese") ("Exercise" OR "Training")
4	Cochrane Library	("Breast cancer" OR "Breast Neoplasm") ("Overweight" OR "Obese") ("Exercise" OR "Training")
5	Web of Science	1. ((ALL=("Breast cancer"))) OR ALL=("Breast Neoplasm") 2. (ALL=("Obese")) OR ALL=("Overweight") 3. (ALL=("Exercise")) OR ALL=("Training") #1AND#2AND#3
6	Science Direct	("Breast cancer" OR "Breast Neoplasm") ("Overweight" OR "Obese") ("Exercise" OR "Training")

Tabel S2. Risk of bias assessment.

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Unclear risk**	**Low risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2018a**
Support for judgment	Two-arm randomized controlled trial compared a progressive combined-aerobic and resistance-exercise intervention with usual care	Participants were randomly assigned (block size = 10 patients) to exercise or usual care after baseline testing using concealed randomization lists.	Information concerning the blinding of participants was not provided	Information concerning the blinding of the assessor was not provided	Four patients in the intervention group did not complete the study post-intervention: two lost to follow-up and two patients were unreachable. Five patients in the control group did not complete the study post-intervention: Three lost to follow up and two patients were unable to post-test as a result of a work conflict. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2018a**
Support for judgment	Two-arm randomized controlled trial compared a progressive combined-aerobic and resistance-exercise intervention with usual care	Participants were randomly assigned (block size = 10 patients) to exercise or usual care after baseline testing using concealed randomization lists	Information concerning the blinding of participants was not provided	Information concerning the blinding of the assessor was not provided	Four patients in the intervention group did not complete the study post-intervention: two lost to follow-up and two patients were unreachable. Five patients in the control group did not complete the study post-intervention: Three lost to follow up and two patients were unable to post-test as a result of work conflict. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2018a**
Support for judgment	The participants were randomly assigned to either the exercise or control group, and scheduled for the baseline visit. Randomization was performed by the Clinical Investigation Support Office (CISO) at the USC NCCC	To prevent possible bias, study personnel involved in the recruitment did not have access to the randomization lists; the biostatistician who developed the randomization list did not have any patient contacts to influence the recruitment and allocation procedure	The participants were blinding	The assessor was blinding	One patient in the intervention dropped out due to the group lost to follow-up. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2018a**
Support for judgment	This two-arm randomized controlled trial compared a progressive combined—aerobic and resistance—exercise intervention with usual care	Participants were randomly assigned (block size = 10 patients) to exercise or usual care after baseline testing using concealed randomization lists	Information concerning the blinding of participants were not provided	Information concerning the blinding of the assessor was not provided	four patients of the intervention group did not complete the study post-intervention: two lost to follow-up and two patients were unreachable. Five patients in the control group did not complete the study post-intervention: Three lost to follow up and two patients were unable to post-test as a result of work conflict. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2019**
Support for judgment	This two-arm randomized controlled trial compared a progressive combined—aerobic and resistance—exercise intervention with usual care.	Participants were randomly assigned (block size = 10 patients) to exercise or usual care after baseline testing using concealed randomization lists	Information concerning the blinding of participants were not provided	Information concerning blinding of participants were not provided	All the participants completed the study	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2019**
Support for judgment	Randomized control trial comparing a weight loss intervention to usual care.	Participants were randomly assigned (block size = 10 patients) to exercise or usual care after baseline testing using concealed randomization lists	Information concerning the blinding of participants were not provided	Information concerning the blinding of the assessor was not provided	All the participants completed the study	Expected outcomes were reported	Other biases have not been identified	

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Unclear risk**	**Low risk**	**High risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Dieli-Conwright 2022**
Support for judgment	A randomized trial comparing a weight loss intervention to usual care.	Twenty-five participants were randomly assigned to intervention and control groups after baseline testing using concealed randomization lists	Participants were not blinded to intervention assignment	Information concerning the blinding of the assessor was not provided	All the participants completed the study	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Brown 2021**
Support for judgment	Participants were randomly assigned in an equal ratio to intervention and control groups	After baseline testing, participants were allocated into two groups and were randomized using a computerized covariate adaptive procedure	Participants were blinding	The assessor was blinding	All the participants completed the study	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Ergun 2013**
Support for judgment	Participants were randomly assigned in an equal ratio to intervention and control groups.	After baseline testing, participants were allocated into two groups and were randomized using a computerized covariate adaptive procedure	Participants were not blinded to intervention assignment	The assessor was blinding	All the participants completed the study	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Rogers 2013**
Support for judgment	A randomized controlled trial compared an intervention with a control group. Randomization was based on computer-generated numbers, performed in blocks of 4, and revealed in the order in which participants completed baseline testing	Allocation was concealed by central randomization and only revealed after baseline assessment	Participants were blinded	The assessor was blinding	One patient in the intervention group lost to follow-up due to lack of time. One patient in the control group dropped out when asked to repeat a blood draw. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Rogers 2014**
Support for judgment	This two-arm randomized controlled trial compared an intervention with a control group using, randomization was done in blocks of four based on computer generated numbers.	Randomization numbers were kept in sealed, opaque envelopes so that study staff and participants were unaware of group allocation until all baseline testing was complete.	Participants were blinded	ALL measures were obtained by individuals who were blinded to the participant's study group allocation	Two participants developed cancer recurrence during the trial (both in the intervention group). These two participants were dropped from the analysis for scientific reasons. Two patients in the control group dropped out due to the lack of time. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Rogers 2014**
Support for judgment	This two-arm randomized controlled trial compared an intervention with a control group, using randomization that was conducted in blocks of four based on computer generated numbers	Randomization numbers were kept in sealed, opaque envelopes so that study staff and participants were unaware of group allocation until all baseline testing was complete.	Participants were blinded	ALL measures were obtained by individuals who were blinded to the participant's study group allocation	Two participants developed cancer recurrence during the trial (both in the intervention group). These two participants were dropped from the analysis for scientific reasons. Two patients in the control group dropped out due to the lack of time. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Unclear risk**	**High risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Hutnick 2005**
Support for judgment	patients with breast cancer were assigned to intervention and control groups.	36 patients with breast cancer were enrolled in a 6-month moderate exercise program very soon after completing chemotherapy or radiation treatment to the intervention and control group.	Participants were not blinding	Information concerning the blinding of the assessor was not provided.	Seven patients in the intervention group dropped out. Six patients in the control group dropped out after the midpoint of the study. However, the reasons for this were not explained. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**	**Battaglini 2007**
Support for judgment	The participants were randomly assigned to exercise or control group	The patients had to choose a number between 1 and 20 for the allocation process. Even-numbered participants were assigned to the experimental group, whereas odd-numbered participants were assigned to the control group	Participants were blinding	The assessor was not blinding.	All the participants completed the study.	Expected outcomes were reported	Other biases have not been identified	

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Low risk**	**Low risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Mutrie 2007**
Support for judgment	The study was a two-group (intervention and control) by three time points (baseline, 12 weeks, and six-month follow-up) randomized controlled trial. The randomization was stratified by hospital and treatment at baseline and used randomized permuted blocks of length four and six (that is, for sequences of four or six women in each hospital-treatment combination, exactly half were allocated to each group).	After written informed consent and baseline measures, participants were randomly allocated women into one of two groups using randomization list.	Blinding of the participants was not possible	The assessors were blinding	14 patients in the intervention group did not complete the study: Seven patients were lost to follow-up, four patients did not return the questionnaire, one patient was too ill, and two patients were not contactable. Eight patients in the control group did not complete the study: Four patients were lost to follow-up, two patients did not return the questionnaire, one died, and one withdrew. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Nieman 1995**
Support for judgment	Sixteen female breast cancer patients between the ages of 35 and 72 years were recruited for the study	After written informed consent and baseline measures, Subjects were randomly assigned to either an exercise or control group.	The participants were blinding	Information concerning the blinding of the assessor was not provided	Two patients (one from each group did not complete the study, because of the recurrence of the disease. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**	**Ligibel 2008**
Support for judgment	101 sedentary, overweight breast cancer survivors were randomly assigned either to exercise intervention or to a usual care control group	After enrolment, participants were randomly assigned 1:1 to an exercise intervention group or control group	The participants were blinding	Participants underwent a series of anthropometric measurements at the time of study enrolment (baseline), and these were repeated after the 16-week study period by study staff who were not blinded to group assignment	11 patients in the intervention group did not complete the study for the following reasons: Two lost to follow-up, one had a family emergency, three had too much of a time commitment, one was too ill for final, one had a disease recurrence, one developed unrelated cancer, one withdrew consent, and one need for unrelated surgery. Seven patients in the control group did not complete the study for the following reasons: Three lost to follow-up, two had disease recurrence, one withdrew upon assignment to the control group, and one for family problems. However, intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation conceal-ment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**High risk**	**Low risk**	**Low risk**	**Low risk**	
Support for judgment	101 sedentary, overweight breast cancer survivors were randomly assigned either to exercise intervention or to a usual care control group	After enrolment, participants were randomly assigned 1:1 to an exercise intervention group or control group	The participants were blinding	Participants underwent a series of anthropometric measurements at the time of study enrolment (baseline), and these were repeated after the 16-week study period by study staff who were not blinded to group assignment	11 patients in the intervention group did not complete the study for the following reasons: Two lost to follow-up, one had a family emergency, three had too much of a time commitment, one was too ill for final, one disease recurrence, one developed unrelated cancer, one withdrew consent, and one need for unrelated surgery. Seven patients in the control group did not complete the study for the following reasons: Three lost to follow-up, two disease recurrence, one withdrew upon assignment to the control group, and one for family problems. However, intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	**Ligibel 2008**
Authors' judgment	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	
Support for judgment	Participants were randomized 1:1 to an exercise and control group. All participants were randomized through the Quality Assurance for Clinical Trials (QACT) Core at Dana-Farber, which served as the coordinating center of the study.	After baseline measures 48 participants were randomly assigned to an exercise intervention group or control group	The participants were blinding	The assessor was blinding	One patient in the intervention group was found to be ineligible after randomization and two patients in the control group withdrew consent after randomization. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	**Ligibel 2019**

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Jones 2020**
Support for judgment	A quasi-randomized design where each group comprised exercising or non-exercising breast cancer survivors of similar age and treatment characteristics	A simple randomization procedure using the number on entry to allocate women as they entered the trial, on a 1:1 basis, was undertaken. Breast cancer survivors with odd numbers began the 12-week exercise treatment protocol immediately, while even-numbered women acted as wait-listed, non-exercising controls. The control women could access the intervention protocol after their testing in week 13. None of the authors were involved in the recruitment of the participants.	The participants were blinding	The assessor was blinding	Three control participants did not complete data collection, one incurred an ankle injury (not intervention-related), one moved to another town, and one chose to withdraw before any baseline measures. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Unclear risk**	**Low risk**	**Unclear risk**	**Unclear risk**	**Low risk**	**Low risk**	**Low risk**	**Lee 2019**
Support for judgment	This randomized clinical trial compared an aerobic and resistance exercise intervention with usual care.	For each patient recruited into the study, written informed consent is obtained before performing randomization or outcome measure testing. Upon written informed consent, the patient is randomly allocated to either the Exercise or Control groups. To prevent possible bias, study personnel involved in the recruitment and allocation did not have access to the randomization lists	Information concerning the blinding of the participants was not provided.	Information concerning the blinding of the assessor was not provided	Three patients in the intervention group did not complete the study for the following reasons: Two had Work conflicts, and one had disease progression. Three participants in the control group lost to follow-up post-intervention for the reasons: one family emergency, and two unreachable. Intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	
Authors' judgment	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Saxton 2014**
Support for judgment	A total of 85 women treated for breast cancer 3 to 18 months were randomly allocated to a 6-month to exercise and control group. Randomization was performed by an independent researcher at the Clinical Trials Research Unit, University of Leeds	A total of 85 women treated for breast cancer 3 to 18 months were randomly allocated to a 6-month to exercise and control group. Randomization was performed by an independent researcher at the Clinical Trials Research Unit, University of Leeds. The randomization sequence and allocation were not disclosed until patients had completed their baseline assessments	The participants were blinding	All the outcomes' measurers were assessed by a trained technician who was blinded to the group allocation	Three women were dropped out due to the lost to follow up in each group. Intention-to-treat analysis was used. However, intention-to-treat analysis was applied	Expected outcomes were reported	Other biases have not been identified	

Tabel S2. Continue…

Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias) All outcomes	Blinding of outcome assessment (detection bias) All outcomes	Incomplete outcome data (attrition bias) All outcomes	Selective reporting (reporting bias)	Other bias	Study
Authors' judgment	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**	**Low risk**		
Support for judgment	Following the assessment of outcome variables at baseline, patients were randomly allocated (1:1 ratio) to one of two groups: (1) intervention or (2) control group. Randomization was performed by an independent researcher at the Clinical Trials Research Unit, University of Leeds. The randomization sequence was not disclosed until patients had completed their baseline assessments.	A total of 90 women were randomly allocated to intervention and control group. The randomization sequence was not disclosed until patients had completed their baseline assessments.	The participants were blinding.	The assessor was blinding	Six patients in the intervention group did not participate in the follow-up for the following reasons: three patients changed their minds at the beginning, one patient due to a change in work conditions, one had a family situation, and one because of loss of contact. Five patients in the control group lost to follow-up for the following reasons: one withdrew at the beginning, two were excluded on medical grounds, and two could not contact with. Intention-to-treat analysis was applied.	Expected outcomes were reported	Other biases have not been identified	**Scott 2013**

Table S3. Excluded full-text articles with reasons (n=18).

#	Study	Reason
1	Milne et al., 2008a	No related outcome measures
2	Fernandez-Lao et al., 2012	
3	Sweeney et al., 2012	
4	Bloomquist et al., 2019	
5	Schmitz et al., 2019	
6	May et al., 2008	
7	Schwartz et al., 2007	No CART (AT or RT alone)
8	Bloomquist et al., 2019	No control group
9	Travier et al., 2014	
10	de Jesus Leite et al., 2021	
11	Courneya et al., 2014a	
12	Milne et al., 2008b	BMI < 25 kg/m^2
13	Harvie	
14	Kim	
15	Gómez	
16	De Paulo et al., 2018	The control group performed structured exercise
17	Paulo et al., 2019	
18	Courneya et al., 2014b	

BMI: body mass index, CART: combined aerobic and resistance training, AT: aerobic training, RT: resistance training.

Table S4. The subsequent reports of original studies (n =6).

#	Original Studies	Reports of original studies	Reason for inclusion (reported parameters)
1	Dieli-Conwright et al., 2018c	Dieli-Conwright et al., 2018a	Cancer-related fatigue
2		Dieli-Conwright et al., 2018b	Sleep quality
3		Dieli-Conwright et al., 2021	Body fat, ADPN, IL-8, and LDL-C
4	Dieli-Conwright et al., 2019	Dieli-Conwright et al., 2021	Quality of life
5	Ligibel et al., 2008	Ligibel et al., 2009	Body fat, hip circumference, LEP, ADPN.
6	Rogers et al., 2014	Rogers et al., 2015	Sleep quality

ADPN: adiponectin, IL: interleukin, LEP, leptin, LDL: low-density lipoprotein cholesterol

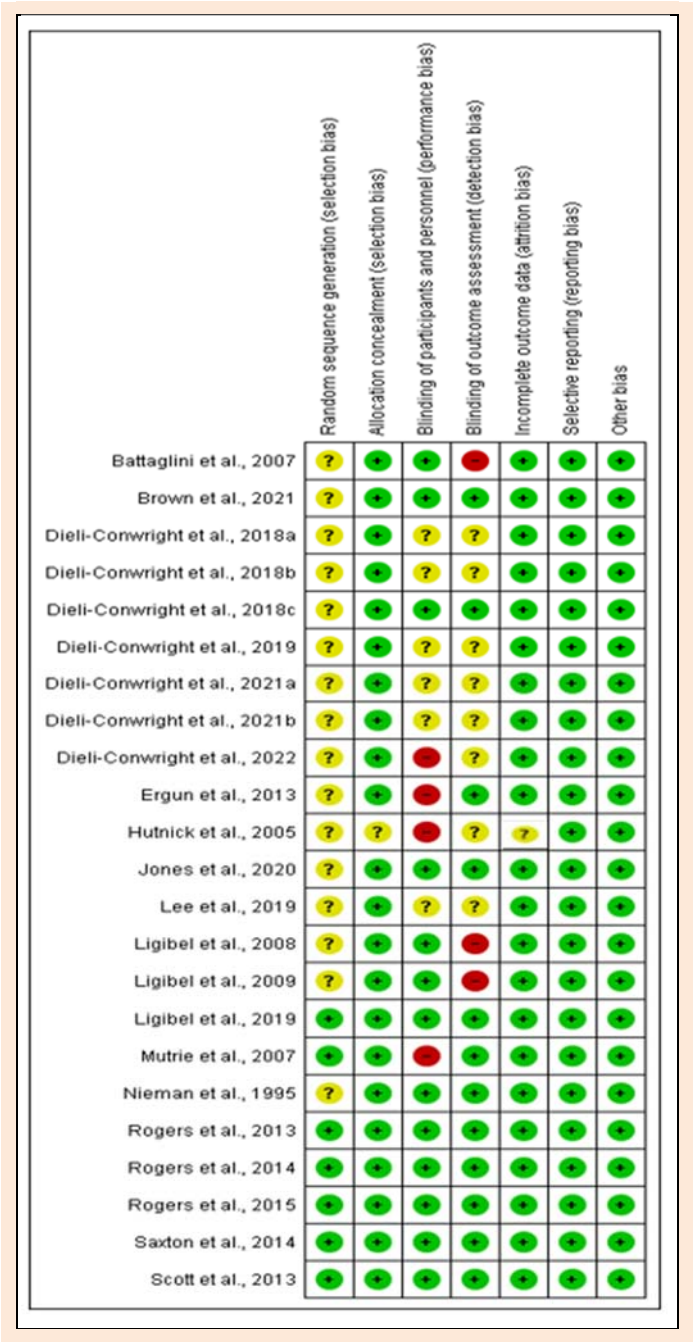

Figure S1. Risk of bias assessment results.

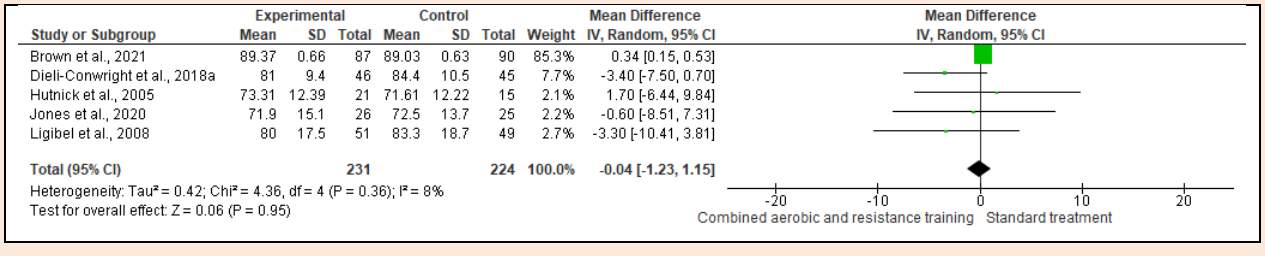

Figure S2. Effects of CART on BM.

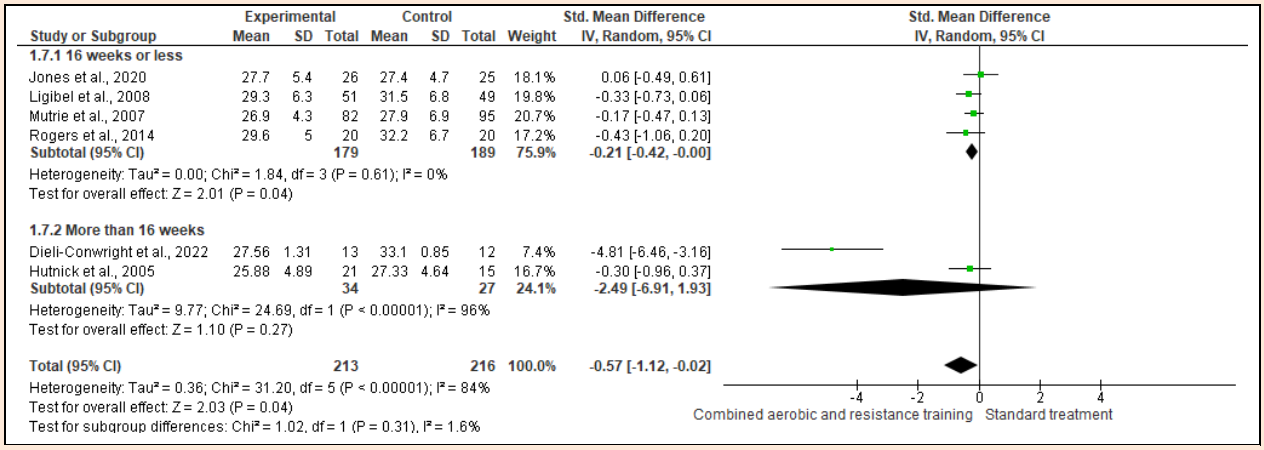

Figure S3. Effects of CART on BMI.

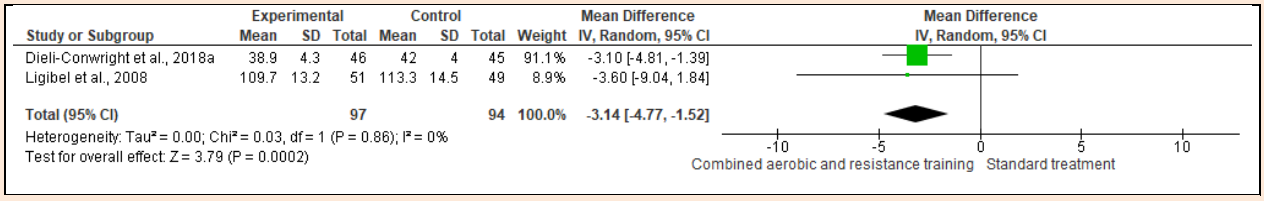

Figure S4. Effects of CART on HC.

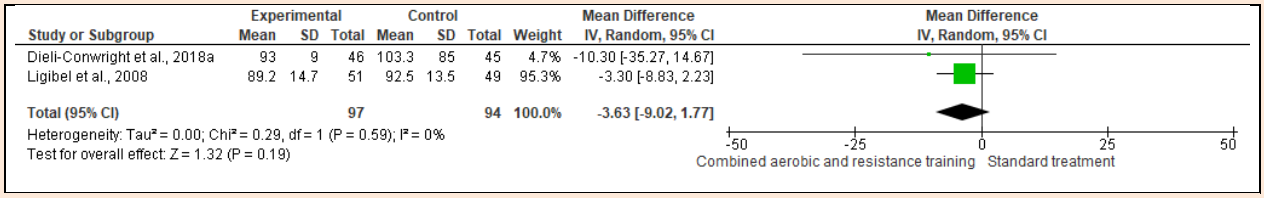

Figure S5. Effects of CART on WC.

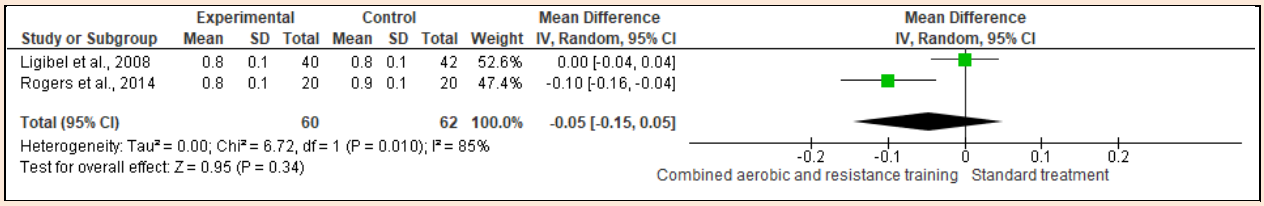

Figure S6. Effects of CART on WHR.

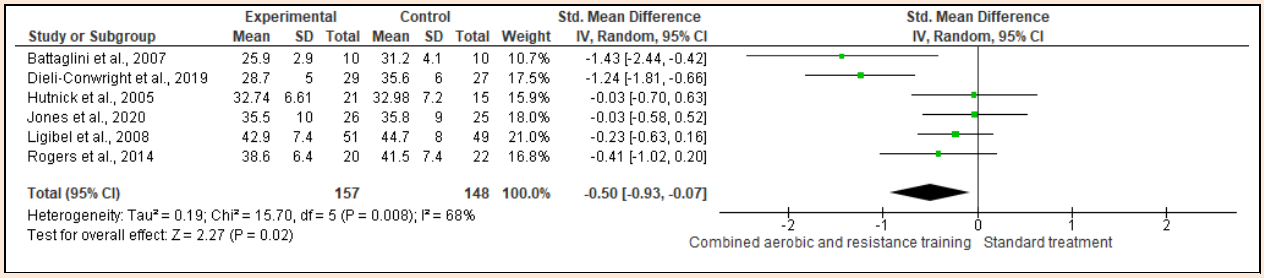

Figure S7. Effects of CART on BF.

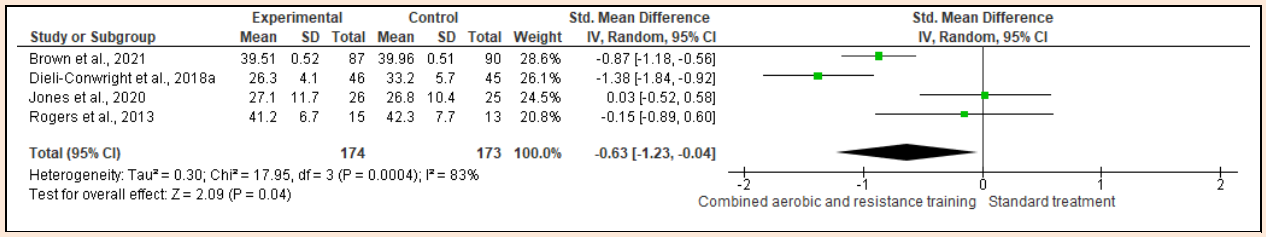

Figure S8. Effects of CART on FM.

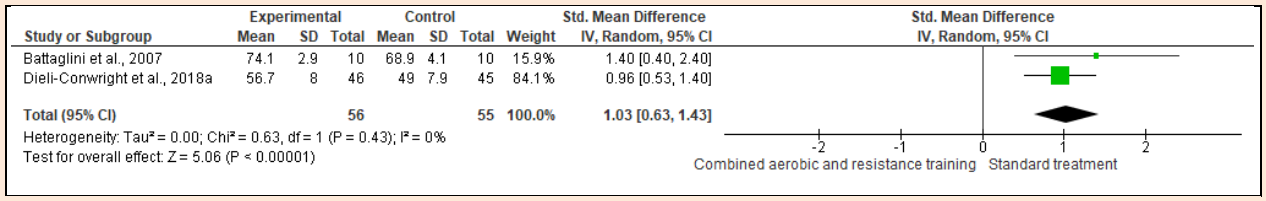

Figure S9. Effects of CART on FFM.

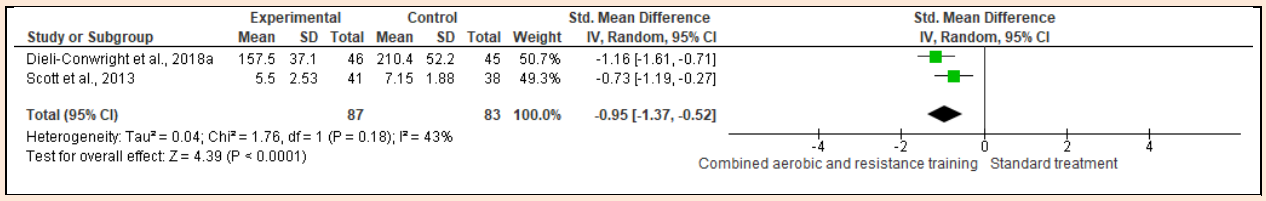

Figure S10. Effects of CART on TC.

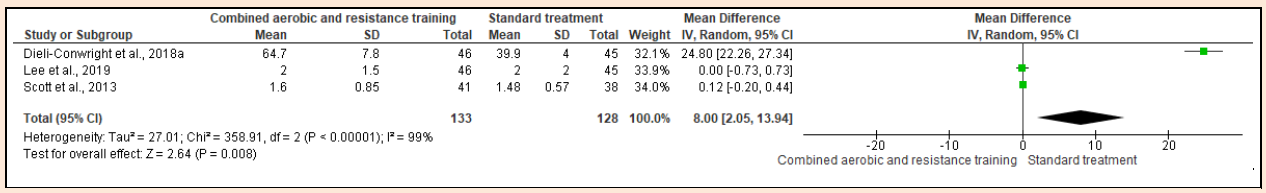

Figure S11. Effects of CART on HDL-C.

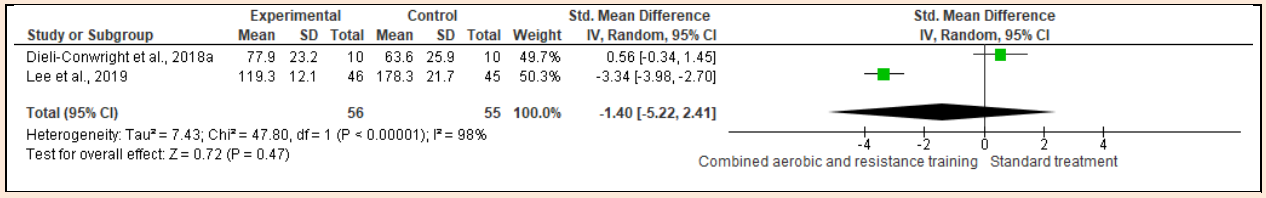

Figure S12. Effects of CART on LDL-C.

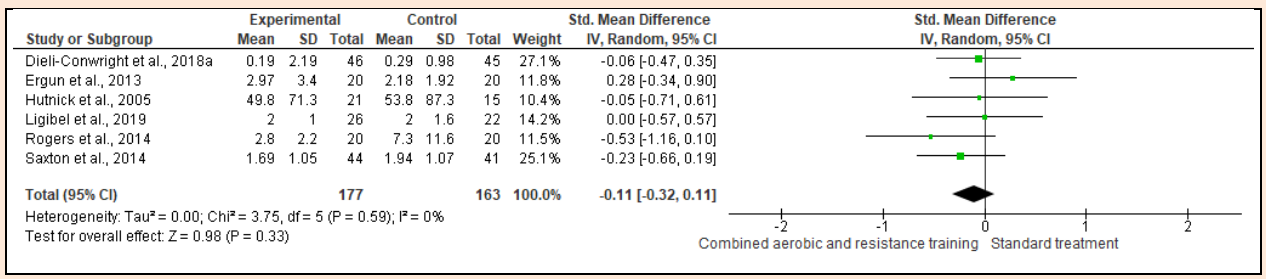

Figure S13. Effects of CART on IL-6.

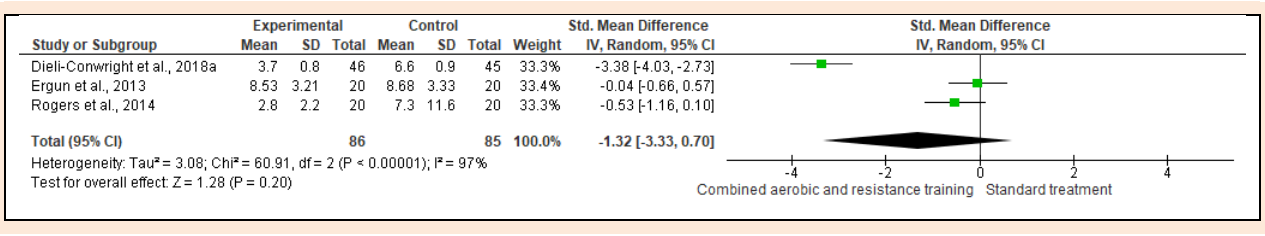

Figure S14. Effect of CART on IL-8.

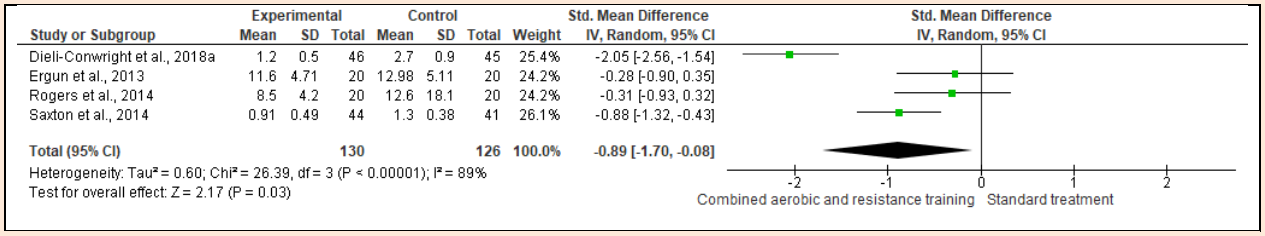

Figure S15. Effects of CART on TNF-*α*.

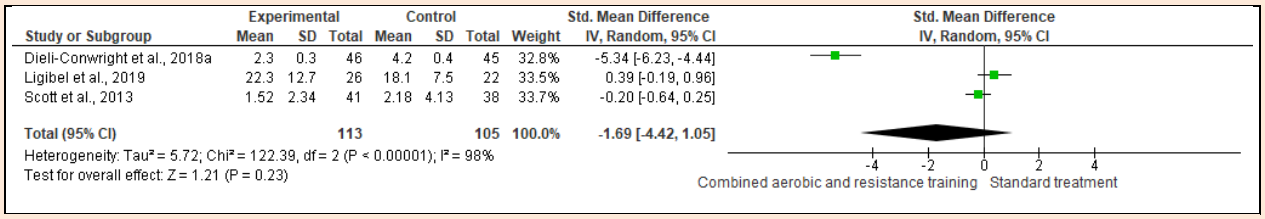

Figure S16. Effects of CART on CRP.

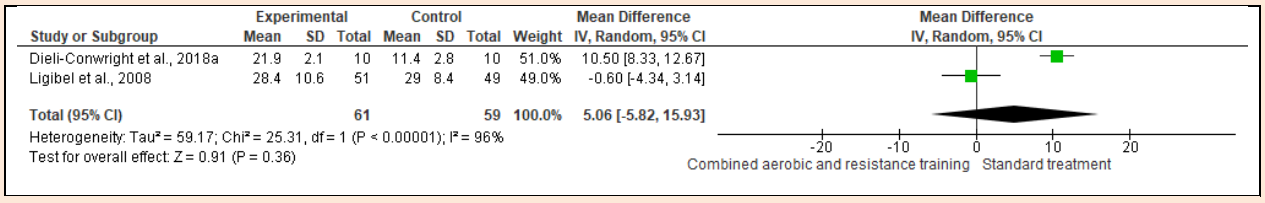

Figure S17. Effect of CART on ADPN.

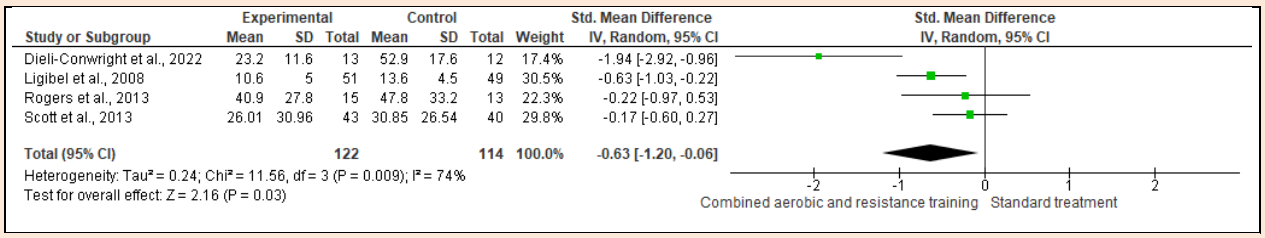

Figure S18. Effect of CART on LEP.

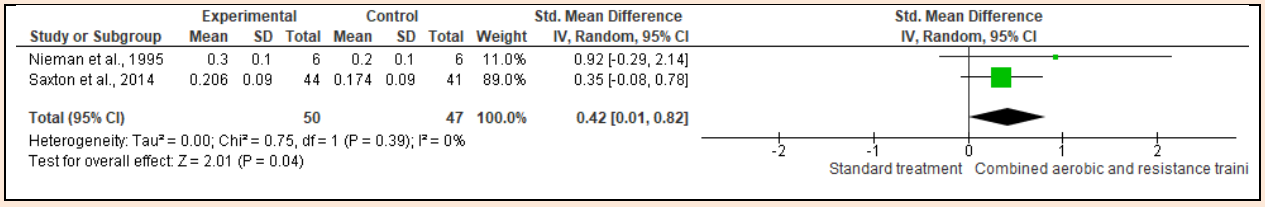

Figure S19. Effect of CART on NK cells.

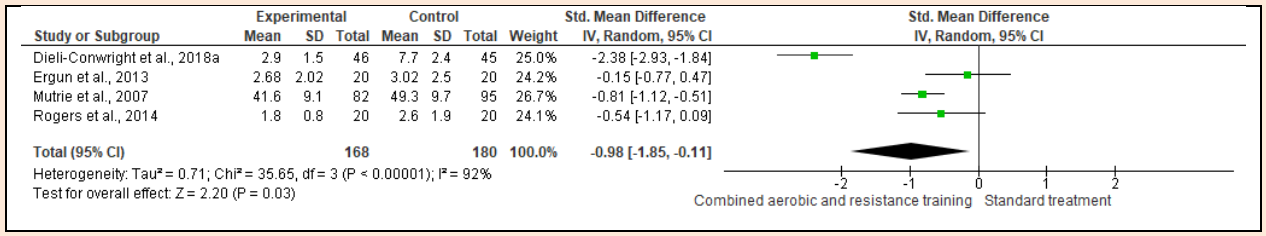

Figure S20. Effect of CART on cancer-related FA.

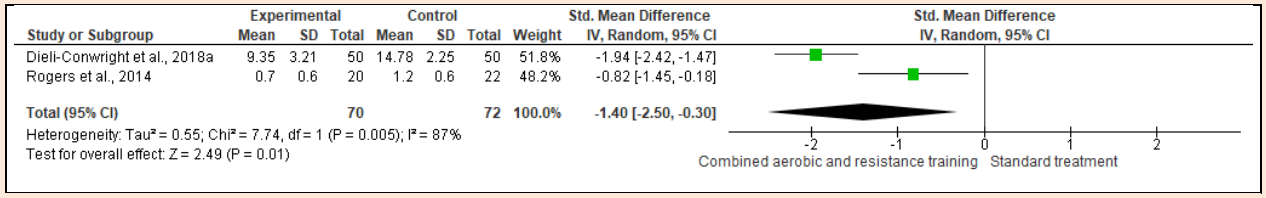

Figure S21. Effects of CART on SQ.

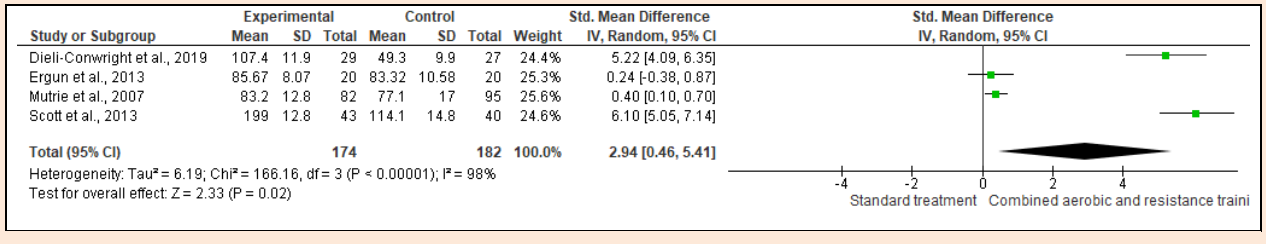

Figure S22. Effect of CART on QoL.