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REVIEW ARTICLE

Resistance training in breast cancer patients undergoing primary treatment: a systematic review and meta-regression of exercise dosage

Pedro Lopez[1,2] · Daniel A. Galvão[1,2] · Dennis R. Taaffe[1,2] · Robert U. Newton[1,2,3] · Giovani Souza[4] · Gabriel S. Trajano[5] · Ronei S. Pinto[4]

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Abstract

Background Exercise is recognised as an adjunct therapy for breast cancer patients; however, little is known about the resistance training dose–response. We conducted a systematic review and meta-regression to examine the resistance training dose–response (i.e., volume and intensity) in breast cancer patients undergoing primary treatment.

Methods Searches in MEDLINE, CINAHL, and SPORTDiscus were conducted for studies published up to November 2019. Experimental studies that evaluated resistance-based exercise interventions in women with breast cancer undergoing primary treatment were included. Information about resistance training components, average change and change per week, as well as standardised mean difference were extracted, and used for meta-regression analysis. Outcome measures were upper and lower body muscle strength and body composition.

Results 10 trials were included in the systematic review and 4 trials in the dose–response analysis. Resistance training weekly prescribed volume was inversely associated with increases in upper and lower body muscle strength ($r^2 = 98.1$–100%; $p = 0.009$), although there was no relationship between resistance training intensity and strength gains. There was insufficient data for the dose–response analysis of body mass index, percent body fat, and lean mass.

Conclusion Low volume resistance training might be a suitable exercise recommendation for breast cancer patients undergoing primary treatment producing superior benefits for muscle strength compared to higher volume training, regardless of the training intensity. Low volume resistance training may provide a conservative and appropriate approach for breast cancer patients, allowing gradual progression and modification throughout the exercise program.

Keywords Breast cancer · Resistance training · Dose–response effects · Health-related outcomes

Introduction

Exercise is a well-established intervention for breast cancer patients to improve physiological and functional outcomes, along with benefits in quality of life (QoL) and reductions in

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✉ Pedro Lopez
p.lopezda@our.ecu.edu.au

[1] Exercise Medicine Research Institute, Edith Cowan University, 270 Joondalup Drive, Perth, Western Australia 6027, Australia

[2] School of Medical and Health Sciences, Edith Cowan University, Perth, Western Australia, Australia

[3] School of Human Movement and Nutrition Sciences, University of Queensland, Brisbane, Queensland, Australia

[4] Exercise Research Laboratory, Physical Education, Physiotherapy, and Dance School, Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil

[5] School of Exercise and Nutrition Sciences, Faculty of Health, Queensland University of Technology, Brisbane, Queensland, Australia

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treatment toxicities during and following primary treatment [1–4]. A number of trials have reported the efficacy of exercise to improve cardiorespiratory fitness, muscle strength, body composition, quality of life and fatigue in this patient group undergoing primary treatment (e.g., START [5]), CARE [6], OPTITRAIN [7], BEST [8], and NEXT trials [9]). Consequently, exercise for the management of cancer patients has been endorsed by many professional organizations such as the *American College of Sports Medicine* (ACSM) [1, 2], the *American Cancer Society* [3], and *Exercise & Sport Science Australia* (ESSA) [10, 11].

A resistance-based multimodal exercise program has been recommended for breast cancer patients given its broad effect on physical fitness, body composition, and quality of life [5, 12]. Specifically, resistance training leads to improvements in muscle strength, functional capacity and lean mass, with the prescription varying from 1 to 3 sets of 8–15 repetitions and at intensities of 60–85% of one-repetition maximum (1-RM) [13]. Considering the potential benefits of this exercise mode, there is a paucity of dose–response information (including minimal exercise volume and intensity required) potentially precluding the design of efficient exercise interventions beyond general recommendations (i.e., one size fits all approach) [14–16]. For instance, it might be that for breast cancer patients, a lower resistance training dosage may be sufficient to enhance relevant gains in health-related outcomes such as muscle strength and body composition given their detrained status resulting from local and systemic treatments, age, and lifestyle behaviour [17]. However, the specific resistance exercise dosage proposed has been based on evidence addressing patient-reported outcomes (e.g., psychological distress and QoL) [13], and the lack of comparative trials prevents further understanding of the dose–response on objectively assessed health-related outcomes. Furthermore, it might well be that a lower resistance training dosage will reduce barriers related to exercise, such as time commitment, resources required, and exercise effort, potentially enhancing exercise adherence.

Beyond the association of muscle strength and body composition with functional performance and fatigue amelioration in breast cancer patients, these health-related outcomes are also related to cancer endpoints. For example, higher levels of muscle strength are associated with longer overall survival [18] and body composition components (lean mass and fat mass) are associated with cancer recurrence [19, 20]. Thus, investigating the resistance training dose–response may also help increase the efficacy of exercise in clinically relevant cancer endpoints. As a result, the purpose of this systematic review and meta-regression analysis was to examine the resistance-based training dose–response relationship on the health-related outcomes of muscle strength and body composition in breast cancer patients undergoing primary treatment (chemotherapy and/or radiotherapy).

Methods

Study selection procedure

The study was undertaken in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [21] and the method used was based on the minimum criteria established by the Cochrane Back Review Group (CBRG) [22]. The review included randomised controlled trials (RCT) and single-group studies that evaluated the effects of resistance-based exercise interventions in women with breast cancer undergoing primary treatment. Trials were excluded when (1) home-based exercise (non-supervised) interventions were used in the whole intervention period, due to lack of control on variables of interest such as the frequency, intensity, time and type (FITT) factors; and (2) written in a language other than English. Eligibility was assessed independently by two authors, with differences resolved by consensus.

The search was conducted up to November 2019 using the following electronic databases: MEDLINE, CINAHL, and SPORTDiscus. The terms used were 'breast cancer', and 'resistance training' in association with a list of sensitive terms to search for experimental studies. In addition, we performed a manual search of references in selected studies to detect studies potentially eligible for inclusion. The search strategy used for the MEDLINE (PubMed) database is shown in the Supplementary Material Table S1. This systematic review was not registered in any prospectively systematic review database (e.g., PROSPERO).

Study quality assessment

The methodological quality was evaluated according to the PRISMA recommendation [21]. Assessments included adequate sequence generation, allocation concealment, blinding of outcomes assessors, use of intention-to-treat analysis, and description of losses and exclusions.

Data extraction

Titles and abstracts of all articles identified by the search strategy were independently evaluated in duplicate (P.L. and G.S.). Abstracts that did not provide sufficient information regarding the inclusion and exclusion criteria were selected for full-text evaluation. In the second phase, the same reviewers independently evaluated these full-text articles and selected them in accordance with the eligibility criteria. Disagreements between reviewers were resolved by consensus. The data extraction was performed via a standardised form. Information on the interventions, outcomes, and patients was collected. Study characteristics, intervention duration, components of the resistance training prescription (i.e. frequency, intensity, volume, and modality), adverse events and feasibility were extracted, along with the main outcomes, assessment techniques, and results. The percentage of studies meeting each criterion was calculated. Outcomes were extracted in their absolute units (e.g., kg for 1-RM muscle strength assessment).

Quantification of resistance training prescription

In the present study, training volume refers to all sessions performed in the week and was determined as the product of sessions per week, sets and repetitions [frequency × sets × repetitions] for the lower and upper body, as well as total volume. Exercise intensity is presented as a percentage of the one-repetition maximum (1-RM). In cases where the intensity was expressed only as a function of how many repetitions the participant was able to perform (e.g. repetitions maximum), we estimated the relative intensity based on data of the relationship between the number of repetitions performed and the 1-RM for the same or similar exercises [23]. When the resistance training volume or intensity was not reported, their values were reported as "missing".

Calculation of change and rate of change

In most of the studies reviewed, the authors reported the change in the outcomes or the pre- and post-training values. When graphs were used instead of numerical data, the graphs were measured through their plots using a specific tool for data extraction (WebPlotDigitizer, San Francisco, California, USA). Relative changes were calculated by dividing the post- with the pre-training values. To allow for comparisons between studies of different duration, percentage change per week was calculated by dividing the change in the outcome with the duration of the training period in each study. The values were then summed and expressed as the mean, standard deviation (SD), and 95% confidence interval (CI).

Data analysis

The outcomes analysed in the present study were upper and lower body muscle strength, body composition (percent body fat, and lean mass), and body mass index (BMI). Furthermore, we used meta-regression to explore the relationship between training characteristics and change in outcomes when four or more data points were available. First, we undertook a meta-analysis to generate standardised mean differences (SMD). Considering within variance of outcomes, the SMD was used for muscle strength (different exercises to test upper and lower body muscle strength) to generate univariate inverse-variance weighted meta-regression assessing the association of resistance training weekly volume (i.e., frequency x sets x repetitions) and intensity (i.e., percentage of 1-RM) with these outcomes. Statistical significance was assumed when the model reached a α value ≤ 0.05. Publication bias was explored by contour-enhanced funnel plots and Egger's test [24]. Analyses were conducted using the package *metareg* from Stata 14.0 software (Stata, College Station, USA).

Results

Studies included

All studies selected reported the aim to investigate the effect of resistance-based training (i.e. resistance exercise alone or combined resistance and aerobic exercise) in breast cancer patients undergoing primary treatment. We retrieved 1,569 studies, 1,462 of which were retained for screening (Fig. 1). Of these, 1,390 studies were excluded, and 72 full-text articles were assessed for eligibility. Sixty-two studies were excluded due to not evaluating the effect of exercise on the main outcomes ($n = 14$), involving women with breast cancer not undergoing primary treatment ($n = 17$), reporting secondary analysis of the main trial ($n = 21$), examining different outcomes ($n = 7$), involving mixed cancer patients without separate data for breast cancer patients undergoing primary treatment ($n = 2$), and the language was not in English ($n = 1$). The eligibility assessment resulted in 10 trials [5, 6, 25–32] which were included in the present review and from which 4 trials [5, 6, 27, 32] were included in the dose–response analysis.

Breast cancer patients and exercise interventions characteristics

The 10 trials [5, 6, 25–32] involved 985 breast cancer patients undergoing primary treatment with an average age of 53.9 ± 8.3 years. Exercise interventions were predominantly undertaken in patients during chemotherapy and radiotherapy (7 [26–32] of 10 trials), or during chemotherapy (3 [5, 6, 25] of 10 trials). Exercise modalities included predominantly combined resistance and aerobic training (9 [6, 25–32] of 10 trials), followed by resistance training only (1 [5] of 10 trials) in a cohort of 478 patients allocated to the intervention group. Eight trials were designed to compare the exercise interventions vs. usual care controls (8 [5, 6, 25, 26, 29–32] of 10 trials), and two trials [27, 28] were single-group exercise studies.

The mean exercise intervention duration was 15.2 ± 6.9 weeks with an average of 2.8 ± 0.4 sessions per week. The average prescribed resistance training volume

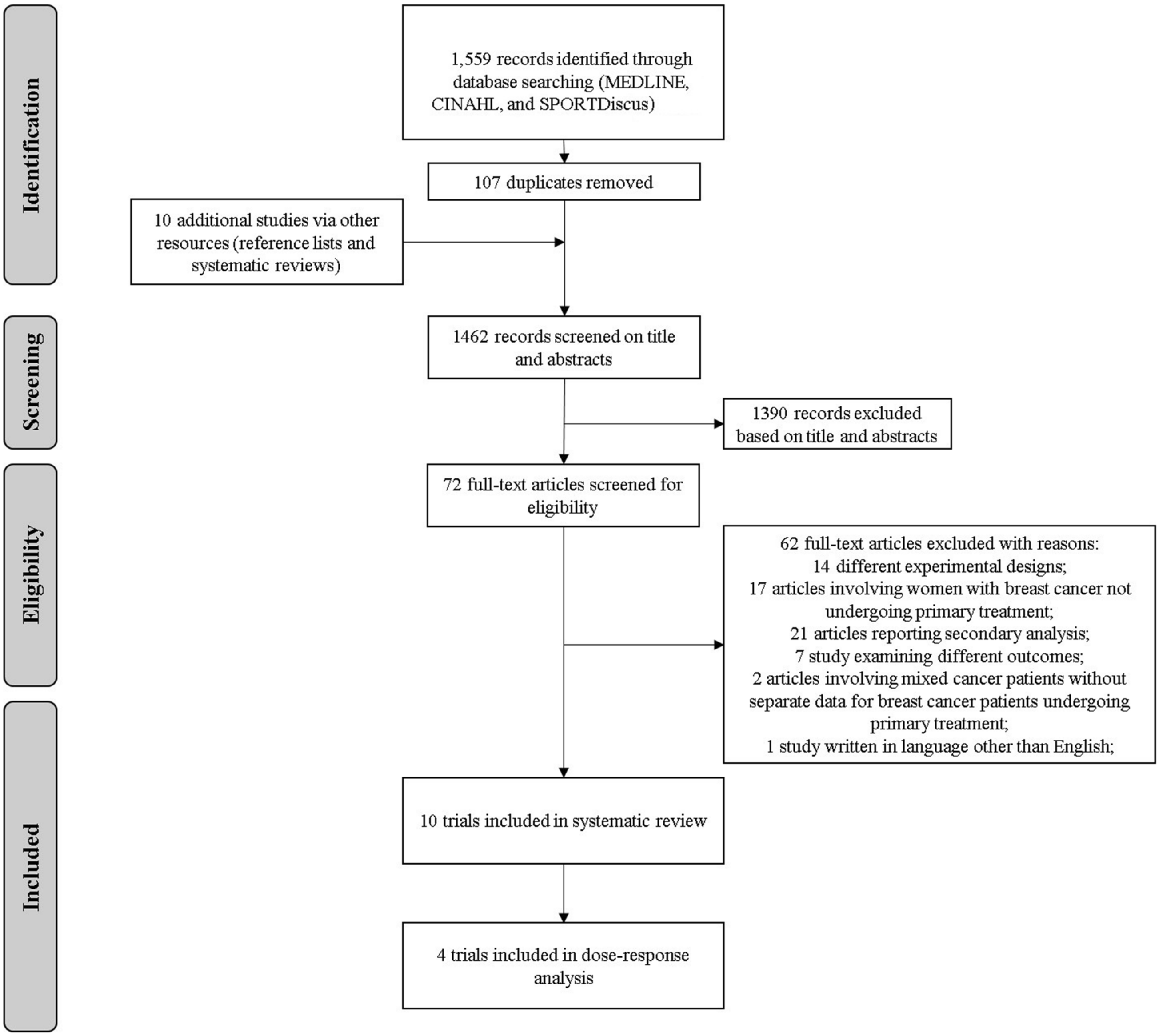

Fig. 1 Flowchart of study selection process

was 7,294 ± 4,725 repetitions with a weekly training volume of 526 ± 143 repetitions. The mean peak intensity reached throughout the resistance training program was 72 ± 8% of 1-RM. Study characteristics, sample size, exercise prescription, included outcomes, and assessment techniques are presented in Table 1. All trials [5, 6, 25–32] reported the frequency of training, 6 trials [5, 6, 25, 29, 31, 32] reported the training volume, and 5 trials [5, 6, 25, 26, 32] reported the training intensity. In the quality assessment, 60% presented adequate sequence generation (6 [5, 6, 25, 29–31] of 10 studies), 20% (2 [5, 6] of 10 studies) reported allocation concealment and had blinded assessment of outcomes [30, 31], 90% described losses to follow-up and exclusions (9 [5, 6, 25–31] of 10 studies), and 40% reported using the intention-to-treat principle for statistical analysis (4 [5, 6, 29, 30] of 10 studies) (Table 2).

Muscle strength

Length of training period, average change, and change per week

Five trials were included in this analysis [5, 6, 25, 27, 32]. The average length of training period was 16.7 ± 6.1 weeks and ranged from 6 to 24 weeks, with the mean total increase in strength for all strength tests of 25.4 ± 9.6% (95% CI 17.0–33.8%). The study of Bataglini et al. [25] reported only the sum of all 1-RM tests in their trial (i.e.

Table 1 Study characteristics: trial, disease and treatment stage, feasibility, exercise prescription and sample, outcomes and adverse events

Author, year	Disease and treatment stage	Feasibility	Exercise prescription and sample	Included outcomes	Adverse events
Courneya et al. 2007 [5] (START trial)	I–IIIa Patients undergoing surgical protocols and first-line adjuvant chemotherapy involving non-taxane and taxane protocols	242 admitted 223 randomized 92.1% adherence	$n = 82$, 3 sessions per week for a median of 17 weeks RT: 2 sets of 8–12 reps at 60–70% of 1-RM	Bench press and leg extension muscle strength (8-RM)[a] Lean body mass, fat mass, %BF (DXA)	1 reported hypotensive symptoms 1 reported dizziness
Bataglini et al. 2007 [25]	Patients undergoing adjuvant chemotherapy	20 admitted 20 randomized 100% adherence	$n = 10$, 2 days per week for 21 weeks RT: 3 sets of 6–12 reps at 40–60% of 1-RM AT: 6–12 min at 40–60% of maximum heart rate	Muscle strength (1-RM) Lean body mass and %BF (skinfold technique)	None
Courneya et al. 2013 [6] (CARE trial)	I–IIIc Patients undergoing adjuvant chemotherapy	728 admitted 301 randomized 99.0% adherence	$n = 104$, 3 days per week for 16,4 ± 3.6w plus 24-month follow-up RT: 2 sets of 10–12 reps at 60–75% of 1-RM AT: 25–30 min at 50–75% of VO_2peak	Bench press and leg extension muscle strength (7–10 RM's)[a] Lean body mass, fat mass, and %BF (DXA)	None
Hutnick et al. 2005 [26]	I–IIIc Patients undergoing chemotherapy and radiotherapy	? admitted 49 randomized 73.5% adherence	$n = 28$, 3 days per week for 24 weeks RT: 1–3 sets of 8–12 at 60–75%1-RM AT: 10–20 min at 60–75% functional capacity	BMI %BF (?)	Not reported
Kolden et al. 2002 [27]	I–III Patients undergoing chemotherapy and radiotherapy	? admitted 51 enrolled 78.4% adherence	$n = 51$, 3 days per week for 16 weeks RT: Missing AT: 20 min at 40–70% of estimated maximal aerobic capacity	%BF (skinfold technique) Bench press and leg press muscle strength (estimated 1-RM)[a]	None
Leach et al. 2016 [28] (BEAUTY trial)	Patients undergoing chemotherapy and radiotherapy	150 admitted 150 enrolled 80.6% adherence	$n = 63$, 3 days per week during 24 weeks RT and AT: Missing	%BF (skinfold technique)	Not reported
Mostarda et al. 2017 [29]	I–III Patients undergoing chemotherapy, radiotherapy and/or hormone therapy	18 admitted 18 randomized 100% adherence	$n = 9$, 3 days per week for 4 weeks RT: 3 sets of 8–12 reps AT: 30 min at 60% of VO_2max	BMI	None
Mutrie et al. 2007 [30]	0–III Patients undergoing chemotherapy and radiotherapy	1144 admitted 203 randomized 85.7% adherence	$n = 101$, 2 days per week for 12 weeks RT and AT: Missing	BMI	None
Reis et al. 2018 [31]	Patients undergoing chemotherapy and/or radiotherapy	300 admitted 31 randomized 90.3% adherence	$n = 15$, 3 days per week for 12 weeks RT: 3 sets of 12 reps AT: 50–60%/ 80–90% of the target heart rate	BMI	Not reported
Schulz et al. 2017 [32]	Patients undergoing chemotherapy and radiotherapy	26 admitted 26 randomized 100% adherence	$n = 15$, 2 days per week for 6 weeks RT: 2 sets of 8–15 reps at 50–80% of 1-RM AT: 10 × 1-min bouts of HIIT at 85–100% of VO_2peak	Bench press, leg press, laterall pulldown, hip abduction and hip adduction muscle strength (estimated 1-RM)[a]	None

[a]Included in meta-regression analysis

%1-RM, percentage of 1-repetition maximum; %BF, percentage of body fat; AT, aerobic training; BMI, body mass index; BP, bench press; DXA, dual-energy X-ray absorptiometry; FM, fat mass; HIIT, high-intensity interval training; HRR, heart rate reserve; RM's, repetitions maximum; RT, resistance training

leg extension, leg curl, lat pulldown, and chest press) and was not included for further analysis of upper and lower body 1-RM strength. The mean strength increase for upper and lower body strength was 25.4 ± 9.6% (95% CI 17.0–33.8%) and 26.1 ± 10.1% (95% CI 17.2–35.0%), and for weekly change 2.6 ± 1.9% (95% CI 1.3–3.9%) and 2.9 ± 1.6% (95% CI 1.6–4.2%), respectively.

Table 2 Methodological quality of included studies

Study	Adequate sequence generation	Allocation concealment	Blinding of outcome	Description of losses and exclusions	Intention to treat analysis
Courneya et al. 2007 [5]	Yes	Yes	No	Yes	Yes
Bataglini et al. 2007 [25]	Yes	Unclear	Unclear	Yes	Unclear
Courneya et al. 2013 [6]	Yes	Yes	No	Yes	Yes
Hutnick et al. 2005 [26]	Unclear	Unclear	Unclear	Yes	No
Kolden et al. 2002 [27]	No	No	Unclear	Yes	Unclear
Leach et al. 2016 [28]	No	No	Unclear	Yes	No
Mostarda et al. 2017 [29]	Yes	Unclear	Unclear	Yes	Yes
Mutrie et al. 2007 [30]	Yes	No	Yes	Yes	Yes
Reis et al. 2018 [31]	Yes	Unclear	Yes	Yes	Unclear
Schulz et al. 2017 [32]	No	No	Unclear	Unclear	Unclear

Frequency and volume

The mean frequency of resistance training was 2.7 times per week. Regarding resistance training volume, studies prescribed 470 ± 170 repetitions (95% CI 320–620 reps) per week, with the mean number of weekly total repetitions for the upper body being 271 ± 77 (95% CI 204–339 reps) and 199 ± 93 (95% CI 117–280 reps) for lower body exercises. Meta-regression analysis resulted in a significant negative relationship between weekly volume and upper body ($r^2 = 100\%$, $p = 0.014$; Table 3) and lower body 1-RM strength gains ($r^2 = 100\%$, $p = 0.009$; Table 3). Publication bias was not observed ($p = 0.111$–0.150).

Intensity

The mean peak intensity (the highest value reached during a session, averaged over the entire period) was 75 ± 4% of 1-RM (95% CI 69–81% of 1-RM). Meta-regression analysis resulted in a non-significant positive association between peak intensity reached and upper body ($r^2 = 24.3\%$, $p = 0.368$; Table 3) and lower body 1-RM strength ($r^2 = 56.8\%$, $p = 0.130$; Table 3). In addition, the increase in strength for the study that did not report resistance training intensity was 2.2 ± 0.1% per week [26].

Body composition and BMI

There were insufficient data points for the dose–response analysis in body mass index (BMI), percent body fat, and lean mass. In summary, 9 trials [5, 6, 25–31] encompassing resistance training only [5] and combined resistance and aerobic training [6, 25–31] reported these outcomes. The average length of the training period was 15.4 weeks and ranged from 4 to 24 weeks, with the total mean change of − 0.56 ± 1.65% (95% CI − 2.0 to 0.9%) in BMI, − 2.0 ± 2.8% (95% CI − 4.2 to 0.2%) for percent body fat, and 2.4 ± 0.04% (95% CI 2.4–2.5%) for lean mass. Regarding resistance

Table 3 Association between main outcomes and resistance training weekly volume and peak intensity

Outcomes	n	RT components	Range	Coeff ± SE	95% CI	Model
Muscle strength						
Upper body	5	RT weekly volume, reps	184–330	− 0.03 ± 0.01	− 0.059 to − 0.008	$r^2 = 100\%$ $I^2 = 0\%$ $p = 0.014$
	5	RT intensity, 1-RM	70–80%	0.41 ± 0.33	− 0.51–1.34	$r^2 = 24.3\%$ $I^2 = 76.0\%$ $p = 0.368$
Lower body	5	RT weekly volume, reps	92–264	− 0.009 ± 0.001	− 0.015 to − 0.003	$r^2 = 100\%$ $I^2 = 0\%$ $p = 0.009$
	5	RT intensity, 1-RM	70–80%	0.15 ± 0.07	− 0.06 to 0.36	$r^2 = 56.8\%$ $I^2 = 83.9\%$ $p = 0.130$

1-RM, 1-repetition maximum; 95% CI, 95% confidence intervals; Coeff, meta-regression coefficient; I^2, statistical test of heterogeneity; *n*, number of comparisons; r^2, coefficient of determination; RT, resistance training; SE, standard error training volume, studies prescribed 576 ± 83 repetitions (95% CI 521–630) per week, with a mean peak intensity of 70 ± 7% 1-RM (95% CI 65–74% of 1-RM).

Discussion

In this review, we investigated the characteristics of resistance training studies (i.e., volume and intensity) undertaken in breast cancer patients undergoing primary treatment and the dose–response relationship with muscle strength and body composition outcomes. Our findings indicate that resistance training weekly volume was inversely associated with increases in lower and upper body muscle strength, indicating superior benefits with lower dose resistance training (i.e., in this case, low volume). Furthermore, the lack of sufficient data precludes further analysis on body composition and BMI changes. Therefore, a low-dose resistance training volume, regardless of the intensity may provide a conservative and appropriate approach for breast cancer patients on primary treatment.

Since the first overview of exercise studies in cancer patients [33] which reported only one study of resistance training in breast cancer patients [27], a growing body of literature has contributed to the development of exercise guidelines in cancer patients and survivors, reporting the safety, physical, physiological, and clinical benefits when a resistance training program is undertaken [1–4, 10, 11]. Nevertheless, it is also well known that the manipulation of resistance training variables such as frequency, volume, and intensity alter the effects on specific physiological outcomes in healthy adults and older people [34], although this information in breast cancer patients and survivors is scarce.

Our findings suggest a superior effect on muscle strength with a lower weekly volume of exercise. Thus, it is advocated that for breast cancer patients undergoing primary treatment, a lower dose of resistance exercise could result in a larger benefit for muscle strength. The reasons for this are unknown, but may be related to immune-related impairments during/after chemotherapy as patients might not fully recover following the exercise bouts and treatment sessions [35, 36], especially due to the toxicity of agents such as taxanes affecting the neurosensory and neuromotor system [12, 35]. Moreover, these results support the design of future exercise trials comparing low vs. high dose (in this case, low and high volume of resistance training) to test responsiveness to this type of training, and beneficial effects on clinical outcomes of interest.

Although exercise has been reported to promote significant benefits for accretion of lean mass and reduction in fat mass [5, 24], the required dosage to achieve such benefits remains to be determined. In the present study, insufficient data precluded the meta-regression analysis to test if changes in body composition outcomes were associated with the resistance training prescribed volume and intensity. Therefore, it is unknown if prescribed higher volumes or intensity of exercise would be of additional benefit. Previous studies undertaken in healthy older women demonstrate that different resistance training dosages (single vs. multiple sets) elicit similar results for muscle mass following short-term training [37, 38] due to the lower threshold for muscular adaptations in older adults. Future studies will be necessary to elucidate if a lower resistance training volume may also be effective in promoting significant changes in lean mass and body fat as it is with muscle strength adaptations in breast and other cancer patients.

Previous exercise trials have investigated the dose–response in cancer patients, but only exploring the effects of aerobic exercise. In the WISER Sister trial [39], 150 min week^{-1} and 300 min week^{-1} of aerobic exercise were compared to usual care control during 5 menstrual cycles in women at high risk for breast cancer. A significant dose–response alteration was reported in favour of higher doses for cardiorespiratory fitness, body fat, and adipokine levels [40], although promising, evidence after the diagnosis of cancer remains unclear. In contrast, the COURAGE trial [41], reported superior benefits for 150 and 300 min aerobic exercise groups compared to usual care control in stage I–III colon cancer survivors, but no differences between dosages on prognostic biomarkers such as serum intercellular adhesion molecule-1 [42], metabolic growth factors such as fasting insulin [43], and circulating tumour cells [44]. However, dosages of 300 or even 150 min week^{-1} of aerobic exercise may not be reached [45], nor represent an appropriate starting weekly dosage for most cancer patients. Furthermore, the same could be evident for resistance training, where higher amounts of exercise and heavier loads may not be well tolerated by the patient. Therefore, it is reasonable to suggest that additional work is required investigating what constitutes a lower and upper threshold of dosage for different types of cancers and treatments undertaken [11]. In this regard, the present review provides important information regarding resistance exercise prescription as no additional benefits for higher doses of resistance training were found for upper or lower body muscle strength. In addition, prescribing low-dose resistance training is also in agreement with a conservative and appropriate approach, allowing gradual progression and modification according to comorbidities and treatment-related side effects as they present [11].

This study included 10 trials [5, 6, 25–32] specifically prescribing resistance training as the sole or part of a combined intervention, examining the respective dose–response relationship with health-related outcomes. However, there are some limitations worthy of comment. The dose–response relationship was assessed by prescribed rather than actual (complied) resistance training dosage. Future studies should provide information on compliance, tolerance, and adherence throughout the resistance training program to better inform not only the design of subsequent studies but also to permit a valid interpretation of the results. In addition, the restricted assessment of health-related outcomes may be considered a limitation given the array of different clinical outcomes in exercise oncology trials. However, changes in muscle strength and body composition including BMI are commonly reported health-related outcomes and associated with disease prognosis [1], and also used to evaluate resistance training responsiveness [13]. Finally, the exercise program duration was considered short in most of the included studies (range 4–24 weeks). As a result, it is difficult to infer our results regarding exercise dosage beyond a short period in duration. Consequently, trials involving longer exercise durations will be necessary to confirm these results.

Conclusions

In summary, the present review suggests that low-dose resistance training might be a suitable exercise recommendation for breast cancer patients undergoing primary treatment to enhance upper and lower body muscle strength. Moreover, a low-dosage program may be of benefit in reducing the barriers to exercise by reducing the time and effort required to undertake the exercise session. We suggest future studies should examine the dose–response of resistance training on clinical outcomes in patients undergoing primary treatment. Further, all exercise studies in cancer patients should report actual dosage of resistance training in sets, repetitions and resistance or load.

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Author contributions Substantial contributions to the conception and design of the work were done by PL; DAG, and RSP. The systematic search and data extraction were done by PL and GS. The work draft and revision, as well as the approval of the final version, were done by PL, DAG, DRT, RUN, GS, GST, and RSP. In addition, all aspects of this work related to the accuracy or integrity were ensured by PL, DAG, DRT, RUN, GS, GST, and RSP.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest, including relevant financial interests, activities, relationships, and affiliations to declare relating to this manuscript. All authors agree to allow the journal to review their data if requested.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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