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Review

Effects of weight-lifting or resistance exercise on breast cancer-related lymphedema: A systematic review

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The purpose of this systematic review was to identify the effects of weight-lifting or resistance exercise on breast cancer-related lymphedema. Published articles written in English were retrieved from electronic databases, including ScienceDirect, PubMed, Scopus, and CINAHL databases. Hand-searches for unpublished papers were also completed. Content analysis was used to examine articles that met the inclusion criteria. Among 525 searched papers, 15 papers met the inclusion criteria: 13 trials evaluated weight-lifting or resistance exercise alone and two trials evaluated weight-lifting or resistance exercise plus aerobic exercise. The results of the review showed that no arm volume change was observed for either exercise modality. In addition, six included studies showed that weight-lifting or resistance exercise did not cause lymphedema or adverse events in patients at risk of breast cancer-related lymphedema. For patients with breast cancer-related lymphedema, six studies reported that change of swelling outcome measures were not significantly different between the weight-lifting or resistance exercise group and the control group. However, three included studies reported that volume of arm was significantly more reduced in the weight-lifting or resistance exercise group than those in the control group. The findings suggest that supervised resistance exercise may be safe, feasible, and beneficial in patients with breast cancer-related lymphedema or at risk for breast cancer-related lymphedema. However, the limitation of small sample size implies that further research is needed to confirm these findings.

1. Introduction

Breast cancer is the most common cancer in women worldwide, both in the developed and developing countries [1]. Due to advances in detection and treatment, breast cancer survival rates been increased [2]. However, survival varies worldwide, ranging from 80% or over in North America, Sweden, and Japan, to around 60% in middle-income countries and below 40% in low-income countries [1]. Although these patients are living longer, they may experience some long-term treatment side-effects, including: fear of recurrence, fatigue, sexual dysfunction, or cognitive problems. One of the negative sequelae of treatment is breast cancer-related lymphedema (BCRL) [3].

BCRL has been defined as a set of pathological conditions in which protein-rich lymphatic fluid accumulates in soft tissues because of interruption of lymphatic flow and as an increase of 2 cm or more in arm circumference [4]. DiSipio et al. [5] reported that about one in five of breast cancer survivors are at risk of BCRL. Shah and Vicini [6] reported that the incidence rates of BCRL might vary depending on treatment types. For example, its incidence rate might be less than 5% with lumpectomy or its incidence rate might be increase to more than 60% with axillary lymph node dissection or axillary radiation. A systematic review by DiSipio et al. [5] reported that the incidence of BCRL was more likely to be increased 2 years after surgery for breast cancer. They also reported that risk factors of BCRL were extensive surgery such as axillary-lymph-node dissection, greater number of lymph nodes dissected, mastectomy, and being overweight or obese. Similarly, a retrospective study by Vieira et al. [7] reported that axillary dissection and the number of lymph nodes resected were related to lymphedema at 10 years.

BCRL is a chronic condition that has a lifelong effect on physical, functional, psychological, social, and emotional aspects of

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breast cancer survivors [3,8]. Dominick et al. [9] reported that, compared to those without lymphedema, patients with lymphedema had worse physical and mental health outcomes. Mwiinga-Kalusopa and Ngoma [10] explained that since hiding physiological manifestations and loss of function related to lymphedema was harder, patients living with BCRL experience more distress. A systematic review by Fu et al. [11] reported that poor social well-being in patient with lymphedema, included negative perceptions related to body image, appearance, sexuality, and social barriers. In addition, the negative psychological impact of BCRL can be described as negative self-identity, emotional disturbance, and psychological distress, whereas negative social impact can be described as marginalization, financial burden, perceived diminished sexuality, social isolation, perceived social abandonment, public insensitivity, and non-supportive work environment [11]. Boyages et al. [3] reported that the impact of lymphedema on work was incremental with increased severity of lymphedema and, when compared to breast cancer survivors without lymphedema, persons living with lymphedema were worse off in terms of work and career. Boyages et al. [12] also reported that breast cancer patients often had to pay out-of-pocket money for expenses due to BCRL. More interestingly, about 56% of these patients indicated that BCRL affected them financially and its cost increased with lymphedema severity.

Currently, there are no cures for BCRL. However, the commonly-used BCRL treatment methods include: compression therapy, therapeutic exercises, pharmacotherapy, and complex decongestive physiotherapy, including: manual lymphatic drainage, compression devices, skin care, and therapeutic exercises [6,13]. Interestingly, a systematic review by Li et al. [14] reported that combined physical therapy with different combinations of surgery, oral pharmaceuticals, low-level laser therapy, weight-reduction, mesenchymal stem cell therapy, kinesio-taping, and acupuncture might be effective in reducing lymphoedema. However, exercise demonstrated no obvious benefit.

In the past, the benefit of exercises in BCRL was described in that it improved lymph flow through repeated contraction and relaxation of muscles [8]. However, patients should be taught and supervised by well-trained therapists and then may continue at home [6]. The National Lymphedema Network (NLN) [15] stated that the three main types of exercise for patients with lymphedema included: aerobic, strength, and flexibility, as exercise would be a part of a healthy lifestyle and essential for effective lymphedema management. The NLN [15] also pointed out that patients with or at risk of lymphedema should perform aerobic and weight-lifting exercise in a safe environment. Weight-lifting exercise is also called resistance exercises. This exercise involves lifting body weight or lifting objects and it can be performed with or without moving a joint [15]. A Cochrane systematic review 2015 by Stuiver et al. [16] reported that resistance training after breast cancer treatment did not increase the risk of developing BCRL. Several scholars completed systematic reviews showing beneficial effects of exercise on health outcomes in women with breast cancer [17–19]. However, previous systematic reviews included all exercise types, included non-randomized studies, or additional types of interventions with the exercise [17–19]. As a result, even though the previous systematic reviews provided up-to-date findings regarding the effects exercise has on cancer patients until 2017 [19], a body of knowledge more specific to the effects of weight-lifting exercise in BCRL is needed. We therefore conducted this systematic review to provide the most up-to-date findings regarding the effects of weight-lifting exercise on BCRL within time range dates ranging from 2007 to 2017.

2. Methods

2.1. Data sources and searches

The Preferred Reporting for Systematic Reviews (PRISMA) was used to conduct this systematic review [20]. A literature review from 2007 to 2017 was performed using the ScienceDirect, Scopus, PubMed, and CINAHL databases. Search terms included a combination of subject headings, terms, and keywords, such as "weight lifting exercise", "weight training", "strength training", "resistance exercise", "resistance training"and "breast cancer survivors", "breast cancer-related lymphedema", "lymphedema", or "lymphoedema". Search query for ScienceDirect and Scopus included: "weight lifting exercise" OR "weight training" OR "strength training" OR "resistance exercise" OR "resistance training" AND "breast cancer survivors" OR "breast cancer-related lymphedema" OR "lymphedema" OR "lymphoedema". Search query for PubMed included: "weight lifting exercise" [tiab] OR "weight training" [tiab] OR "strength training" [tiab] OR "resistance exercise" [tiab] OR "resistance training" [tiab] AND "breast cancer survivors" [tiab] OR "breast cancer-related lymphedema" [tiab] OR "lymphedema" [tiab] OR "lymphoedema". Search query for CINAHL included: TI "weight lifting exercise" OR TI "weight training" OR "strength training" OR "resistance exercise" OR "resistance training" AND TI "breast cancer survivors" OR "breast cancer-related lymphedema" OR "lymphedema" OR "lymphoedema"; AB "weight lifting exercise" OR AB "weight training" OR AB "strength training" OR AB "resistance exercise" OR AB "resistance training" AND AB "breast cancer survivors" OR AB "breast cancer-related lymphedema" OR AB "lymphedema" OR AB "lymphoedema". Additionally, reference lists of electronically-retrieved manuscripts were hand-searched to retrieved additional relevant citations within the search timeframe.

2.2. Inclusion and exclusion criteria

All studies were selected based on inclusion and exclusion criteria. The following inclusion criteria were applied followed PICOS concept: (1) Population: Participants were breast cancer patients with (or at risk for) breast cancer-related lymphedema; (2) Intervention: The study was required to have weight-training or resistance exercise as the intervention; (3) Control: The study was required to have a control group or at least two comparative groups; (4) Outcomes: The primary outcome was BCRL by comparing the volume difference between the operative and contralateral arms. Volume could be measured indirectly using the water displacement method or other non-invasive methods, such as perometry or circumferential measurement using a measuring tape; and(5) Study: Only randomized controlled trials (RCT) were included in the review. We excluded quantitative studies using cross-sectional or longitudinal design, qualitative studies, case-studies, reviews, and expert-opinion papers. Non-refereed articles, abstracts, and dissertations were excluded. Secondly, when the papers appeared to meet the inclusion criteria, we obtained the full text and two review authors independently screened them. If there was disagreement, it was resolved by consensus with a third reviewer.

2.3. Data extraction and synthesis

Data from each study were extracted into the literature review form created by the authors. One author extracted data and these were checked by another. Disagreements were resolved by consensus with a third reviewer to ensure appropriate and accurate representation of the material.

2.4. Quality assessment

The methodological quality of the studies was assessed by two independent reviewers using the Physiotherapy Evidence Database (PEDro) scale [21]. The tool is comprised of 11 items to evaluate the risk of bias and statistical reporting of randomized control trials. The items include:(1) Eligibility criteria were specified, (2) Subjects were randomly allocated to groups, (3) Allocation was concealed, (4) The groups were similar at baseline, (5) There was blinding of all subjects, (6) There was blinding of all therapists, (7) There was blinding of all assessors, (8) Measures of at least one key outcome were obtained from more than 85% of the subjects,(9) All subjects for whom outcome measures were available received the treatment or control condition, (10) The results of between-group statistical comparisons are reported for at least one key outcome, and (11) The study provides both point measures and measures of variability for at least one key outcome. The items are scored from 0 to 10 points, as the first item that relates to external validity is not be used to calculate the PEDro score. Studies receiving less than 6 points were considered as low quality and those with six points and over were considered as high quality. Any disagreement was resolved with a third reviewer.

3. Results

The main search results yielded 519 articles and six additional articles were retrieved from references of included studies; these 525 articles underwent initial screening. After checking for duplication, the inclusion and exclusion criteria were applied to 226 articles; 186 articles were excluded based on title and abstract. Of the 40 articles that underwent further detailed inspection, 25 were excluded due to not measuring limb volume difference or only a single-group design. The remaining 15 articles are included in the final review (Fig. 1). The data were extracted and synthesized into a summary table (Table 1).

3.1. General characteristics of the included studies

The methodological quality using the PEDro scale revealed that the included studies ranged from 7 to 10 points of a maximum of 10 points, implying that all studies were considered high quality and presented a low risk of bias. Among 15 included studies, 9 studies focused on patients diagnosed with BCRL [22,25,28,31–36], whereas six studies focused on patients at risk of BCRL [23,24,26,27,29,30]. A total of 1580 women were evaluated by the included studies. Arm volumes was evaluated in all included studies. Nine trials used a single method to measure arm volume: five trials used water displacement [23–27]; two used limb circumference [28,34]; one used perometry [30]; one used self-report [29]. The balance of the studies used 2–4 mixed methods to measure arm volume [22,29,32,33,35,36].

3.2. Resistance exercise alone VS resistance exercise plus aerobic exercise

The systematic review revealed that 13 trials evaluated resistance exercise alone [24–36], whereas only two trials evaluated resistance exercise plus aerobic exercise [22,23].

Regarding the resistance-exercise-alone interventions, the majority of the studies used manual resistance exercise in which the resistance force was applied by the therapist to either a dynamic or isometric contraction [22–24,26,28–36]. Few studies examined the effects of mechanical resistance exercise in which the resistance was provided by equipment to either an isotonic or isometric

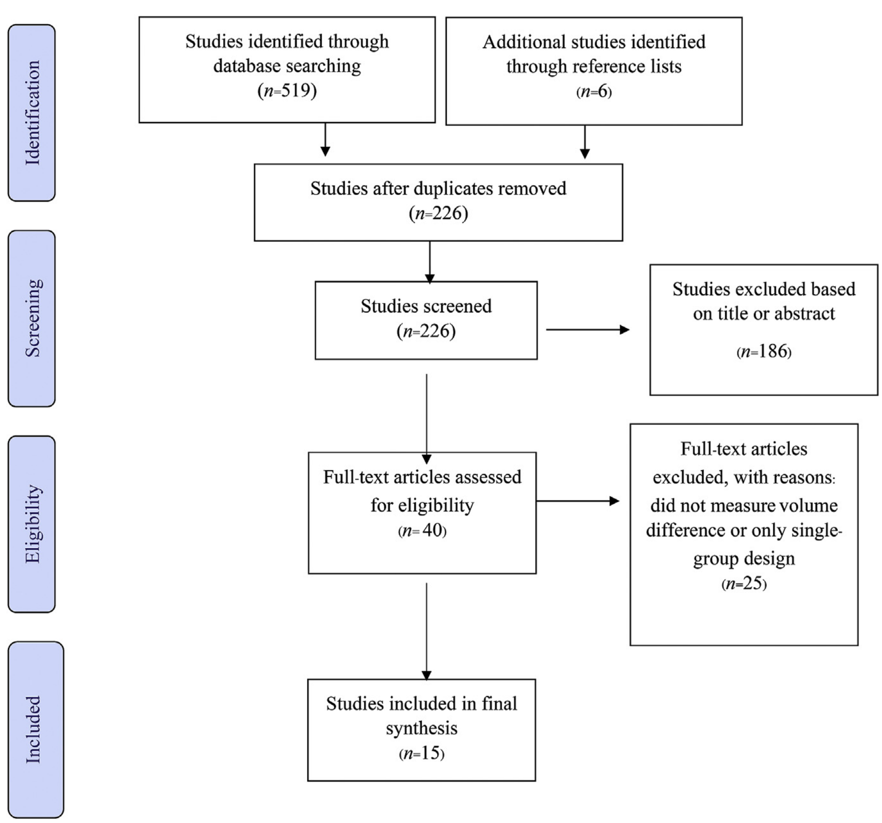

Fig. 1. Literature review flow diagram.

Table 1
Summary of the effects of resistance exercises on BCRL.

Study	Design and Sample	Intervention	Outcome Assessment	Findings	PEDro Scores
Resistance Exercise Alone					
Hayes et al., 2009 [22]	A randomized, controlled trial with 32 women with BCRL	The intervention group (IG) participated in 20 supervised, group, aerobic, and resistance exercise sessions over 12 wk. The control group (CG) was instructed to continue habitual activities.	- Bio impedance spectroscopy - Perometry	No group change was observed between pre-intervention and 3-month follow-up ($P > 0.05$)	8
Anderson et al., 2012 [23]	A randomized, controlled, single-blind study of 104 adult women with newly-diagnosed stages I–III female breast cancer	The RESTORE program began with a Lymphedema Prevention Module, followed by a center-based tailored exercise component (aerobic and resistance exercise).	Water displacement	Adjusted mean change in arm volume in the intervention group was 33.5 ml versus 60.4 in the control group ($P = 0.54$).	7
Resistance Exercise Plus Aerobic Exercise					
Courneya et al., 2007 [24]	A multicenter randomized, controlled trial with 242 breast cancer patients initiating adjuvant chemotherapy	The supervised aerobic exercise group exercised three times per week on a cycle ergometer, treadmill for 12 weeks. The supervised resistance exercise group exercised three times per week performing two sets of eight to 12 repetitions of nine different exercises at 60%–70% of their estimated one repetition maximum. The usual care group was asked not to initiate an exercise program	Water displacement	The percentage of participants experienced increase in the difference between their affected and unaffected arm volumes from baseline to after intervention among 3 groups were not significantly difference ($P = 0.081$).	7
Schmitz et al., 2009 [25]	A randomized, controlled trial of twice-weekly progressive weight-lifting involving 141 breast-cancer survivors with stable lymphedema of the arm	For the first 13 weeks, women were instructed, in small groups, in a 90-min session, twice weekly. Then participants continued twice-weekly unsupervised exercise for 39 additional weeks. Participants in the control group were asked not to change their exercise level during study participation.	Water displacement	The proportion of women who had an increase of 5% or more in limb swelling was similar in both groups ($P = 0.49$). The weight-lifting group had greater improvements in self-reported severity of lymphedema symptoms and a lower incidence of LE exacerbations than the control group ($P = 0.03$).	8
Sagen et al., 2009 [26]	A randomized, controlled trial with 204 women who had breast cancer and underwent mastectomy or breast-conserving surgery with axillary node dissection	The no-activity restriction (NAR) group had no restrictions on the physical activities for 6 months. The NAR patients followed a supervised physical therapy program, which emphasized moderate progressive resistance exercise 2–3 times a week. The activity restriction (AR) group was told to restrict the activity of the affected limb for 6 months. The patients participated in the usual-care physical therapy program carried out weekly, which comprised six different standardized passive manual techniques.	- The Voldiff -Water displacement Instrument (SWDI)	Arm volume of the affected or control arms, Voldiff, and the development of arm lymphedema (ALE) did not differ significantly between the two groups at 3 months, 6 months, or 2 years after surgery ($P > 0.05$). Arm volume increased significantly over time in both the affected and the control arms ($P < 0.001$). The development of ALE from baseline to 2 years increased significantly in both groups ($P = 0.001$).	8
Schmitz et al., 2010 [27]	A randomized, controlled equivalence trial with 154 breast cancer survivors	A 1-year weight-lifting intervention included a gym membership and 13 weeks of supervised instruction, with the remaining 9 months unsupervised.	Water volume displacement	The proportion of women who experienced incident BCRL onset was 11% in the weight-lifting group and 17% in the control group ($P = 0.04$).	9
Kim et al., 2010 [28]	A randomized, controlled trial with 40 women with BCRL	An active resistive exercise for 15 min/day, 5 days a week for 8 weeks	Circumference	The volume of arm was significantly more reduced in the intervention group than those in the control group ($P < 0.05$).	7
Hayes et al., 2011 [29]	A randomized, controlled intervention study, with 295 women who were treated for breast cancer	Twice-weekly progressive weight-lifting during a 12-month period.	- Water displacement -Circumferences, - Bioimpedance spectroscopy - Self-report survey	No between-group differences were noted in the proportion of women who had a change in interlimb volume, interlimb size, interlimb ratio, or survey score ($P > 0.05$).	9
Kilbreath et al., 2012 [30]	A randomized, controlled trial with 160 women who had undergone surgery for stages I–III breast cancer	The exercise program comprised a weekly session and home program of passive stretching and progressive resistance training for shoulder muscles. The control group attended fortnightly assessments, but no exercises were provided.	- Self-report survey	Both the groups reported few impairments, including swelling, following the intervention and 6-months post-intervention ($P > 0.05$).	8
Jeffs & Wiseman, 2013 [31]	A randomized, controlled trial with 23 women with stable unilateral BCRL	A daily home-based exercise program combined a series of gravity-resistive isotonic arm exercises. The exercise program combined a series of gravity resistive isotonic arm exercises in a sequence designed to simulate MLD.	Perometer 350S	The intervention group showed a clinically and significantly improvement in relative excess limb volume at week 26, whereas the control group improvement crossed the line of no effect($P > 0.05$).	9
Cormie et al., 2013 [32]	A randomized, cross-over two groups, with 17 women with mild to severe BCRL	A high load (6–8 repetition maximum) and low load (15–20 repetition maximum) exercise session consisting of 2 sets of 5 upper body resistance exercises.	- Bioimpedance spectroscopy , Dual-energy x-ray absorptiometry - Circumference	No changes in the extent of swelling or the severity of symptoms were observed between pre-exercise and immediately post-exercise, 24 h post-exercise or 72 h post-exercise ($P > 0.05$). No differences in the response to the high or low load exercise were observed ($P > 0.05$).	10

(continued on next page)

Table 1 (*continued*)

Study	Design and Sample	Intervention	Outcome Assessment	Findings	PEDro Scores
Cormie et al., 2013 [33]	A randomized, three-group trial of 62 women with a clinical diagnosis of BCRL	The high-load and low-load resistance exercise programs involved two, 60-min sessions per week for 3 months in an exercise clinic setting supervised by accredited exercise physiologists.	- Bioimpedance spectroscopy - Dual-energy X-ray absorptiometry - Circumference	Change to the extent of swelling outcome measures across the 3-month intervention did not differ between groups ($P > 0.05$).	9
Do et al., 2015 [34]	A prospective randomized controlled trial with 44 patients with breast cancer who were beginning CDT for lymphedema	A moderate intensity resistance exercise program for 8 weeks in conjunction with intensive CDT for 1 or 2 weeks.	- Circumference	No significant pre-post difference between the groups in arm volume ($P > 0.05$). Arm volume showed significant improvement after treatment in both groups ($P < 0.05$).	7
Cormie et al., 2016 [35]	A randomized, cross-over three groups with 21 women with BCRL	A low-load (15–20 RM), moderate-load (10–12 RM), and high-load (6–8 RM) exercise sessions consisting of 3 sets of 6 upper-body resistance exercises.	- Bioimpedance spectroscopy - Circumferences - Visual Analogue Scales	No significant changes in arm swelling or symptom severity scores across the 3 resistance exercise conditions ($P > 0.05$).	7
Buchan et al., 2016 [36]	A randomized, two-group trial of 41 women with a clinical diagnosis of stable unilateral, upper-limb lymphedema secondary to breast cancer	A resistance- or aerobic-based exercise group. Both groups undertook 150 min of supervised and unsupervised exercise (resistance- or aerobic-based) each week at a MET level of 3–3.5 (weeks 1–6), increasing to 5 in weeks 7–12.	- Bioimpedance spectroscopy - Circumferences	No statistically significant or clinically relevant differences in objectively measured lymphedema were found between resistance- and aerobic-based exercise ($P > 0.05$).	7

Note:BCRL=Breast Cancer-Related Lymphedema; MLD = Manual Lymphedema Drainage; CDT= Complete Decongestive Therapy; RM = Repetition Maximum; MET = Metabolic Equivalent of Task.

muscle contraction [25,27]. The results of the included studies showed that manual resistance exercise and mechanical resistance exercise did not significantly affect change of arm volumes.

Only two studies examined the effects of resistance exercise plus aerobic exercise on BCRL. Firstly, Hayes et al. [22] conducted a RCT to examine the effect of participating in a 12-week supervised, mixed-type, exercise program on lymphedema status among 32 women with lymphedema after breast cancer. The results of the study showed that no changes of arm volume were observed over time for either group. Another study, conducted by Anderson et al. [23], examined the effects of a comprehensive program consisting of tailored exercise, lymphedema prevention, patient and diet education, and counseling in 104 women with breast cancer. The results of the study showed that changes in arm volume in the intervention group were not significantly different from those in the control group.

3.3. *Resistance exercise for patients at risk of BCRL VS patients with BCRL*

The results of the six included studies showed that resistance exercise did not cause lymphedema or adverse events in patients at risk of BCRL. One study conducted a three-arm parallel group to examine the effects of resistance exercise on the change of arm volume between the affected and unaffected arms [24]. The results of the study showed that the percentage of participants who experienced a 200-mL increase in the difference between their affected and unaffected arm volumes before and after the supervised resistance group program was not significantly different from those in the usual care group and the supervised aerobic exercise group. The rest of the five conducted a two-arm RCT to compare the difference in arm volume between the affected and unaffected arms [23,26,27,29,30]. Interestingly, although each study focused on different outcome measures, all studies reported similar results. For example, Anderson et al. [23] reported that adjusted mean change in arm volume measured in the intervention group was 33.5 ml versus 60.4 in the control group ($P = 0.54$). Sagen et al. [26] reported that the difference in arm volume between the affected and control arms was not significantly different between the no-activity-restriction group and the moderate resistance exercise group. Likewise, Schmitz et al. [27] reported that clinician-defined BCRL onset occurred in 1.5% in the slowly progressive weight-lifting intervention group and 4.4% in the control group ($P = 0.12$). Similarly, Hayes et al. [29] reported that no differences were found in the proportion of women who had a change in interlimb volume, interlimb size, or interlimb ratio between the progressive weight-lifting exercise group and the control group. Finally, Kilbreath et al. [30] reported that the change in symptoms was not significantly different between resistance exercise and the control groups immediately following the intervention or at 6-month post-intervention. Therefore, based on these previous studies, it may be deduced that resistance exercise did not cause lymphedema in patients at risk of BCRL. However, it should be noted that various methods were used to measure LE in these studies. Therefore, more rigorous studies are needed to confirm whether resistance exercise is of benefit for patient at risk of BCRL.

For patients with BCRL, of nine studies, six studies reported that change to the extent of swelling outcome measures was not significantly different between the resistance exercise group and the control group [22,32–36]. However, there were three previous studies which reported that arm volume was significantly more reduced in the resistance exercise group than in the control group [25,28,31]. For example, Schmitz et al. [25] reported that the weight-lifting group had greater improvements in self-reported severity of lymphedema symptoms ($P = 0.03$) and a lower incidence of lymphedema exacerbations ($P = 0.04$). Kim et al. [28] reported the arm volume was significantly more reduced in the intervention group than those in the control group ($P < 0.05$). Finally, Jeffs and Wiseman [31] reported that the intervention group showed a clinically and statistically significant improvement in relative excess limb volume at Week 26, whereas the control group improvement crossed the line of no effect. Based on these previous studies, resistance exercise might reduce arm volume or at least did not increase arm swelling. However, small sample size was a main limitation. Therefore, more randomized controlled trials are needed.

4. Discussion

Based on the 15 articles meeting criteria for inclusion in this review, resistance exercise alone or resistance exercise plus aerobic exercise appears to be a potentially effective procedure for patients at risk of BCRL and patients with BCRL. The systematic review showed that resistance exercise might reduce limb volume or did not increase lymphedema incidence in patients with BCRL and did not increase the risk of developing lymphedema in patients at risk of BCRL.

In the past, we were afraid that resistance exercise might cause muscle damage and inflammation due to increase in creatinine kinase and various inflammatory biomarkers 72 h post-exercise [37]. However, it has been reported by Cormie et al. [35] that muscle damage and inflammation after upper-body resistance exercise in women with BCRL might not depend on load (low, moderate, and high) of resistance exercise. Interestingly, lymphedema status and symptom severity also was not affected by the load lifted. However, Cormie et al. [35] claimed that their study was limited by a small sample size and short-term period of blood sample assessment (24 h post-exercise). Longer-term periodic assessment should be performed in the future studies.

These findings of the systematic review also supported the position statement of the National Lymphedema Network [15] that: "Individuals with or at risk for lymphedema can and should perform aerobic and resistance exercise in a safe manner." Recommendations for patients with lymphedema to perform aerobic and resistance exercise include: Allowing adequate rest between sets; Avoiding wrapping arms tightly; Wearing compression sleeves or bandages during exercise; Maintaining hydration; Avoiding extreme heat or overheating; and 6) Exercising in a circuit within the exercise session [15]. It is also noteworthy that both resistance exercise types should be cautiously performed under the supervision of trained professionals, such as physical therapists or certified cancer exercise specialists, as the supervision will help to alleviate fear of developing BCRL among these women, in addition to increasing knowledge about exercise program [38,39].

Regarding the effects of resistance exercise plus aerobic exercise, the results of this systematic review show that it appears to be safe to perform this type of exercise for women with BCRL or women at risk of BCRL. However, caution should be mentioned as these findings are based on small sample size and only two RCTs were included in the review. So, although results indicated that the combination of resistance exercise plus aerobic exercise was safe in the majority of patients, more rigorous studies with larger sample size are needed. Moreover, whether resistance plus aerobic exercise is better for health outcomes of patients with BCRL than resistance exercise alone is still unanswered. Randomized controlled trials are needed to identify this question.

In terms of manual and mechanical resistance exercises, the study results report that they both did not significantly affect change of arm volumes. This is congruent with a previous study by Chulvi-Medrano et al. [40] who compared the effects of an 8-week manual resistance exercise and conventional resistance exercise on maximum strength and muscular endurance in 20 recreationally-trained men. The results of the study reported that neither group showed significant changes in muscular strength or endurance. Further research to compare manual and mechanical resistance exercises on lymphedema status or severity in patients with BCRL and at risk of BCRL will be illuminating.

5. Limitations

The limitation of the reviewed studies was that some studies were based on a small sample size. So future research with a larger sample size is needed. In addition, although the results showed that BCRL could be prevented or improved by resistance exercise, no long-term follow-up was performed. So we cannot conclude whether the effects could be maintained or even be enhanced over time. Future research in long-term measures is needed. In addition, because this is a systematic review, its limitation is that a conclusion cannot be drawn for absolute effects. Therefore, a meta-analysis, a mathematical synthesis of the results of primary studies, should be conducted. Moreover, as this systematic review focused more on women with or at risk of BCRL, future systematic review is needed to perform subgroup analysis for women such as those with or without radiotherapy. Finally, all papers were retrieved from only four databases. As a result, this could represent an incomplete retrieval may occur.

6. Conclusion

Based on this systematic review, it can be concluded that resistance exercise is beneficial for effective lymphedema management among patients with BCRL and women at risk of BCRL. However, performing resistance exercise should be supervised by certified lymphedema therapists or physical, occupational, or massage therapists or nurses trained in oncology and lymphedema case. More importantly, resistance exercise should be used as a supplement or complement to traditional lymphedema treatment, and not as a sole therapy.

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Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Appendix A. Supplementary data

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