

Upper Extremity Strength Imbalance after Mastectomy and the Effect of Resistance Training



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Key words

breast cancer, exercise training, arm curl

received 14.04.2017

revised 15.06.2017

accepted 18.06.2017

Bibliography

DOI <https://doi.org/10.1055/s-0043-115105>

Sports Medicine International Open 2017; 1: E160–E165

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ISSN 2367-1890

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ABSTRACT

The purpose of this non-randomized pre/post comparison trial was to explore the effect of resistance training (RT) on upper extremity strength imbalance in breast cancer survivors. Seventeen right-side dominant female breast cancer survivors (age: 58.2 ± 2.7 years; BMI: 27.8 ± 1.1 kg/m²) with right-sided (RSM) or left-sided (LSM) mastectomy completed strength testing (30-second arm curl) before and after an 8-week RT program. At baseline, LSM ($n = 8$) had equal strength bilaterally (right = 16.8 ± 1.1 repetitions; left = 16.4 ± 1.4 repetitions), whereas RSM ($n = 9$) had impaired strength on the right (16.7 ± 1.3 repetitions) compared to the left (18.6 ± 1.1 repetitions) side ($p < 0.01$). After RT, RSM increased strength by 25% on the right (initially weaker) side and 19% on the left (initially stronger) side, which resolved the imbalance. By comparison LSM increased 19% on both sides that were initially equal in strength. Based on our findings, breast cancer survivors with dominant-side mastectomy are at risk for upper extremity strength imbalance that can be resolved with a relatively short-term RT program.

Introduction

Among breast cancer survivors, surgical mastectomy results in damage to the axillary area, including muscle, nerve and circulatory tissues [10]. Over time, this damage can cause muscular atrophy with loss of upper body strength and function [10, 38]. Mastectomy rates are increasing and are estimated to be 45% among women of all ages who have been diagnosed with breast cancer [11]. The increasing incidence of surgical mastectomy places breast cancer survivors at risk for development of upper extremity strength imbalances [17, 28, 39, 42].

Side-to-side muscle imbalance has been well studied among athletes [4, 9, 12, 22, 23, 26, 27, 34, 43]. Findings indicate that strength imbalances increase the risk for acute [12, 34, 43] and chronic injury [4, 23, 26], and that rehabilitation with resistance training can resolve these imbalances and decrease risk for injury [9, 33]. Less is known about non-athletic populations, although

among healthy younger adults [20] and older clinical populations [25, 40] evidence regarding risk is consistent with that of athletes.

In healthy women, upper extremity strength should be relatively equal bilaterally [21, 32]. However, compared to healthy women, breast cancer survivors have greater upper extremity loss of strength, leading to functional impairment [15]. Traditionally, after mastectomy women have been instructed to avoid all lifting and muscular exertion with their treated arm [36], so surgically-induced atrophy leading to muscular imbalance may have gone relatively unappreciated. However, women must have full functional use of both upper extremities for participation in normal activities of daily living. In particular, tasks requiring elbow flexion, including lifting and carrying, are difficult for women who have undergone mastectomy after breast cancer [18].

Research evaluating upper extremity strength imbalance in breast cancer survivors has been inconsistent. Three observational

studies reported greater strength loss on the affected side using either a multi-joint chest or shoulder press [28] or a single-joint shoulder raise [39, 42], whereas one reported greater loss on the non-affected side using a combined upright row/shoulder press exercise [17]. One intervention study reported baseline strength differences, with greater weakness on the affected side, using electromyographic (EMG) analysis of the pectoralis major and triceps brachii. [14] None of these studies evaluated elbow flexion, although it is the most problematic movement for this population. Furthermore, although intervention studies demonstrate overall increases in upper extremity strength in breast cancer survivors after a resistance training program, strength has primarily been measured using a chest press involving elbow extension [8, 37, 44, 45]. Only one study evaluated strength using an arm curl to measure elbow flexion [29]. Unfortunately, none of these studies measured side-to-side differences in upper extremity strength. Finally, in the only intervention study to evaluate side-to-side differences, EMG was used for measurement, and although strength increased in both upper extremities, differences were not resolved with training [14]

Intervention studies evaluating imbalances in elbow flexion strength in breast cancer survivors after mastectomy are needed. The 30-second arm curl (flexion) test is a well-recognized field measure of upper extremity strength and functional ability. It has been validated as a surrogate for direct laboratory measurement of maximal upper-body strength [2, 35]. The 30-second arm curl test is an appropriate measurement tool for evaluation of impairments in upper extremity strength related to elbow flexion. This study was designed to explore the effect of resistance training on upper extremity strength imbalance in breast cancer survivors after unilateral mastectomy using the arm curl test to measure elbow flexion strength. Our hypothesis was that the affected side would be initially weaker and that this imbalance would be resolved with resistance training.

Methods

Seventeen female breast cancer survivors (time since diagnosis = 6.3 ± 1.8 years) with unilateral mastectomy were included in the pilot study after receiving informed consent. All were recruited from the community by flyers and word of mouth as part of a larger resistance training study for breast cancer survivors at least 30 years of age that has previously been described [3]. Nine had right-sided mastectomy (RSM) and eight had left-sided mastectomy (LSM). All were right-arm dominant. Exclusion criteria were bilateral mastectomy, lymphedema, pregnancy or the intent to become pregnant, participation in any regular exercise program, or any medical condition limiting participation in an exercise program. All participants completed anthropometric and upper extremity strength measurement before and after an 8-week resistance training program. All testing and training was done in a university research center by the same experienced investigator. The study was approved by the university institutional review board for protection of human subjects and conducted in accordance with the ethical standards of this journal [16].

Anthropometrics

Height was measured in centimeters using a wall-mounted stadiometer with the measuring tongue aligned with the top of the par-

ticipant's head. Participants removed their shoes and positioned themselves with their backs aligned against the wall and heads erect.

Weight was measured in kilograms using a portable computerized scale. Participants removed their shoes and voided prior to the procedure.

Waist circumference was measured in centimeters at the level of the umbilicus using standardized procedures following the guidelines of Callaway et al. [5] A Gulick tape was used to ensure constant tension during measurement.

Upper extremity strength measurement

For the arm curl test, participants sat upright in a straight-backed chair with both feet flat on the floor and a 5 lb dumbbell held laterally in their untreated (non-mastectomy) hand. The investigator stabilized their elbow at their side while they repeatedly raised and lowered the dumbbell through a full range of motion. The test was then repeated on the treated (mastectomy) side. Partial curls that did not complete the full range of motion were not counted. The number of full curls completed in 30 s with good form was recorded as the score for each arm.

Resistance training

The 8-week resistance training program has previously been described [3]. Briefly, participants completed two sessions per week for 8 weeks with at least 2 days rest between sessions. Adherence was 97%. All sessions were directly supervised by the same investigator. A total-body progressive training strategy was used. Participants completed three sets each of a seated chest press, shoulder press, parallel grip cable pulldown, standing cable bar curls, and standing cable bar pushdowns for the upper body, and a seated leg press, leg extensions, and lying leg curls for the lower body using pin-loaded weight machines (Precor, USA). Participants were asked to achieve 8–12 repetitions at a given weight, and when they were able to complete 10–12 repetitions with good form for all 3 sets, the weight was increased 5–10% at the next training session. To minimize training time, exercises were paired into opposing supersets, with the exception of the leg press, which was trained alone with a one-minute rest between sets.

Statistical analysis

Data were analyzed using SPSS version 22, with a level of significance set at $p < 0.05$. All data were reported as mean and standard error (SE). Participant characteristics were analyzed using descriptive statistics, and differences between and within groups were evaluated using repeated measures analysis of variance (ANOVA) and independent samples t-tests. As a surrogate for clinical significance, effect sizes were calculated as eta-squared (η^2). An effect size of 0.01 was considered small, 0.06 was considered medium, and 0.14 was considered large [13].

Results

As a single group, participants were middle-aged (age: 58.2 ± 2.7 years), overweight (BMI: 27.8 ± 1.1 kg/m²), and centrally obese (waist circumference: 89.7 ± 2.6 cm). There were no significant differences between participants with RSM and LSM for age or anthro-

pometric measurements (► **Table 1**). At baseline, the LSM group that was status post-mastectomy on the non-dominant side was observed to have equal upper extremity strength bilaterally (► **Fig. 1**). There was no significant difference in arm curl repetitions achieved in 30 s between the dominant right and non-dominant left sides (16.8 ± 1.2 repetitions and 16.4 ± 1.4 repetitions, respectively). By comparison, the RSM group demonstrated significantly greater (11 %) weakness on the dominant right side compared to the non-dominant left side (16.7 ± 1.3 repetitions versus 18.6 ± 1.1 repetitions, $p < 0.01$; $\eta^2 = 0.07$).

After participation in 8 weeks of resistance training two times a week, all participants were significantly stronger ($p < 0.001$) and the RSM group no longer demonstrated right-sided weakness (► **Fig. 2**). Specifically, the RSM group increased arm curl repetitions by 25 % ($p < 0.001$; $\eta^2 = 0.35$) on the dominant (initially weaker) side and 19 % ($p < 0.001$; $\eta^2 = 0.27$) on the non-dominant (initially stronger) side; and the LSM group increased 19 % ($p < 0.01$;

$\eta^2 = 0.32$) on the dominant and 19 % ($p < 0.01$; $\eta^2 = 0.28$) on the non-dominant sides that were initially equal in strength. Furthermore, although training volume load increased significantly over the 8-week period, there were no between-group differences in any of the five upper body exercises used either before or after the training program (► **Table 2**).

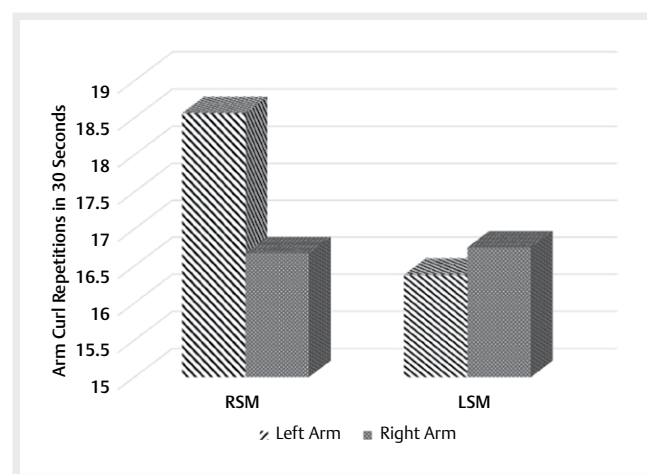
Discussion

The principal finding of this study was that women who experience surgical mastectomy on their dominant right side demonstrate a significant imbalance in upper extremity strength, and that a program of progressive resistance training only two days a week over an 8-week period can reverse that imbalance. Although it is well-recognized that resistance training can improve upper extremity strength in breast cancer survivors [6, 37], its effect on strength imbalance secondary to surgical mastectomy is unclear. Among

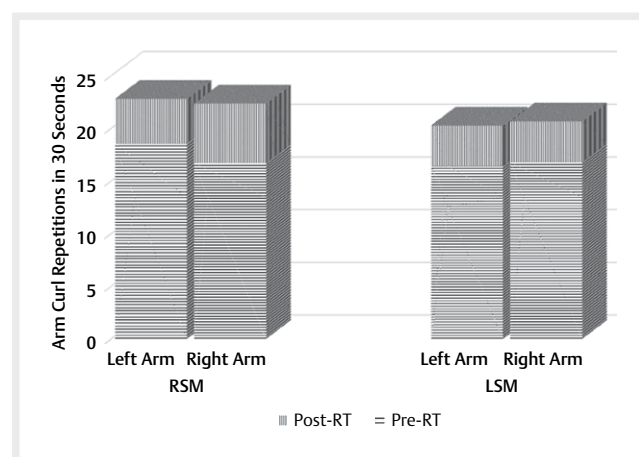
► **Table 1** Anthropometric and upper extremity strength measurements before and after resistance training in 17 right-arm-dominant women with unilateral mastectomy.

	RSM (n=9)		LSM (n=8)	
	Baseline	After RT	Baseline	After RT
Age (years)	60.6 ± 3.4		55.5 ± 4.3	
Weight (kg)	76.2 ± 4.2	76.7 ± 4.1	69.4 ± 5.0	68.7 ± 4.9
Body Mass Index (kg/m ²)	27.2 ± 1.5	27.4 ± 1.5	28.4 ± 1.8	28.2 ± 1.6
Waist Circumference (cm)	91.0 ± 3.6	89.8 ± 3.2	88.2 ± 3.9	87.9 ± 4.4
Arm Curls (repetitions)				
Right	16.7 ± 1.3 *	22.3 ± 1.5 ††	16.8 ± 1.2	20.6 ± 0.9 †††
Left	18.6 ± 1.1 *	22.8 ± 1.3 †	16.4 ± 1.4	20.3 ± 1.0 ‡

Data presented as Mean ± SE. * Significant difference between right and left sides ($p < 0.01$; $\eta^2 = 0.07$); † Significant improvement from baseline ($p < 0.001$; $\eta^2 = 0.27$); †† Significant improvement from baseline ($p < 0.001$; $\eta^2 = 0.35$); ‡ Significant improvement from baseline ($p < 0.01$; $\eta^2 = 0.28$); ††† Significant improvement from baseline ($p < 0.01$; $\eta^2 = 0.32$); **RSM** = right side mastectomy; **LSM** = left side mastectomy; **RT** = resistance training



► **Fig. 1** Comparison of side-to-side upper extremity differences before 8 weeks of resistance training. In women with mastectomy on the dominant side (RSM), the dominant arm was 11 % weaker than the non-dominant arm ($p < 0.01$; $\eta^2 = 0.07$), whereas women with mastectomy on the non-dominant arm (LSM) had equal strength bilaterally.



► **Fig. 2** Comparison of side-to-side upper extremity differences after 8 weeks of resistance training. In women with mastectomy on the dominant side (RSM), there was a 25 % increase ($p < 0.001$; $\eta^2 = 0.35$) in strength in the dominant (right) arm and a 19 % increase ($p < 0.001$; $\eta^2 = 0.27$) in the non-dominant (left) arm that completely compensated for the initial imbalance. In women with mastectomy on the non-dominant side (LSM), there was a 19 % increase bilaterally ($p < 0.01$; $\eta^2 = 0.28-0.32$) that resulted in no side-to-side difference either before or after training.

► **Table 2** Changes in training volume load (total repetitions X load) for upper body exercises over the 8-week resistance training program. Both groups increased significantly and there were no differences between groups either before or after training.

	RSM (n=9)		LSM (n=8)	
	Baseline	After RT	Baseline	After RT
Seated Chest Press (kg)	411 ± 44	698 ± 55 †	419 ± 42	721 ± 47 †
Parallel Grip Cable Pulldown (kg)	515 ± 37	716 ± 62 †	438 ± 57	672 ± 51 †
Shoulder Press (kg)	259 ± 27	589 ± 46 †	258 ± 24	607 ± 24 †
Standing Cable Bar Curls (kg)	221 ± 24	330 ± 40 †	200 ± 14	327 ± 25 †
Standing Cable Bar Pushdowns (kg)	245 ± 26	367 ± 36 †	218 ± 12	381 ± 26 †

Data presented as Mean ± SE. **RSM** = right side mastectomy; **LSM** = left side mastectomy; **RT** = resistance training; † Significant improvement from baseline ($p < 0.001$; $\eta^2 = 0.72-0.94$)

participants who demonstrated baseline imbalance, strength gains in the initially weaker upper extremity were approximately 50 % greater than in the initially stronger upper extremity, although a bilateral training strategy was used. Specifically, rather than being asked to train each arm individually, a more time-efficient approach was employed in which participants used two-handed grip machines and bars that distributed exertion equally between both upper extremities. As a result, after only 16 training sessions, gains were such that bilateral strength was equalized and there was complete compensation for the initial imbalance.

The effect of resistance training on side-to-side strength differences has not been widely studied. In a previous study, Janzen and colleagues [21] evaluated the effect of 26 weeks of bilateral upper extremity training (chest press, shoulder press, latissimus pulldown, biceps curl) three days a week on unilateral upper extremity strength in healthy post-menopausal women, using the latissimus pulldown for strength measurement. There were no appreciable side-to-side differences prior to training, and after the training program unilateral upper extremity strength improved equally between sides [21]. Although they measured strength using a different exercise than the present study, their training protocol was similar and included the same upper body exercises that the breast cancer survivors in our study completed. It would seem probable, therefore, that had they measured changes in the biceps (arm) curl, side-to-side strength increases would also have been relatively equal. By comparison, we also observed bilaterally equal strength increases in participants who initially had no side-to-side strength differences; but among those who exhibited an initial imbalance in upper extremity strength, we observed not only overall, but differential increases that resolved side-to-side differences. Hence, it would appear that when unilateral strength is similar, a bilateral stimulus increases both sides equally, but when imbalance is present there is a differential effect favoring the weaker side.

In a more recent study, Hagstrom and colleagues [14] evaluated the effect of a 16-week whole-body resistance training program on side-to-side differences in pectoralis and triceps strength in breast cancer survivors. At baseline, the affected side was found to be weaker, which agrees with our baseline findings; but contrary to our results, the training program they reported did not resolve the initial imbalance. The difference in outcomes may have been related to their training protocol. The upper body exercises they utilized were compound, multi-joint exercises (chest press, back row, lat

pulldown), which may have allowed selective recruitment of stronger muscle groups that compensated for weaker ones. By comparison, our training program utilized both multi- and single-joint exercises that allowed isolation of specific muscle groups, in particular the biceps brachii used for elbow flexion. It is possible that if Hagstrom and colleagues [14] had used isolation exercises such as chest flies or triceps extensions, the side-to-side imbalance they observed may have been resolved.

Consideration should be given to bilateral versus unilateral training. Unilateral training involves training one side only for the purpose of increasing strength on both sides [30]. It is used in clinical populations exhibiting weakness or immobility on one side, such as stroke patients [41]. Although the cross-education effect of unilateral upper extremity training is well recognized [24], gains in the trained extremity have consistently been found to exceed gains in the untrained extremity [1, 19, 31, 32]. Therefore, in this population unilateral training of the stronger side only would be unlikely to resolve the imbalance by sufficiently strengthening the weaker side.

Unilateral training can also involve training both sides separately. In the same study of post-menopausal women previously discussed, Janzen and colleagues [21] evaluated unilateral training of both upper extremities. Their results mirrored those of bilateral training. Upper extremity strength, which was equal bilaterally at baseline, increased equally on each side with either bilateral (both upper extremities trained together) or unilateral (both upper extremities trained separately) training. Although it is possible that unilateral training of both upper extremities would resolve side-to-side strength differences to the same extent as bilateral training, bilateral training is more time-efficient [21] and, because participants can achieve more repetitions with less perceived exertion [7], may be better tolerated.

We recognize that there are limitations to our study that include a small sample size. However, all of the effect sizes were medium and large, which supports the clinical significance of our data. Furthermore, all of the participants were right-hand dominant. Although with a small sample size, it was considered important to control for arm dominance by including only right-hand dominant participants, it may have affected the outcomes. Our use of the 30-second arm curl test to measure strength may also be considered a limitation. Although the arm curl test has been validated against a maximal (1RM) chest press [2, 35], the 30-second times-

pan involves muscular endurance as well as strength. However, we considered measurement of maximal (1RM) elbow flexion as potentially dangerous in this population, so made an a priori decision that may have influenced our findings. Finally, potential differences in muscle mass between the treated and untreated sides were not assessed. Both muscle quality (strength) and quantity (mass) should be considered in light of the potential effects of surgery on upper extremity musculature. Future intervention studies should include a larger sample size with both right- and left-arm-dominant women, and evaluate muscle mass as an outcome.

Conclusions

Our results demonstrate a statistically and clinically significant imbalance in upper extremity strength among women with mastectomy on their dominant side, which may place them at risk for either acute or chronic injury. Although our findings are preliminary, they demonstrate the feasibility of an 8-week resistance training program to resolve this strength imbalance. More research is needed to identify the most appropriate testing and training strategies for this population.

Acknowledgements

Acknowledgements: This study was supported by a J. Patrick Barnes grant from the Daisy Foundation.

Conflict of Interest

The authors have no conflicts of interest to disclose.

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