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Impact of Strength Training on Body Composition, Volumetrics and Strength in Female Breast Cancer Survivors

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Abstract: Background/Aims: This cross-sectional study investigates body composition and strength in female breast cancer survivors, focusing on the effects of radical mastectomy and the presence of upper extremity lymphoedema. The main objective was to understand body composition, volumetry and strength, as well as response to strength training in female breast cancer survivors. Methods: Twenty-three women with radical mastectomy were assessed by measuring body composition (weight, water percentage, fat, muscle and lean mass), maximal strength, perimeters and brachial volumes. Participants completed a 10-week strength training programme. No significant differences were found between the affected/healthy hemispheres in terms of composition, perimeters and volumetrics. However, 11 women were found to have lymphoedema (47.8%). No statistically significant differences were found between hemibodies after the intervention, although improvements were obtained in pectoral strength and manual grip, as well as in muscle mass, lean mass [p=0.002 each]. Cases with lymphoedema were reduced to 5 (21.73%). Conclusions: While strength training is shown to benefit body composition, strength and incidence of lymphoedema in mastectomised women, further scientific evidence is needed with larger controlled trials and follow-up studies to validate these findings, as well as the impact on the quality of life of these survivors.

Keywords: breast cancer; radical mastectomy; lymphoedema; body composition; muscle strength; survivorship

1. Introduction

Cancer is one of the leading causes of morbidity and mortality globally, according to the World Health Organisation (WHO), with 9.6 million deaths registered in 2018. In Spain, the National Institute of Statistics (INE) lists it as the second leading cause of death, accounting for 26.4% of total deaths [1]. Data from the Global Cancer Observatory (GCO) indicate that in 2021, 285,530 new cases of cancer were diagnosed in the country, of which 34,333 were breast cancer, the most common type in women [2,3]. It is estimated that 1 in 8 women in Spain will develop breast cancer, especially in the 46-65 age group, and this type of tumour is responsible for 5.8% of annual cancer deaths in women. Although the five-year relative survival rate is 89.2%, 30% of women diagnosed in early stages will suffer a relapse with distant metastasis [4–6].

Although it has increased in recent years, it accounts for only 1% of all breast cancer cases and is responsible for 0.1% of cancer deaths in men [7,8]. In Europe, the incidence of male breast cancer is 1 case per 100,000 population, affecting mostly men in their 70s and 80s, with a peak incidence at age 71 [9–11].

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Among the most frequent and debilitating complications is lymphoedema, which mainly affects the upper limb on the affected side after surgical treatments such as mastectomy. Lymphoedema can cause swelling, pain and decreased functionality of the arm, directly affecting patients' quality of life and autonomy [12–14]. This complication, estimated to affect about 20-30% of women treated for breast cancer, is chronic in nature and difficult to reverse, underscoring the need for effective prevention and management strategies [15,16].

Body composition may play a key role in the development and management of lymphoedema. Recent research suggests that factors such as body mass index (BMI), fat mass and muscle mass influence the predisposition to develop lymphoedema and its severity [17,18]. A higher percentage of fat mass has been associated with an increased risk of complications, whereas adequate muscle mass may be a protective factor. Understanding this relationship is essential to identify high-risk patients and guide more precise interventions. However, the evidence remains limited and has mainly focused on BMI, without a thorough assessment of lean and muscle mass, which could be determining variables in the onset and progression of lymphoedema [19,20].

Systematically measuring muscle strength and body composition in breast cancer survivors can help assess patients' functional status and post-treatment recovery. These measurements not only allow monitoring the progress and effectiveness of interventions, but also provide valuable data for adjusting rehabilitation programmes [21,22]. In addition, it has been shown that strength training, when introduced in a controlled and progressive manner, can have positive effects on the prevention and control of lymphoedema. Muscular strength exercise improves lymphatic circulation, strengthens muscle mass and can reduce fluid accumulation, mitigating symptoms and promoting a more complete functional recovery [23–25].

This study aims to analyse body composition, volumetry and strength in female breast cancer survivors, as well as their response to a ten-week strength training programme. In addition, it aims to explore whether strength training contributes to improving the physical condition of these patients and reducing the incidence of lymphoedema, generating evidence that can inform personalised physical exercise interventions.

2. Materials and Methods

2.1. *Participants*

To understand the physical characteristics of breast cancer survivors and their response to strength training, a longitudinal study was conducted with a total of 23 women who underwent radical mastectomy, a surgical procedure first described in the late 19th century by Halsted, and whose current protocol was established in 1972 by Madden [26], according to which the surgery involves ablation of the entire breast as well as the axillary lymphatic tissue [27].

Inclusion criteria were: having been diagnosed with breast cancer, having undergone radical mastectomy, having less than five years since their last surgery, and having voluntarily completed the informed consent form. The sample was selected by non-probabilistic methods through an open invitation to breast cancer survivors' associations in Sonora, Mexico.

2.2. *Procedure*

The variables assessed were: height, weight, percentage of fat mass, fat mass in kilograms, muscle mass, lean mass, percentage of water, manual grip strength of the affected and healthy sides, maximum strength in chest press, maximum strength of bilateral pectoral contraction, maximum strength of unilateral pectoral contraction of the healthy and affected sides, as well as perimeters and volumetrics of both arms.

Body composition analysis included measurements of: weight, height, percentage of fat mass, kilograms of fat mass, lean mass, muscle mass and percentage of water. This analysis was carried out using a professional scale, model TANITA SC331S, used in different populations [28,29], scrupulously following the user manual. Grip strength was measured using a dynamometer, taking three measurements and determining the arithmetic mean.

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The evaluation of the maximum force (1RM) of unilateral and bilateral chest contraction was carried out using the protocol described by Tanori et al [30], on a multi-station machine (EXM2500Sv Body Solid). For the determination of the maximum force in unilateral pectoral contraction, we started with an initial load equivalent to 10% of the body weight of each participant, making increments of 5% until the maximum load that each participant was able to mobilise on a single occasion was individually established. For the determination of maximum strength in chest press and bilateral pectoral contraction, we started with an initial load of 20% of body weight. After each successful attempt, a 10% increase in load was applied.

These increments were applied as a function of perceived exertion using the OMNI-RES scale [30] with two minutes of recovery between each attempt, so that if load shifting was achieved twice, the load increase was continued; if not, the weight was decreased by 5% to achieve greater accuracy.

On the other hand, the assessment of arm circumferences was performed using the procedure employed by Tánori et al., 2020 [31]. Accordingly, measurements were performed while seated, with the shoulder in flexion and abduction of approximately 30º, extending the arm in a relaxed manner on a table, with the elbow in extension, and the forearm in a supinated posture. Depending on the length of each participant's arms, 10 to 12 points were marked on the skin, spaced every 4 cm starting from the distal wrist crease to the region near the axilla. Circumference measurements were taken perpendicular to the main axis of the limb, with a retractable tape and without pressing on the skin.

Taking the perimeter measurements of the participants' limbs as a reference, the volumetries of the segments of each arm were found and, consequently, the total volume of the limbs. To do this, starting from each of the perimeters, the brachial radius of each measurement point was calculated using the equation:

$$r = \frac{P}{2\pi}$$

The height of each segment was then determined by taking the four centimetres between measuring points as the generatrix. Finally, using the calculated data, the volume of each segment of the arms was found using the mathematical formula for the truncated cone [32].

$$h = \sqrt{g^2 + (r2 - r1)^2}$$

$$Volume = \frac{h\pi}{3}\,(r1 + r2 + r1r2)$$

Once the volumetric data for all upper limb segments were available, the output variables were calculated by summation: forearm volume, upper arm volume and total upper limb volume. The measurement of perimeters and subsequent calculation of volumetrics has proven to be a highly appropriate and reliable practice [33,34].

The diagnostic criteria for lymphoedema were followed, indicating the presence of lymphoedema if there is a volumetric difference between the two upper limbs of at least 200 millilitres [35].

The study is subject to current biomedical research legislation and the principles of the Declaration of Helsinki. Written informed consent was collected from all participants prior to the start of the study. Approval was obtained from the ethics committee of the University of Sonora (DMCS/CBIDMCS/D-50).

2.3. *Intervention*

All participants underwent a 20-session strength training programme using multi-station training machines. Two sessions were performed twice a week. Each muscle group was exercised in three sets with repetitions of 12-10-12. The load was increased from the second week of training by varying the repetitions to 16-13-16. Every two weeks the increments were modified by an additional 5% of the load, following the recommendations of the American College of Sports Medicine (ACSM) [36], which have been used in studies with this population.

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2.4. *Statistical Analysis*

All statistical analyses were performed using SPSS v.25. Firstly, socio-demographic and body composition characteristics were analysed using descriptive analyses. Qualitative variables were shown by frequencies and percentages, quantitative variables were studied through means and Standard Deviations (SD). Before proceeding to inferential analyses, Shapiro-Wilk normality analysis was performed. Those variables with a normal distribution were tested using parametric tests (Student's t-test for related and independent samples), while variables with a non-normal distribution were compared using non-parametric analyses (Mann Whitney U and Wilcoxon signed-rank test).

3. Results

The sample comprising the present study consisted only of women (n=23), with a mean age of 55.70 years and a mean BMI of 27.72 (Table 1). Most of the participants (56.5%) were diagnosed and mastectomised on the right side of the body, with one participant undergoing double radical mastectomy. The presence of lymphoedema was identified in 11 participants, representing 47.8% of the sample (Table 2).

Table 1. Description of the body characteristics of the sample.

	M	*SD*
Age	55.70	9.508
Height	159.78	6.557
BMI	27.72	3.64
Weight	71.14	12.17
Fat mass (percentaje)	37.23	8.01
Fat mass (kg)	27.29	9.04
Muscle mass	41.617	3.93
Lean mass	43.85	4.12
Water percentaje	43.81	4.90

[1] Mean (M), Standard Deviation (SD).

Table 2. Clinical data of the sample.

	N	%
Operated side		
Right	13	56.5
Left	9	39.1
Both	1	4.3
IMC		
Normal weight	5	21.7
Overweight	12	52.2
Obesity	6	26.1
Lymphedema		
Yes	11	47.8
No	11	47.8

The differences in perimeter measurements of both upper limbs were not statistically significant in any of the cases, as can be seen in Tables 3 and 4.

Table 3. T-test independent samples. Perimeter measurement differences.

	Affect hemibody		**Healthy hemibody**		**t-student independent samples**	
	M	*SD*	*M*	*SD*	*t*	*p*
Perimeter 1	15.791	1.006	15.681	0.853	0.397	0.693

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Perímeter 2	17.066	1.442	17.004	1.328	0.152	0.880
Perímeter 3	19.725	1.868	19.763	1.887	-0.070	0.945
Perímeter 5	24.591	1.827	24.572	1.987	0.034	0.973
Perímeter 6	25.775	2.128	25.427	2.289	0.534	0.576
Perímeter 7	26.612	2.626	26.500	2.893	0.137	0.892
Perímeter 8	28.375	3.282	28.313	3.567	0.061	0.952
Perímeter 9	30.275	3.731	30.118	3.977	0.138	0.891
Perímeter 10	32.412	4.117	32.131	3.911	0.237	0.814
Perímeter 11	33.916	4.025	34.418	4.734	-0.274	0.786

[1] Mean (M), Standard Deviation (SD).

Table 4. Mann-Whitney U. Perimeter measurement differences.

	Affect hemibody		Healthy hemibody		Mann-Whitney U
	N	*Mid-range*	*N*	*Mid-range*	*p*
Perimeter 4	24	22.96	22	24.09	0.775
Perímeter 12	2	2.50	2	2.50	0.999

With regard to upper limb volumes, no significant differences were found in this sample, neither in the forearm [t(44) =.511,p=.612], nor in the upper arm, nor in the whole upper limb. The comparison of unilateral pectoral strength and manual grip also showed no significant differences (Table 5).

Similarly, after the intervention, no significant differences were found between forearm [t(44) =.035,p=.972], arm or full upper limb volumes, as well as in unilateral pectoralis and manual grip strength.

Table 5. Mann-Whitney U. Pretest and post-test intergroup differences.

	Affect Hemibody		Healthy Hemibody		Mann-Wtihney U
	N	*Mid-Range*	*N*	*Mid-Range*	*p*
1RM unilateral pretest	24	22.94	22	24.11	0.763
Pre-test manual grip strength	24	22.44	22	24.66	0.571
Arm volume pre-test	24	24.25	22	22.68	0.692
Pre-test upper limb volume	24	24.33	22	22.59	0.660
1RM unilateral post	24	22.08	22	25.05	0.451
Post-test unilateral grip strength	24	22.65	22	22.33	0.934
Arm volume unilateral post-test	24	24.83	22	22.05	0.482
Unilateral upper limb volume post-test	24	24.46	22	22.45	0.613

In addition, intergroup comparisons were established to determine the existence of differences in the characteristics of body composition and maximum strength in chest press and bilateral chest contraction with respect to the presence or absence of lymphoedema (Tables 6 and 7). In this case, no significant differences were found in any of the variables, so it could be concluded that the presence of lymphoedema does not imply differences in body composition or bilateral maximum strength measurements.

Table 6. Mann-whitney U. Intergroup differences.

	Not lymphedema		Lymphedema		Mann-Wtihney U
	N	*Mid-range*	*N*	*Mid-range*	*p*
Fat mass percentaje	11	11.27	11	11.73	0.898

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Water percentaje	11	11.36	11	11.64	0.849

Table 7. T-test independent samples. Intergroup differences.

	Not lymphedema		Lymphedema		T Student Independent Test
	N	*Mid-Range*	*N*	*Mid-Range*	*p*
BMI	11	28.263	11	27.027	0.450
Wheight	11	73.400	11	68.245	0.340
Fat mass kg	11	28.691	11	25.682	0.459
Muscle mass	11	42.436	11	40.391	0.227
Lean mass	11	44.709	11	42.564	0.227
Chest fly press	11	25.978	11	26.391	0.854
Bilateral contraction chest	11	26.391	11	23.504	0.424

The number of people affected by lymphoedema was calculated, with a total of 5 people maintaining lymphoedema after the intervention (21.73%). Intra-group comparisons showed significant differences in unilateral pectoral strength of affected and healthy limbs, as well as in the grip of both arms. Differences in volume were not significant in the forearm, upper arm or whole upper limb. Differences in muscle mass and lean mass were significant, as were differences in fat mass and body water.

Finally, the differential scores of the variables with significant responses to treatment were analysed with respect to the affected or healthy hemibody. No significant differences were found in unilateral pectoral strength [U=.440, p=.660]; in grip strength [U= -.158, p=.875]; in muscle mass [t(44) =.205, p=.838]; or in lean mass [t(44) =.206, p=.838].

Table 8. T-test related samples. Intragroup comparison.

	Pre-test		Post-test		Student Related Samples Test
	M	**SD**	**M**	**SD**	**p**
Affected pectoral strength	25.514	8.060	27.310	7.813	0.009
Healthy forearm volume	663.198	110.935	691.917	97.116	0.092
Affected forearm volume	679.59	106.44	692.953	104.357	0.347
Muscle mass	41.617	3.932	40.217	4.316	0.002
Lean mass	43.852	4.129	42.378	4.543	0.002
Weight	71.143	12.170	71.178	12.159	0.861

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Table 9. Wilcoxon test. Intragroup comparison.

	Wilcoxon
	p
Healthy pectoral strength	0.003
Grip affect side	0.047
Grip healthy side	0.032
Affected arm volume	0.092
Healthy arm volume	0.115
Affected upper limb volume	0.209
Healthy upper limb volume	0.077
Water percentaje	0.291
Fat mass percentaje	0.267
Fat mass kg	0.322

4. Discussion

The present cross-sectional study aimed to analyse the body composition, volume and strength of 23 female breast cancer survivors, as well as their response to a ten-week strength training programme. In our results, the comparison of perimeters showed no significant differences between hemispheres. The same was true for forearm, upper arm and whole upper limb volume.

Likewise, following the diagnostic criteria, the analyses performed showed the presence of lymphoedema in 47.8% of the sample, however, this condition did not imply differences in terms of body composition or maximum strength in chest press or bilateral pectoral contraction.

The mean BMI of the participants was 27.72 kg/m2, with 12 of them being overweight. This is consistent with the findings of San Felipe et al. [37], who noted the high frequency of overweight and obesity in women breast cancer survivors, especially those undergoing chemotherapy. This factor, they note, worsens the prognosis of breast cancer, increasing the mortality rate. Albuquerque et al [38], ave also confirmed the high rate of obesity and overweight, as well as the correlation between this variable and the increase in pain experienced.

In contrast, other authors such as Schlesinger et al. [39], showed the obesity paradox, according to which a certain degree of overweight acts as a protector against mortality, although without going into the origin of the overweight, which could be due in these cases to a high muscle mass, with the lack of skeletal muscle being the cause of the complications. This is the assumption demonstrated by Caan et al [40] in their trial. In our study the mean muscle mass showed slight differences between people with lymphoedema and those without lymphoedema, although these differences were not significant.

Similarly, McClain et al. [41], corroborated how comprehensive analysis of body composition is critical in breast cancer, having found associations that fat mass and lean mass are associated to a greater degree than BMI with the metabolites under study. However, in our study lean mass and fat mass did not differ significantly between those with lymphoedema and those without.

After intervention, differences were found in muscle mass and lean mass, as opposed to fat mass and water percentage. Improvements were also found in the strength of both pectoral muscles, as well as in the grip of both hemibodies. Improvements were modest, possibly due to the brevity of the intervention, as well as being performed with whole body composition measurements, which may not be affected by partial training limited to specific muscle groups. However, those affected by lymphoedema were reduced from 11 (47.8%) to 5 (21.73), reflecting the remarkable effect of this training.

This is consistent with the findings of Fonnegra et al. [42], according to which strength and endurance intervention for at least six months generate positive effects on strength and body composition in breast cancer survivors. These interventions also lead to improvements in cardiorespiratory fitness and other physiological variables, which in turn lead to improved physical and psychological fitness in these individuals.

This study was limited by the small sample size and further expansion of the trial is recommended. Although comparisons were made between both hemibodies, it would be advisable to expand this field of research in the future with control groups, since body composition variables could not be controlled in the present study. Furthermore, it would be advisable to expand the available evidence on the influence of body composition on the development of lymphoedema and other specific complications, since the literature consulted is limited, on most occasions, to participants' weight and BMI, but not much evidence has been found regarding muscle, lean and fat mass, as well as other variables of interest, such as bone density. Consequently, future lines of research should consider the study of strength interventions in breast cancer survivors with large, controlled groups, and include variables such as bone density, cardiorespiratory capacity, and psychological and functional variables, since they determine, in turn, another of the fundamental variables to be taken into account: the quality of life of these people.

5. Conclusions

Individuals with lymphoedema accounted for half of the sample, corroborating the high incidence of this complication. Intergroup analyses showed no conclusive differences between people with and without lymphoedema, in terms of weight, BMI, lean, muscle and fat mass, as well as maximal pectoral strength in different measurements. However, after strength training, improvements in lean and muscle mass, as well as in pectoral and grip strength of both hemispheres were observed.

However, it is necessary to go deeper into this field, developing research with a larger sample size and control group to ensure whether or not there are associations that can help us to identify and treat these cases, in order to provide survivors with a better quality of life.

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Conflicts of Interest: The authors declare no conflict of interest.

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