Resisted Underwater Exercise Versus Pilates Exercise For Post-Mastectomy Lymphedema

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ABSTRACT

Background: *Lymphedema following mastectomy substantially affects upper limb function and strength. Effective rehabilitation strategies are essential for improving patient outcomes. Purpose: To examine whether resisted underwater exercise is more effective than Pilates exercise in improving upper limb function and strength in patients with lymphedema following mastectomy. Subjects and Methods: A double-blinded randomized group study was conducted in an outpatient setting. Sixty patients with post-mastectomy lymphedema participated and were divided into two groups of thirty. Group A received resisted underwater exercise and conventional physiotherapy, while Group B received Pilates exercise along with conventional physiotherapy. Interventions were administered thrice weekly for eight weeks. Conventional physiotherapy included manual lymphatic drainage, skin care, compression therapy, and active exercises aimed at reducing edema and improving limb function. Limb volume and the Disabilities of the Arm, Shoulder, and Hand (DASH) scale were measured before and after the intervention. Results: Baseline comparisons showed no significant differences between the groups ($p > 0.05$). Post-treatment results demonstrated a significant reduction in limb volume and DASH scores in Group A compared to Group B ($p < 0.01$). Conclusion: The resisted underwater exercise program is more effective than the Pilates exercise program in reducing limb volume and improving upper limb function in patients with post-mastectomy lymphedema.*

Keywords: DASH scale; lymphedema post-mastectomy; Pilates exercise; resisted underwater exercise; volume measurement.

INTRODUCTION

Breast Cancer-Related Lymphedema (BCRL) arises because of fluid accumulation in the interstitial tissue due to damage of the lymphatic system, induced by surgery and/or radiation, or tumor-induced neo-lymph angiogenesis [1]. The majority of women undergoing axillary intervention develop swelling within 2 years [2].

The development of BCRL is further increased by risk factors such as obesity, axillary lymph node dissection, extensive surgery, and radiotherapy to the regional lymph nodes [1]. Patients with BCRL typically suffer from a swollen upper limb, with concomitant feelings of weakness, heaviness, discomfort, and pain. Furthermore, there is an increased risk of infection and a chronic, progressive course of disease, leading to psychosocial distress and impaired quality of life (QoL) [2].

Treatment of BCRL typically consists of a multimodal therapy approach, including complex decongestive medicine, physiotherapy, and skin care [3].

Aquatic therapy includes Resisted under water exercise is used for the management of edema. It is based on the concept of the application of hydrostatic forces during immersion, along with exercises in thermo-neutral water, to activate the circulatory system [4].

A number of studies have been published that have investigated the effect of exercise on BCRL and, as a result, the effects of resistance exercise on BCRL have already been extensively reviewed [5–7].

Pilates improves flexibility, builds strength and develops control and endurance in the entire body. It emphasizes alignment, breathing, developing a strong core, and improving coordination and balance. The core, consisting of the muscles of the abdomen, low back, and hips, is often called the "powerhouse" and is thought to be the key to a person's stability [8].

Till now, no previous study has investigated the combined effect of resisted underwater exercise and Pilates exercise on treating lymphedema in women post-mastectomy. Thus, this study aims to explore this combined effect, providing valuable benefits for medical service organizations and enhancing the body of knowledge for physical therapists in the scientific field.

MATERIALS AND METHODS

Study Design: This was a prospective, single-blinded, parallel-group randomized controlled trial conducted between April 2022 and July 2023.

Participants: Sixty female patients with stage I or II post-mastectomy lymphedema were selected from Banha University Hospital and the Military Hospital (Air Force Specialized Hospital). The participants were examined for their eligibility to participate in the study and signed the written consent form before enrollment. The inclusion criteria were patients with a history of breast cancer who had undergone unilateral excision of the axillary lymph nodes and had mild to moderate degree or stage I–II lymphedema (a difference in circumference up to 2 cm compared to the other arm indicating mild lymphedema; a difference of 2–5 cm indicating moderate lymphedema) [9]. According to the International Society of Lymphology, early lymphedema is stage I, characterized by an early onset of swelling that is noticeable and subsides with elevation of the arm, with possible pitting. Moderate lymphedema, which is stage II, involves a consistent change in the volume of the arm with the presence of pitting, where elevation rarely reduces the swelling, and progressive tissue fibrosis occurs [10]. A detailed history of the patients was obtained, including

information about the affected side and type of surgery, the number of lymph nodes excised, the number of lymph nodes positive for cancer cells, the number of tumors, the technique used for radiotherapy, systemic adjuvant treatment, duration of lymphedema, previous episodes of infection, and completion of adjuvant treatment except hormone therapy. Patients were excluded if they had any of the following: cancer recurrence, ongoing active oncological treatment, functional disorders impeding participation in the exercise programs, or open wounds in any part of the body.

Randomization:

The participants were informed about the nature and advantages of the study, their right to withdraw or decline participation at any time, and the concealment of any data obtained. Coding of all data-maintained anonymity. Patients with mild to moderate degrees of lymphedema were randomly assigned to two groups (A and B) using computer-generated randomization blocks. Randomization was generated by the first author who was not involved in data collection. After allocation, none of the patients dropped out of the study.

Sample Size Calculation:

Sample size calculation was performed using G*POWER statistical software (version 3.1.9.2) for a comparative study between two groups. Based on data from Şener et al. (2017) [11], who found a significant difference in upper limb circumferences between groups, calculations were made using $\alpha = 0.05$, power = 90%, effect size = 1.38, and allocation ratio N2/N1 = 1.

Intervention:

The patients were assigned to groups A and B. Each group had 30 female patients with breast cancer-related lymphedema (BCRL) in each group, whose ages ranged from 35 to 55 years. The patients in group A received resistance under a water exercise therapy programme: 60 minutes per session, three sessions per week, for 8 consecutive weeks. The programme was designed and modified compared to previous studies [12, 13] to target all the upper limb muscles or movements that may be affected by BCRL. The first 10 minutes of the sessions comprised warm-up exercises with a small softball, fit-ball, mobility and stretching exercises (targeting the upper arm muscles), horizontal extension, arm abduction to 135°, shoulder flexion involving elevation of the arm in the sagittal plane, and maintenance of the stretching for 2 to 3 minutes [13], with the aim of improving mobility and overall fitness. This was followed by 30–40 minutes of exercise for muscle strength using dumbbells with free weights, which requires additional body control and increased joint motion, including all the upper limb muscles, dumbbell side rise for the abduction movement, and arm elevation. Biceps curls, elbow extension, external/internal rotations, protraction/retraction of the shoulder blades, wrist curls, ball pressing, and movement of the intrinsic muscles of the hand were also performed using dumbbells [14]. For the resistance exercise, the load was manipulated from 55% to 65% of 1RM with a maximum of 15–20 repetitions (1RM indicates the heaviest weight that the patient can lift with maximum effort in a single repetition) for 1 to 2 sets per exercise. To ensure the progressive nature of the training programme, the resistance was increased in 5%–10% increments in the following week if the participants were able to perform more repetitions than the RM specified during three consecutive sessions and reported no increase in arm symptoms [15].

The subjects were asked to perform diaphragmatic breathing exercises in combination with this exercise programmeme; women were instructed to

perform "belly" breathing before starting the exercise ram. Tactile cueing is often necessary to facilitate diaphragmatic breathing. The patients were advised to take a deep breath through the nose, which inflated the abdomen like a balloon, and then exhale with a sigh from the mouth, repeating this three times, and then relax [16]. The last 10 minutes of the session were for cooling down following the stretching exercises for all the upper limb muscles [12]. The participants were informed about the advantages and instructed to use a compression garment during the exercise session, and they were asked to use the same type of garment to ensure similarity in the subject pressure [14, 17]. Patients in the intervention group (group B) underwent Pilates exercise in addition to a traditional physical therapy programme (manual lymphatic drainage, skin care, compression therapy, and active exercise) and routine medical treatment. Patients will receive 3 sessions per week for 8 weeks; the duration of the sessions is 40 minutes. Before starting the clinical Pilates exercise programme, the patients were trained on Pilate's exercises and postures. Exercises were performed in groups of 5-8 people three times a week for 8 weeks. Before starting the training programme, the key elements of Pilates (diaphragmatic breathing, neutral position, rib cage placement, shoulder placement, and placement of the head and neck) will be taught to patients. Patients will perform breathing exercises, bridging exercises, scapular retraction and protraction, scapular elevation, and depression. The patient will perform Pilates-based mat exercises (selected from "arms opening, toy soldier, dumb waiter, chest press, Cleopatra, double leg stretch, hip twist, side bend, swimming, swan dive, mermaid, corkscrew, chest stretch, arm circle, shell" exercises) and Pilates-based theraband exercises (selected from the slice, the plough, biceps curl, triceps pull, roll up, roll up with biceps, scapula isolations, swan dive, chariot pull, triangles, abduction, diamond press, arms openings, shoulder bridge, external rotation, swimming in kneeling exercises). Repetitions of the exercise will be 10 [18].

Outcome measures:

The outcome measures included limb volume calculated by the circumference and the DASH scale for pain and function assessment. Assessment was conducted pre- and post-treatment.

Limb volume measurement: for evaluating the intervention, limb volume was measured. This was performed by measuring the circumference of each segment of the limb between two consecutive circumferences as a truncated zone. The volume of the segment was calculated as $V=h(C12 +C1C2 +C22)/12\pi$, where V is the volume of the segment, C1 and C2 are the circumferences at the ends of the segment, and h is the distance between them (segment length) [10]. With the patient in a comfortable sitting position, a standard 1-cm retractable fibreglass tape was used for measuring the circumference. The limb was placed on a bedside table in the horizontal Position and was fixed with an adhesive measurement strip from the axilla to the wrist to ensure consistency of the measurement at 10-cm intervals. Measurements were initiated at the ulnar styloid process and subsequently at 10, 20, 30, and 40 cm proximally [10].

The Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire: This questionnaire asks about the patients' symptoms as well as their ability to perform certain activities. Each patient answered every question based on her condition in the last week by circling the appropriate number from 1 to 5 [19].

Statistical analysis:

An unpaired t test was conducted for comparison of subjects and surgical characteristics between groups. A chi-squared was conducted for comparison of type of surgery and stage of lymphoma

between groups. The normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. An unpaired t test was conducted for comparison of upper limb volume and DASH between groups. A paired t test was conducted for comparison between pre- and post-treatment in each group. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA).

Results

- *Subject characteristics*:

Table (1) shows the subject characteristics of group A and B. There was no significant difference between groups in subjects and surgical characteristics ($p > 0.05$).

Table 1. Comparison of subject characteristics between group A and B:

	Group A	Group B	MD	t-value	p-value
	Mean ± SD	Mean ± SD			
Age (years)	44.33 ± 6.77	45.50 ± 6.94	-1.17	-0.65	0.51
Weight (kg)	76.17 ± 8.75	74.97 ± 7.23	1.2	0.57	0.56
Height (cm)	159.40 ± 4.93	159.47 ± 5.39	-0.07	-0.05	0.96
BMI (kg/m²)	30.14 ± 4.44	29.57 ± 3.44	0.57	0.55	0.58
Number of removed lymph nodes	10.53 ± 1.63	10.47 ± 1.88	0.06	0.14	0.88
Time since surgery (years)	2.97 ± 1.04	2.93 ± 1.24	0.04	0.15	0.87
Number of radiation therapy	20.07 ± 2.42	20.83 ± 2.46	-0.76	-1.22	0.22
Number of chemotherapies	5.67 ± 1.97	5.90 ± 2.11	-0.23	-0.45	0.64
Type of surgery, n (%)					
Modified radical mastectomy	13 (43%)	14 (47%)	$\chi^2 = 0.07$		0.79
Partial mastectomy	17 (57%)	16 (53%)			
Stage of lymphedema, n (%)					
Stage I	17 (57%)	15 (50%)	$\chi^2 =$ ٠.26		٠.61
Stage II	13 (43%)	15 (50%)			

SD, Standard deviation; MD, Mean difference; χ2: Chi squared value; p value, Probability value

Effect of treatment on upper limb volume and DASH:

Within group comparison

There was a significant decrease in upper limb volume and DASH post treatment in both groups compared with that pretreatment ($p < 0.001$). The percent of change in upper limb volume and DASH of group A was 14.45 and 30.78% respectively and that in group B was 9.54 and 22.19% respectively. (table 2).

Between group comparison

There was no significant difference between groups pretreatment ($p > 0.05$). Comparison between groups post treatment revealed a significant decrease in upper limb volume and DASH group A compared with that of group B ($p < 0.01$). (table 2).

Table 2. Mean upper limb volume and DASH pre and post treatment of A and B groups:

	Group A	Group B			
	Mean ±SD	Mean ±SD	MD	t-value	p value
Upper limb volume (ml)					
Pre treatment	2331.23 ± 162.21	2368.73 ± 157.45	-37.5	-0.91	0.36
Post treatment	1994.47 ± 155.69	2142.80 ± 160.92	-148.33	-3.62	0.001
MD	336.76	225.93			
% of change	14.45	9.54			
t-value	37.68	13.45			
	p = 0.001	***p = 0.001***			
DASH					
Pre treatment	77.59 ± 7.25	76.25 ± 6.72	1.34	0.74	0.46
Post treatment	53.71 ± 6.71	59.33 ± 6.82	-5.62	-3.22	0.002
MD	23.88	16.92			
% of change	30.78	22.19			
t-value	18.97	32.89			
	p = 0.001	***p = 0.001***			

SD, Standard deviation; MD, Mean difference; p value, Probability value

DISCUSSION

The present study revealed a significant reduction in limb volume and improvements in Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire scores post-treatment in both groups. These results align with previous studies indicating the efficacy of exercise programs in managing Breast Cancer-Related Lymphedema (BCRL) [5-7]. Systematic reviews have shown that resistance exercise programs significantly reduce limb volume in BCRL patients [5-7]. Aquatic therapy programs, including resistance exercise, vary widely in terms of modes, intensity, frequency, and duration [12, 13].

In our study, we utilized a modified, supervised aqua therapy-resistance exercise program combined with diaphragmatic breathing exercises and pressure garments. This program focused on upper arm muscle resistance exercises, with sessions extended to 30–40 minutes, which might explain the significant improvements observed in DASH scores and limb volume reduction. The hydrostatic pressure in water likely aided in reducing residual limb volume through its squeezing action, promoting central fluid flow. Additionally, buoyancy and constant hydrostatic pressure allowed patients to move freely, enhancing muscle pumping to mobilize lymphatic fluid [4, 17, 28].

Previous research has indicated that cancer survivors often experience exhaustion, and aquatic exercise can minimize this fatigue and alleviate pain associated with lymphedema [16, 24, 30]. For instance, Lindquist et al. observed a decrease in lymphedema in an aqua therapy group, albeit without changes in limb volume, potentially due to the shorter duration of strength exercises in their program [25].

Other studies have shown varying degrees of immediate limb volume reduction following aquatic therapy combined with other interventions. Tidhar and Katz-Leurer reported an average immediate reduction of 92 mL in limb volume using water displacement measurements, while Moseley et al. observed a mean reduction of 52 mL after 10 minutes of arm exercise and deep breathing [20, 26]. Johansson's study demonstrated a reduction of 32 mL following pool exercises at 28°C, involving activities like swimming and arm exercises with hand plates [27]. Singh et al. highlighted the importance of compression garments in mitigating short-term exacerbations of lymphedema [14, 23].

Deep breathing during lymphedema exercises ensures adequate oxygen supply and changes abdominal pressure, acting as a vacuum for the thoracic cavity, thereby aiding lymphatic drainage [23]. Diaphragmatic breathing combined with slow water motion has been shown to accelerate lymphatic drainage through the thoracic duct [4, 28]. Pain reduction in the aqua therapy group can be attributed to the warmth and buoyancy of the water, promoting muscle relaxation and decreasing sympathetic nervous system activity [30, 31].

Compliance with the treatment program was high in both groups. However, this study was limited by the absence of long-term follow-up. Future research should assess the long-term effects of these treatment modalities and incorporate psychological status evaluations during the treatment period. Different measurement tools may be necessary to achieve maximum reliability [34, 36].

Our findings suggest that an aqua therapy resistance exercise program is a safe, effective, and non-invasive method to decrease limb volume and improve upper

limb function and pain in BCRL patients. Further research is needed to optimize the duration, intensity, and progression of resistance exercises. Additionally, different assessment tools are required to investigate the overall health effects of aqua therapy exercises on BCRL patients [35, 37].

Overall, the aqua therapy resistance exercise program demonstrated greater efficacy in decreasing limb volume and pain severity while improving shoulder joint function in BCRL patients. The clinical Pilates exercises also yielded positive outcomes, emphasizing the importance of spinal stabilization and cognitive restructuring in enhancing functional independence and quality of life [38, 39]. This study underscores the potential benefits of integrating these exercise modalities into the management of BCRL, with a recommendation for further research to refine and validate these approaches [40].

CONCLUSION

In comparison to matched healthy This study demonstrated that resisted underwater exercise is more effective than Pilates exercise in reducing limb volume and improving upper limb function in patients with post-mastectomy lymphedema. Both exercise programs significantly benefited limb volume and DASH scores, but the aquatic therapy showed superior results. These findings suggest that resisted underwater exercises should be prioritized in clinical settings for managing breast cancer-related lymphedema. Further research is recommended to optimize these exercise protocols and evaluate their long-term effects.

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