Asia-Pacific Journal of Oncology Nursing 12 (2025) 100756

Contents lists available at ScienceDirect

Asia-Pacific Journal of Oncology Nursing

journal homepage: www.apjon.org

Original Article

Effects of resistance exercise on reducing the risk of lower-limb lymphedema after gynecological cancer surgery

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ARTICLE INFO

Keywords:
Gynecological cancer
Lymphedema
Quality of life
Resistance exercise
Self-management

ABSTRACT

Objective: To compare the effectiveness of resistance and non-resistance exercises on limb circumference, self-management of lymphedema, and quality of life among patients after gynecological cancer surgery.
Methods: A randomized controlled design enrolled 60 patients with gynecological cancer in either the elastic-band resistance or non-resistance exercise groups after surgery. Outcomes were evaluated at three-time points: T0 (baseline, before interventions), T1 (one week after the completion of interventions), and T2 (three months after the interventions).
Results: No group effect over time was observed for lymphedema, lymphedema self-management, and quality of life (QoL). However, both exercise groups exhibited significant improvements in physical function ($\beta = 0.79$), role function ($\beta = 0.63$), and global health status ($\beta = 1.35$) related to cancer quality of life from T0 to T1 and from T0 to T2 ($\beta = 0.69$, 0.65, and 1.43; respectively). No significant differences were observed in the lymphedema-related quality of life or limb circumference between the two groups. However, significant time effects were observed for lymphedema self-management from T0 to T1 ($\beta = 1.11$) and T0 to T2 ($\beta = 1.09$).
Conclusions: Compared to non-resistance exercise, resistance exercise was not different in reducing the risk of lower limb lymphedema or improving quality of life within the initial three months following gynecological cancer surgery. Both types of exercise can be seamlessly integrated into a woman's daily activities to reduce the risk of lower limb lymphedema after surgery. Lower limb resistance exercises do not exacerbate the adverse effects of lymphedema.
Trial registration: Registered on ClinicalTrials.gov (NCT05666947).

Introduction

Lymphadenectomy, dissection of lymph nodes, has been included during surgery for gynecological malignancies (e.g., endometrial, ovarian, cervical, and vulvar cancers) at various cancer stages.[1] Evidence has shown that lymphadenectomy is associated with higher complications and mortality, such as longer operative time, increased blood loss, the need for intensive care, and increased risk of lower limb lymphedema.[2] Radiation therapy for gynecological malignancies can also lead to lymphedema.[3] After surgery or radiation therapy for gynecological cancer, the incidence of lower limb lymphedema has ranged from 11% to 38%.[3,4]

Lymphedema is typically manifested within the one year following surgical treatment with lymphadenectomy.[4,5] However, some women developed initial symptoms of lower limb lymphedema, such as leg swelling, immediately after gynecological cancer surgery.[5–7] In some cases, the symptoms and signs of lymphedema may not be recognized early due to a lack of awareness and self-management. Delayed detection leads to delayed treatment and inadequate referrals. Patients with lower limb lymphedema are more likely to limit their daily activities and become inactive, which can lead to psychological and social issues.[8] Inactivity reduces muscle movement, alters gait patterns, and may weaken muscles.[9] Research has indicated that lower limb lymphedema is associated with declined mobility, depression, sleep disturbance,

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https://doi.org/10.1016/j.apjon.2025.100756
Received 18 March 2025; Accepted 8 July 2025
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fatigue, and negative body image.[10] When lower limb lymphedema is not managed or treated appropriately, it can worsen or lead to lower limb infection.[3] Many patients complain of not being informed about the risk of lymphedema, which leads to delays in seeking treatment and information.[11,12]

Evidence-based studies have emphasized the reduction of the risk of lymphedema after cancer surgery with lymphadenectomy.[13] Although lymphedema cannot be cured, it can be reduced by early intervention or early detection of lymphedema, which can improve the patient's quality of life.[14]

To reduce the risk of lymphedema, women with gynecological cancer requiring lymphadenectomy are typically advised to undergo complete decongestive physiotherapy, which includes manual lymphatic drainage (MLD), compression therapy, skin care, and extremity exercise. However, MLD and compression are typically used for reducing the limb swelling due to lymphedema, not used prophylactically,[15] are also considered a component of decongestive physiotherapy. Extremity exercises have the pumping effect of skeletal muscles to improve circulation and lymphatic flow.[16] Muscular strength in the legs is an effective indicator of physical function after exercise.[17] Evidence-based research has well documented the benefits of exercise in reducing limb volume and managing lymphedema, with moderate-intensity exercise being recommended.[18,19] Previous studies have highlighted the effect of non-resistance exercises on the quality of life in patients with gynecological or breast cancer, encompassing physical, emotional, social, and functional well-being measures.[20,21]

In contrast to non-resistance exercise, resistance exercise has been recommended for the reduction or treatment of lymphedema. Progressive resistance exercise promotes strength gains through a neuromuscular mechanism and encompasses muscle fiber hypertrophy.[22] However, most studies have primarily focused on the upper limbs in women with breast cancer, with limited emphasis on lower limb lymphedema.[20,23] One pilot study demonstrated that progressive resistance exercise training is both safe and feasible for patients to reduce the risk of lower limb lymphedema after cervical cancer surgery.[17] However, only a few studies have investigated the effects of resistance exercise on reducing the risk of lower limb lymphedema, but the resistance exercise is a hospital-based intervention.[24]

Notably, lower limb lymphedema may develop immediately after gynecological cancer surgery.[5,7] Women diagnosed with gynecological cancer often express unmet needs for information on detection and reduction of the risk of lymphedema.[12,25] To address the inconvenience of frequent hospital visits for complete decongestive physiotherapy, many women choose home-based exercises or lymphatic drainage as alternative approaches.[12] From a symptom management perspective, health care should of prioritize reducing the risk lower limb lymphedema. However, there is a lack of empirical research on home-based resistance exercises specifically targeting the lower extremities to reduce the risk of lymphedema in postoperative gynecological cancer patients. To address the gaps, a randomized controlled trial was introduced to evaluate the effectiveness of resistance exercise in reducing the risk of lower limb lymphedema following gynecological cancer surgery.

This study aimed to compare the effects of resistance and non-resistance exercises in reducing the risk of lower-limb lymphedema, increasing self-management, and improving quality of life in women following gynecological cancer surgery.

Methods

Study design

A single-blind, randomized controlled design was employed with three-time points: T0 (baseline, one week after surgery), T1 (one week after intervention completion), and T2 (three months after intervention completion). In this single-blind study, data analyst did not know the participants' group allocation when they implemented data analyses.

Participants and setting

Participants were recruited from the gynecological ward of a medical center in southern Taiwan. Inclusion criteria included women over 20 years old who required gynecological cancer surgery involving a possible lymphadenectomy. Exclusion criteria included a history of abscess or infection in the legs, cardiovascular accidents, heart failure, renal failure, or psychological disorders.

Sample size estimation

G-power software (version 3.1.9.4) was utilized to estimate the sample size for the study. The primary outcome, quality of life, specifically the physical function parameter, was the reference for calculating effect size. An effect size of 0.25 was derived from a previous study by Cormie et al., which examined the impact of resistance exercise on physical function in 62 women with breast cancer-related lymphedema.[23] Sample size estimation was employed by ANOVA with a repeated measure, within–between interaction, using the F-test family. The parameters for the sample size calculation included a significance level (α) of 0.05, an effect size of 0.25,[23] a desired statistical power of 0.80, two groups, three measurement time points, and a nonsphericity correction ε of 0.50. Based on these parameters, the required total sample size was 44 participants. To account for an anticipated 20% dropout rate over time, the minimum required sample size was adjusted to 55 participants (44/0.80), or approximately 27 participants per group. However, the study ultimately included 30 participants in each group to enhance the robustness of the study and ensure sufficient power in the event of participant attrition.

Randomization and blinding

Eligible participants were randomly assigned to either the experimental or control group using block randomization with a 1:1 allocation ratio. A block size of four was used, generating six possible allocation sequences to equally distribute the participants into the two groups. The random allocation sequence was generated by a research staff member who was not involved in data collection or intervention. Each participant's group assignment, along with a sequential identification number, was placed in a sealed, opaque envelope. Following the order of these sealed envelopes, participants were randomly allocated to one of the two groups after completing the baseline assessment during data collection period.

In the current study, a total of 64 participants were randomly assigned, with 32 allocated to the experimental group and 32 to the control group. The experimental group participated in an eight-week home-based program featuring an elastic-band resistance exercise regimen, while the control group followed a conventional home-based program involving non-resistance exercises for the same duration. Due to the intrinsic nature of the exercise interventions, the blinding of participants, intervention providers, and outcome evaluators was not feasible; however, the data analyst was blinded to group allocation. The randomization process is illustrated in the Consolidated Standards of Reporting Trials (CONSORT) flow diagram,[26] presented in Fig. 1.

Interventions

The exercise programs, including resistance and non-resistance, were progressively advanced to the next exercise session every two weeks. Resistance gradually increased by transitioning from low to medium-resistance elastic bands, while non-resistance exercises were intensified by increasing their complexity and duration.

Home-based resistance exercise

The experimental group participated in an eight-week home-based exercise program (Table 1) using an elastic band for resistance exercise.

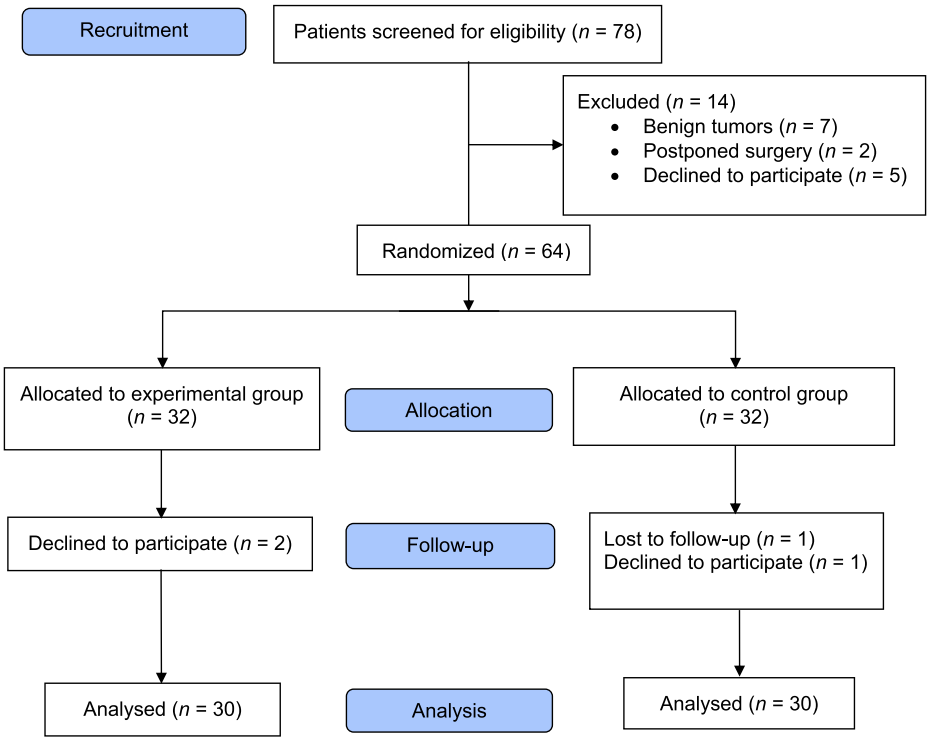

Fig. 1. Flow diagram for participants.

The exercise intervention program, developed by the investigators, was derived from a study by Cormie et al.[23] The use of elastic-band resistance aimed to simultaneously enhance muscle strength in both upper and lower limbs, and promote blood circulation to support lymphatic reflux.

The home-based exercise program was instructed into four progressive stages: warm-up, start-up, vigorous, and reinforcement (Table 1). The warm-up stage was introduced to the participants at bedsides during the first week of post-surgery. The subsequent three stages were introduced to participants during their outpatient visit. For example, non-resistance upper and lower limb exercises included in the warm-up stage were initiated at the bedside in the first week after surgery. They were instructed to continue daily warm-up exercise for the next two weeks. In the third postoperative week, during an outpatient visit, participants received training in the start-up stage, which included resistance exercises using low-resistance elastic bands targeting both upper and lower limbs. The vigorous stage, scheduled for weeks 4–6, involved exercises with low-to-medium resistance bands. Finally, the reinforcement stage, from weeks 6–8, introduced medium-resistance elastic bands to participants for further strengthening limb function. A printed exercise booklet containing the four progression stages of exercise and an instructional video were introduced to the participants across the eight-week periods.

Non-resistance exercise

The control group participated in a conventional non-resistance exercise program over an eight-week period, structured into four progressive stages: warm-up, start-up, vigorous, and reinforcement. Participants advanced to the next stage every two weeks and completed the full program within eight weeks. The program targeted both upper and lower limb mobility and strength using non-resistance movements. Within one week after surgery, the participants received individualized one-on-one training from a trained research assistant on non-resistance upper and lower limb exercises. In addition to in-person instruction, participants in the control group received guidelines from a booklet and a video about conventional non-resistance exercises.

Table 1
Resistance exercise program.

Stages	Warm-up	Start-up	Vigorous	Reinforcement
Time	1–2 weeks after surgery	3–4 weeks after surgery	5–6 weeks after surgery	7–8 weeks after surgery
Exercise strength	No resistance	Low resistance	Low–medium resistance	Medium resistance
Plastic band	No plastic band	Plastic band (Yellow)	Plastic band (Yellow)	Plastic band (blue)

Adherence to exercise

To ensure comprehension and proper skills, participants were asked to demonstrate each exercise during the instructional session. The research assistants provided real-time feedback and corrections, emphasizing elements such as proper body posture, controlled breathing, and safe movement patterns. Both groups of participants were encouraged to perform the resistance or exercise at least 20–30 minutes/per day throughout different stages of the exercise program.

Each participant received a home exercise log sheet to record the date, duration, and any perceived discomfort following each session. Instant messaging was also used to maintain communication with participants and support adherence to the exercise regimens. When the diary log indicated unsatisfactory adherence at every outpatient visiting, communication with patients was initialized to understand patient's concerns, identify barriers to participants, and offer tailored support to encourage continued engagement.

Instruments

Primary outcomes

The primary study outcomes included assessments of lymphedema-related quality of life, cancer-related quality of life, and change in limb circumference.

Lymphoedema Functioning, Disability, and Health Questionnaire for Lower Limb Lymphoedema (Lymph–ICF–LL scale).

The Chinese version of the Lymph–ICF–LL assessed the quality of life related to lower-limb lymphedema.[27] The scale comprises 28 items across five domains: physical function (6 items), mental function (6 items), general tasks/household (3 items), mobility (7 items), and life/social life (6 items). Participants rated responses on an 11-point scale (ranging from 0 = no problem to 10 = very serious). For items deemed unsuitable for the respondent, a 'non-applicable' option is provided for nine items if a given complaint is unsuitable. The total score of the scale and each domain is computed by dividing item totals by item responses. A higher score indicates a lower quality of life related to lower limb lymphedema, with scores ranging from 0 to 100.

The psychometric properties of the Chinese version of Lymph–ICF–LL were assessed in Taiwanese women who had undergone gynecological cancer surgery.[27] The Lymph–ICF–LL-C demonstrated acceptable internal consistency (Cronbach's alpha $\geq$ 0.84) and test-retest reliability (intraclass correlation coefficient: 0.55–0.90). Concurrent validity was supported by a significant correlation between the measurement and the bilateral difference in lower limb circumference ($r = 0.24$–0.36), as well as with a fatigue scale ($r = 0.46$).[27] In the current study, Cronbach's alpha for the five subscales ranged from 0.85 to 0.98, with a value of 0.98 for the total scale. A higher score indicates a lower quality of life related to lower limb lymphedema, ranging from 0 to 100.

European organization for the research and treatment of cancer quality of life questionnaire (EORTC QLQ-C30). The EORTC QLQ-C30 Version 3 was employed to assess the quality of life related to cancer.[28] The questionnaire comprises 30 questions, including five functional items (i.e., physical, role, emotional, cognitive, and social function), nine symptom items, and a single item on global health status. Each question, except for the global health status, is rated on a scale of 1 (not at all) to 4 (very much). The global health status is rated on a scale from 1 (very poor) to seven (excellent).[28] The Taiwanese version of the EORTC QLQ-C30 has demonstrated favorable psychometric properties. Test-retest reliability ranged from 0.46 to 0.85, and Cronbach's alpha was $\geq$ 0.70.[29] In this study, the Cronbach's alpha for the EORTC QLQ-C30 was 0.80.

Limb circumference measurements (LCM). Bilateral LCM measurements assessed lymphedema status. In this study, bilateral lower leg circumferences were measured using a tape measure at six anatomical points: 10 cm above the patella, 20 cm above the patella, peroneus longus, metatarsophalangeal joint, femoral epicondyle, and ankle.[30] Calculating the absolute value (ABS) of the relative circumference difference between the bilateral lower limbs involves the formula (Right circumference – Left circumference)/the smallest circumference of the bilateral limbs. The presence of lower limb lymphedema is indicated by a difference of $\geq$ 7% in the relative circumference between bilateral measurements.[30]

The intraclass correlation coefficients of the LCM for inter- and intra-rater reliability have been reported as 0.96–0.99 and 0.98–1.0, respectively.[30] The intra-rater reliability for LCM in the study was satisfactory, with an r value of 0.98.

Secondary outcomes

Lymph self-management. The Lymph Self–management Scale, developed by the primary researcher (YYH), assessed participants' lymphedema self-management over the past two weeks. The self-reported questionnaire consists of 20 questions, covering aspects such as self-examination for limb edema, wearing comfortable shoes, consuming protein-rich foods, avoiding spicy or caffeinated foods, engaging in regular exercise, avoiding prolonged periods of standing or sitting, protecting the skin, and maintaining a healthy weight. Each question is rated on a scale of 1 (never) to 5 (always). Total scores range from 20 to 100, with a higher score indicating better lymph self-management. Five experts in gynecological cancer or lymph disorders evaluated the questionnaire's content to ensure that each item appropriately measured the intended construct. The internal consistency of the scale was assessed, yielding a Cronbach's alpha of 0.70, which confirms acceptable reliability.

Demographic information

A self-reported demographic questionnaire gathered data regarding participants' age, education level, occupation, religion, and marital status. Information about cancer diagnosis, adjunct cancer therapies, and chronic diseases was retrieved from medical records after obtaining informed consent from the participants and before allocation group assignment.

Data collection

Research assistants approached potential participants while they were awaiting cancer surgery in the gynecological wards, providing information about the study's purpose and procedures. After surgery, those who met the inclusion criteria were invited to participate and provided written informed consent. Baseline data were collected before the intervention. Participants were then randomly assigned to either the experimental or control group.

Both groups were instructed to perform the home-based exercise program at least once per day and to record their exercise time in a notebook. Outcome measures were assessed at three time points: baseline (T0), post-intervention (T1), and follow-up (T2). For T1 and T2 assessments, research assistants collected data during the participants' visits to the outpatient department.

To enhance adherence to the home-based exercise program, research assistants connected participants through a desktop application or phone calls. Data collection was conducted between January 2017 and December 2019.

Data analysis

Data were managed and analyzed using SPSS version 26. Descriptive statistics were applied to summarize the participants' characteristics and study outcomes. Demographic data and baseline outcome variables were compared using Chi-square tests, Fisher's exact test, or Mann–Whitney *U*-tests.

For assessing changes in primary and secondary outcome variables, generalized estimating equations (GEE) were used to evaluate the effects of time, group, and the interaction between group and time. A significance level of $P < 0.05$ was used.

Ethical considerations

This study was conducted after obtaining approval from the Research Ethics Review Committee of the National Cheng Kung University Hospital (Approval No. B-ER-105-444). All participants provided written informed consent. Participants were provided with information regarding the study's purpose and procedures. They were entirely voluntary and could withdraw from the study without adversely impacting their care or treatment. Patients signed informed consent was obtained from patients who expressed willingness to participate in the study.

Results

Participants' characteristics and outcomes at baseline

Before gynecological cancer surgery, 78 women were approached, and 14 were subsequently excluded from the study after surgery. Of the excluded women, seven revealed benign tumors, two had postponed

surgery, and five women expressed a lack of interest. Sixty-four women were recruited and randomly assigned, with 32 in the experimental group and 32 in the control group. During the intervention, three participants withdrew from the study, and one was lost to follow-up, resulting in 60 subjects contributing study data, with an overall attrition rate of 3.2% (Fig. 1).

The mean age of the participants was 54.0 ± 9.2 years in the experimental group and 52.1 ± 8.4 years in the control group. The majority of participants were married (71.7%). The most prevalent cancer type was endometrial cancer (61.7%), and 66.7% of the women had no comorbid or chronic diseases. The majority of participants underwent lymphadenectomy (93.3%), and 6.7% underwent lymph node sampling. The most common locations of lymphadenectomy were the combination of the pelvic and para-aortic regions (n = 35, 58.3%). The number of lymph nodes removed was 16.7 ± 9.9 in the experimental group and 16.6 ± 8.1 in the control group. After surgery, 30.0% of the women underwent chemotherapy, with 12% receiving radiotherapy. Baseline assessments indicated no lymphedema in either group, as determined by bilateral lower LCM. There were no discernible differences between the two groups on the Lymph–ICF–LL scale, the Lymph management scale, or the EORTC QLQ-C30 scores (Table 2).

Table 2
Baseline demographic data, clinical characteristics, and outcomes (N = 60).

Variables	All (n = 60)	Experimental group (n = 30)	Control group (n = 30)	U[d]	χ^2	P
Age (yrs) (mean ± SD)	53.03 ± 8.78	54.00 ± 9.20	52.07 ± 8.39	−1.00		0.31
Education level, *n* (%)					0.43[e]	0.81
Elementary/Junior	16 (26.7)	7 (23.3)	9 (30.0)			
High/Senior school	22 (36.7)	12 (40.0)	10 (33.3)			
University/Graduate	22 (36.7)	11 (36.7)	11 (36.7)			
Occupation, *n* (%)					1.07[e]	0.30
Yes	28 (46.7)	16 (53.3)	12 (40.0)			
No	32 (53.3)	14 (46.7)	18 (60.0)			
Marital status, *n* (%)					1.03[e]	0.60
Unmarried	11 (18.3)	4 (13.3)	7 (23.3)			
Married	43 (71.7)	23 (76.7)	20 (66.7)			
Divorced	6 (10.0)	3 (10.0)	3 (10.0)			
Chronic disease, *n* (%)					0.3[e]	0.58
Yes	20 (33.3)	11 (36.7)	9 (30.0)			
No	40 (66.7)	19 (63.3)	21 (70.0)			
Diagnosis, *n* (%)					1.97[e]	0.74
Cervical cancer	11 (18.3)	7 (23.3)	4 (13.3)			
Ovarian cancer	7 (11.7)	4 (13.3)	3 (10.0)			
Endometrial cancer	37 (61.7)	16 (53.3)	21 (70.0)			
Vulva cancer	2 (3.3)	1 (3.3)	1 (3.3)			
Other	3 (5.0)	2 (6.7)	1 (3.3)			
Chemotherapy, *n* (%)					0.32[e]	0.57
Yes	18 (30.0)	8 (26.7)	10 (33.3)			
No	42 (70.0)	22 (73.3)	20 (66.7)			
Radiotherapy, *n* (%)					0.16[e]	1.00
Yes	7 (11.7)	4 (13.3)	3 (10.0)			
No	53 (88.3)	26 (86.7)	27 (90.0)			
Dissection location, *n* (%)					3.79	0.20
Pelvis (two sides)	21 (35.0)	14 (46.7)	7 (23.3)			
Pelvis + para-aortic	35 (58.3)	14 (46.7)	21 (70.0)			
Others (sampling)	4 (6.7)	2 (6.7)	2 (6.7)			
Lymph node metastatic, *n* (%)					0.48[e]	0.49
Yes	10 (16.7)	4 (13.3)	6 (20.0)			
No	50 (83.3)	26 (86.7)	24 (80.0)			
No. of nodes dissected (mean ± SD) (range)	16.70 ± 9.02 (0–39)	16.73 ± 9.97 (0–39)	16.67 ± 8.13 (0–33)	−0.29[a]		0.77
Total ICF[a] (mean ± SD)	9.76 ± 12.12	10.54 ± 14.27	8.98 ± 9.68	−0.02		0.99
Physical	4.94 ± 11.56	5.61 ± 14.41	4.28 ± 7.96	−0.04		0.97
Mental	7.72 ± 18.27	6.44 ± 13.89	9.00 ± 21.97	−0.47		0.64
Household	7.67 ± 15.35	9.56 ± 19.11	5.78 ± 10.32	−0.83		0.41
Mobility	20.16 ± 3.02	22.06 ± 26.39	18.26 ± 19.36	−0.18		0.86
Social	8.31 ± 13.80	9.03 ± 14.50	7.58 ± 13.27	−0.19		0.85
LCM[b] > 7%, *n* (%)	0	0	0		–	–
Lympho-management (mean ± SD)	64.52 ± 8.47	65.57 ± 7.90	63.47 ± 9.01	−1.27		0.21
EORTC[c] (mean ± SD)						
Physical	10.13 ± 4.27	10.43 ± 4.01	9.83 ± 4.56	−0.18		0.86
Role	4.53 ± 2.17	4.70 ± 2.05	4.37 ± 2.31	−0.67		0.50
Emotion	6.48 ± 2.33	6.53 ± 2.36	6.43 ± 2.34	−0.16		0.87
Cognitive	3.22 ± 1.18	3.17 ± 1.12	3.27 ± 1.26	−0.17		0.87
Social	3.75 ± 1.50	3.77 ± 1.50	3.73 ± 1.53	−0.07		0.95
Global health	7.47 ± 2.78	7.63 ± 2.82	7.30 ± 2.77	−0.62		0.54

SD, standard deviation; IQR, interquartile range.
[a] ICF: lymphoedema functioning, disability and health questionnaire for lower limb lymphoedema.
[b] LCM: limb circumference difference > 7% between the bilateral lower limbs.
[c] EORTC: European organization for the research and treatment of cancer quality of life questionnaire.
[d] Mann–Whitney U-test.
[e] Fisher's Exact Test.

Changes in quality of life and limb circumference

No significant group effect over time (group × time) was observed for outcome variables of quality of life related to cancer (EORTC QOL-C30), quality of life related to lymphedema (Lymph–ICF–LL), or limb circumference. Also, no differences in group effects between the experimental and control groups were found regarding the quality of life related to lymphedema, quality of life related to cancer, or limb circumference (Table 3). However, Quality of Life related to Cancer (EORTC QOL-30) showed statistically significant differences over time (time effect). The time effects presented in physical function from T0 to T1 ($\beta = 0.79$, 95% CI [0.67–0.93], $P = 0.005$) and from T0 to T2 ($\beta = 0.69$, 95% CI [0.57, 0.83], $P < 0.001$), as well as in role function from T0 to T1 ($\beta = 0.63$, 95% CI [0.51–0.77], $P < 0.001$) and from T0 to T2 ($\beta = 0.65$, 95% CI [0.50–0.85], $P = 0.002$). The declines suggested an improvement in the quality of life related to cancer over time. Both groups demonstrated statistically significant increases in global health status scores related to cancer quality of life (EORTC-GHS) from T0 to T1 ($\beta = 1.35$, 95% CI [1.15–1.58], $P < 0.001$) as well as from T0 and T2 ($\beta = 1.43$, 95% CI [1.19–1.71], $P < 0.001$) (Fig. 2).

No significant differences were observed in lymphedema status based on measures such as limb circumference and the Lymph–ICF–LL scale (Fig. 3). Lymphedema in the lower limbs was considered present if the relative difference between bilateral measurements of lower limb circumference was equal to or greater than 7%. At T1, lymphedema was present in two women (3.3%) of the participants, with one in the experimental group and one in the control group. Similarly, at T2, the prevalence of lymphedema remained the same in these women.

Changes in lymphedema management

In terms of lymphedema self-management, no significant group effect over time was observed for the lymphedema management outcomes. However, both groups exhibited a significant time effect on lymphedema management, showing improvement from T0 to T1 ($\beta = 1.11$, 95% CI [1.05–1.18]) and from T0 to T2 ($\beta = 1.09$, 95% CI [1.03–1.18], $P = 0.003$).

Adherence to the exercise programs

In the experimental group, participants engaged in resistance exercises for an average of 65.4 sessions (SD = 27.3, range = 21–112), accumulating a mean total of 829.3 exercise minutes (SD = 614.8, range = 200–2600 minutes). This corresponds to an average of 5.5 sessions per week (SD = 2.3; range = 1.8–9.3) over the 12-week intervention period. In comparison, participants in the control group performed non-resistance exercises for an average of 86.2 sessions (SD = 52.8, range = 20–254), accumulating with a mean total of 928.4 exercise minutes (SD = 691.0, range = 200–3360). This equates to an average of 7.2 sessions per week (SD = 3.58, range = 1.7–21.1) over 12 weeks. Additionally, exercise time per session was calculated by dividing the total accumulated exercise time by the number of exercise sessions completed. The mean exercise time per session was 12.2 minutes (SD = 6.3) in the experimental group and 11.4 minutes (SD = 6.5) in the control group. No significant differences were found between the groups in terms of exercise adherence, including the number of exercise sessions, exercise time per session, frequency of exercise per week, and total accumulated exercise time.

Table 3
Generalized estimating equation model for the comparison of outcome variables between groups across the study period.

Outcome variable	Control group	Experimental group	Time effect		Group effect		Group*time effect	
			B (95% CI)	*P*	B (95% CI)	*P*	B (95% CI)	*P*
EORTC–Physical [mean (SD)]					1.06 (0.86, 1.31)	0.58		
T0	9.83 (4.56)	10.43 (4.01)						
T1	7.77 (2.73)	8.20 (3.52)	0.79 (0.67, 0.93)	**0.005**			1.00 (0.79, 1.25)	0.97
T2	6.77 (2.62)	6.83 (3.04)	0.69 (0.57, 0.83)	**< 0.001**			0.95 (0.74, 1.22)	0.70
EORTC–Role [mean (SD)]					1.08 (0.85, 1.37)	0.55		
T0	4.37 (2.31)	4.70 (2.05)						
T1	2.73 (1.23)	3.27 (1.70)	0.63 (0.51, 0.77)	**< 0.001**			1.11 (0.85, 1.46)	0.45
T2	2.83 (1.49)	2.72 (1.22)	0.65 (0.50, 0.85)	**0.002**			0.89 (0.64, 1.25)	0.51
EORTC–Emotion [mean (SD)]					1.02 (0.85, 1.22)	0.87		
T0	6.43 (2.34)	6.53 (2.36)						
T1	6.33 (2.22)	6.37 (2.61)	0.98 (0.83, 1.17)	0.86			0.99 (0.78, 1.26)	0.94
T2	5.73 (2.00)	6.07 (2.09)	0.89 (0.76, 1.05)	0.17			1.04 (0.83, 1.30)	0.72
EORTC–Cognitive [mean (SD)]					0.97 (0.81, 1.17)	0.74		
T0	3.27 (1.26)	3.17 (1.12)						
T1	3.17 (1.15)	3.17 (1.44)	0.97 (0.82, 1.15)	0.72			1.03 (0.83, 1.29)	0.78
T2	2.87 (1.17)	3.21 (1.24)	0.88 (0.73, 1.06)	0.17			1.15 (0.91,1.46)	0.23
EORTC–Social [mean (SD)]					1.01 (0.83, 1.23)	0.93		
T0	3.73 (1.53)	3.77 (1.50)						
T1	3.37 (1.65)	3.27 (1.66)	0.90 (0.76, 1.07)	0.24			0.96 (0.74, 1.25)	0.77
T2	3.20 (1.42)	3.17 (1.14)	0.86 (0.68, 1.08)	0.20			0.98 (0.74, 1.31)	0.91
EORTC–GHS [mean (SD)]					1.05 (0.87, 1.26)	0.64		
T0	7.30 (2.77)	7.63 (2.82)						
T1	9.50 (3.07)	9.53 (2.69)	1.35 (1.15, 1.58)	**< 0.001**			0.93 (0.76, 1.13)	0.47
T2	10.40 (2.71)	9.97 (2.35)	1.43 (1.19, 1.71)	**< 0.001**			0.92 (0.73, 1.15)	0.45
ICF [mean (SD)]					1.32 (0.75, 2.34)	0.34		
T0	8.98 (9.68)	10.54 (14.27)						
T1	9.60 (9.60)	11.31 (17.00)	1.11 (0.74, 1.66)	0.61			1.01 (0.57, 1.78)	0.98
T2	8.52 (11.18)	8.26 (14.17)	1.14 (0.73, 1.70)	0.62			0.78 (0.41, 1.49)	0.45
Lympho-Management [mean (SD)]					1.03 (0.97, 1.10)	0.33		
T0	63.47 (9.01)	65.57 (7.90)						
T1	70.63 (8.39)	72.93 (6.96)	1.11 (1.05, 1.18)	**< 0.001**			1.00 (0.92, 1.09)	0.99
T2	69.07 (7.63)	71.59 (7.88)	1.09 (1.03, 1.15)	**0.003**			1.00 (0.93, 1.09)	0.94

Significance p 0.05
SD, standard deviation; CI, confidence interval; GHS, global health status; EORTC QOL-30, European organization for the research and treatment of cancer quality of life questionnaire-30.
T0: Baseline, T1: 1 week after intervention, T2: 3 months after intervention; ICF, lymphoedema functioning, disability and health questionnaire for lower limb lymphoedema.

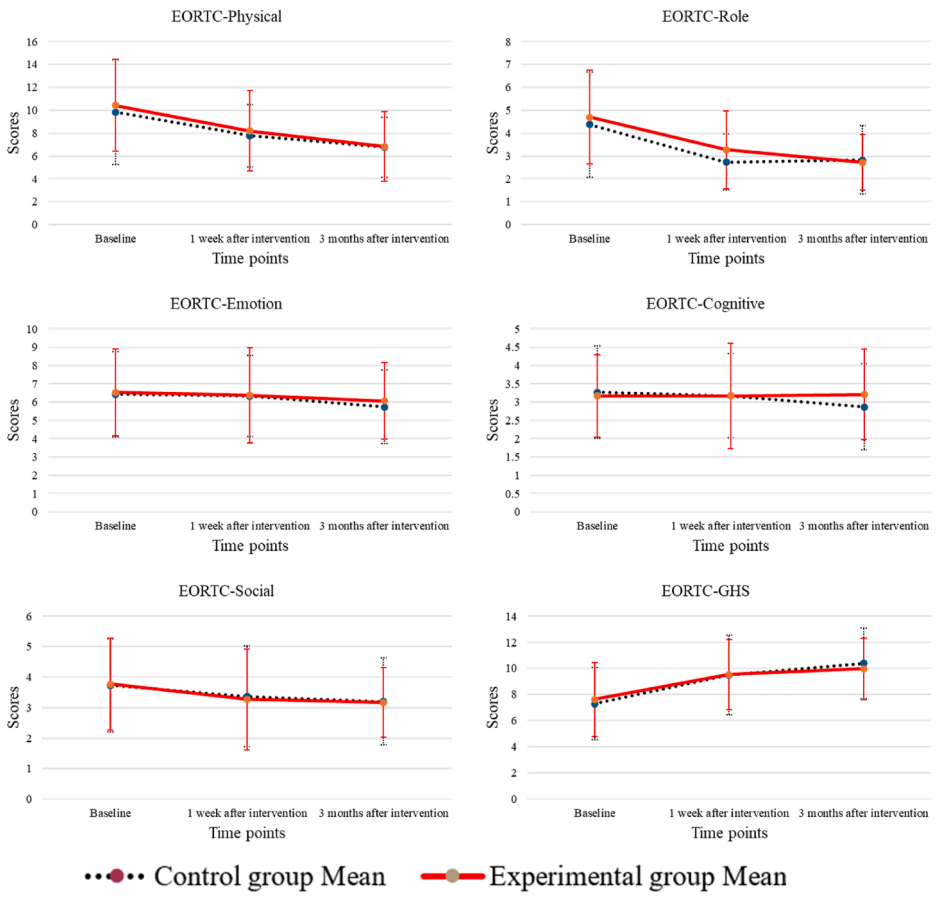

Fig. 2. Changes in quality of life related to cancer over time between control and experimental groups. EORTC: European organization for the research and treatment of cancer; GHS, global health status.

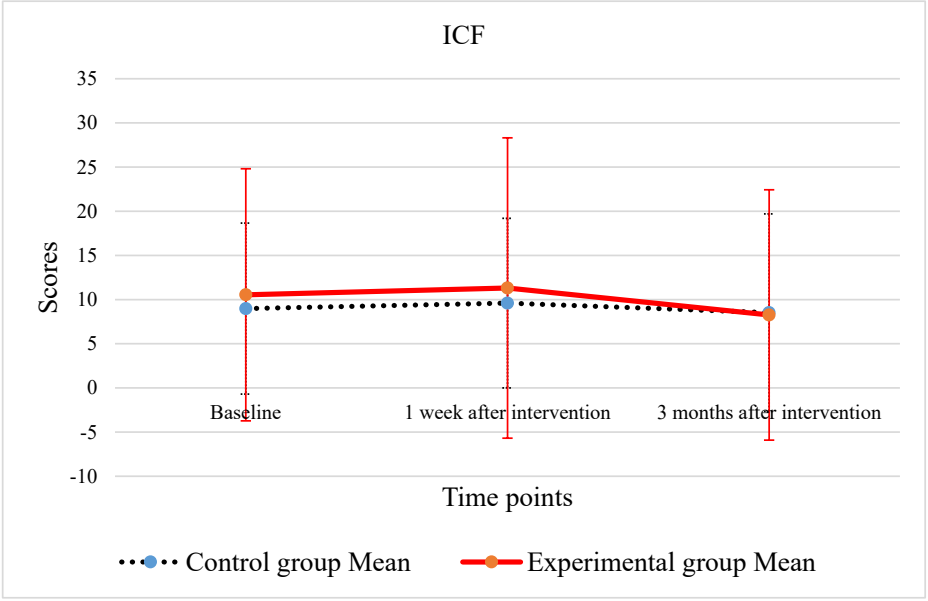

Fig. 3. Changes in lymphoedema functioning, disability, and health for lower limb lymphoedema (ICF) scores over time between control and experimental groups.

Discussion

Main findings

Sixty patients undergoing surgery for gynecological cancer participated in the randomized controlled trial. The findings from this study provide evidence that there is no apparent group difference in the changes observed in the quality of life related to cancer and lymphedema self-management behaviours over time between those who engaged in elastic-band resistance exercise and those who underwent non-resistance exercise. However, both exercise groups showed improvements in lymphedema self-management and quality of life related to cancer over time, including physical and role functions, as well as global health status.

Quality of life related to cancer is an important patient-centered outcome. Our study shows that the quality of life related to cancer improves over time in both exercise groups, with notable improvements in physical ($P = 0.005$ at T1; $P < 0.001$ at T2) and role functions ($P < 0.001$ at T1; $P = 0.002$ at T2), as well as overall health status ($Ps < 0.001$ at T1 & T2). The findings are consistent with one study that early preventive rehabilitation exercise can improve patients' quality of life related to cancer among gynecological cancer patients.[31] Improvement in role and physical functioning through exercise may be partly due to the mitigation of physical fatigue, which in turn enhances patients' ability to fulfill daily roles.[32] Furthermore, quality of life tends to improve gradually over time as patients recover from surgery.[33] Physical activity is associated with better QOL in gynecological cancer patients[34,35] and lung cancer patients.[36] Moreover, higher levels of physical activity have been linked to a reduction in lower limb lymphedema.[37]

In the study, by the end of the three-month follow-up, only one patient in each group, developed lower limb lymphedema. The prevalence rate of the lower limb lymphedema is 3.3% in the current study. In addition, the outcomes measured through limb circumference were not significantly different between the two groups. Previous research has indicated that the occurrence of lower limb lymphedema in women with gynecological cancer can manifest within the first year after lymphadenectomy, with a peak around three-to-six months after surgery.[4] Evidence has reported that the onset of lymphedema may occur immediately or delayed to 1–3 years after surgery.[5,6] Our study only followed up with participants three months post-surgery, therefore, long-term follow-up such as up to two years is needed to evaluate the sustained impact of the intervention on the development of lower limb lymphedema and quality of life. Future studies should consider extending the follow-up period and incorporating long-term follow-up data to evaluate the sustained impact of the intervention on LLL development and quality of life.

The association between Taxane-based chemotherapy and lymphedema has been observed in patients with breast cancer, although the relationship has not yet been fully established.[38,39] Taxane-based chemotherapy, in particular, leads to fluid retention and secondary swelling in the extremities.[39] In our study, only 30% of the participants had received chemotherapy; therefore, the potential relationship between Taxane-based chemotherapy and lower limb lymphedema was not examined. Future research should investigate the association between Taxane-based chemotherapy and lower limb lymphedema to clarify its role in gynecological cancer patients.

Both exercise programs provided women an opportunity to develop self-management skills for the reducing the risk of lymphedema, with non-significant in group*time effect ($P = 0.99$ at T1, $P = 0.94$ at T2). These home-based exercises have the potential to positively change lymphedema and reduce the risk of lymphedema in patients following surgery. Additionally, no adverse effects of the exercise programs on the assessed outcome parameters were reported, and only two women developed lymphedema over the study period. Similar findings have been reported in previous research, indicating that early rehabilitation exercise can reduce the risk of lower limb lymphedema and improve the quality of life related to cancer after gynecological cancer surgery.[31]

The participants in both groups engaged well in the daily exercise regimen. However, no significant differences in exercise adherence were observed between the resistance and non-resistance exercise groups, suggesting that both types of exercises were equally acceptable and manageable for participants. Home-based exercise interventions are not constrained by equipment, personnel, or location, which makes them cost-effective. Similar to previous research, the elastic-band resistance exercise is recognized as a safe and affordable strategy to reduce the risk of lower limb lymphedema in women with gynecological cancer following lymphadenectomy.[17] This home-based form of exercise should be considered as a key component of prehabilitation programs implemented after cancer surgery for women undergoing lymphadenectomy.

Both resistance and non-resistance exercises appear to be beneficial in clinical practice due to their accessibility, ease of implementation, and potential to enhance quality of life. It is possible that resistance training may improve muscle strength and circulation, while non-resistance exercises can also promote movement, reduce sedentary behaviour, and support overall physical recovery post-surgery.[12] Furthermore, the lack of significant differences in lymphedema prevention between groups suggests that maintaining an active lifestyle, regardless of the type of exercise, may be key to reducing post-surgical complications. Future studies should investigate whether specific exercise components, such as intensity, duration, or frequency, contribute differently to lymphedema reduction and improvements in quality of life.

The patient population in our study included women undergoing gynecological cancer surgery with lymphadenectomy. Unlike one previous RCT, which focused solely on cervical cancer patients undergoing radical hysterectomy with pelvic lymphadenectomy,[24] our study included a broader range of gynecological malignancies. This inclusion criterion enhances the generalizability of our findings to a broader gynaecological cancer patient population undergoing lymphadenectomy.

The intervention protocol in our study was distinct in its phased application of elastic-band resistance exercises. Our home-based program consisted of four progressive stages: warm-up, start-up, vigorous, and reinforcement, gradually increasing resistance levels over an eight-week period. Unlike previous study,[24] which employed a five-phase progressive resistance exercise training (PRET) program designed by a multidisciplinary expert group and only included hospital-based sessions, our intervention emphasized home-based adherence with remote support via booklets and video tutorials. Additionally, our study incorporated non-resistance exercises as a control group. In contrast, the previous RCT included a graduated compression stocking group as an alternative intervention.[24] Future studies may consider comparing the effectiveness and adherence between home-based and hospitalized exercise training programs to further evaluate their applicability and patient outcomes.

The follow-up procedures in our study differed from those in the prior RCT. While the previous study followed participants for up to 24 months, with frequent hospital visits and self-reported limb volume measurements,[24] our study monitored patients through outpatient visits at three key time points. Our pragmatic approach aligns with real-world clinical settings, where frequent long-term follow-up may not be feasible for all patients. Additionally, our study used a diary log system to assess adherence to the exercise program, providing a more comprehensive understanding of patient compliance and engagement with home-based interventions. Furthermore, future research will consider multifrequency bioelectrical impedance analysis to enhance the reliability of intervention assessment, such measuring changes in limb fluid and body cell mass following exercise interventions.

Implications for nursing practice and research

The findings of this study hold important clinical significance and implications. This study highlights the advantages of home-based exercise programs in promoting patient self-management behaviours for reducing the risk of lower-limb lymphedema. To enhance adherence and support self-management, a photographic booklet and exercise videos were used, enabling patients to better understand and implement the exercises. The role of prehabilitation combined with education may be a significant factor in reducing the risk of lymphedema. In clinical practice, integrating structured home-based exercise programs into routine postoperative care for women with gynecological cancer presents a promising and feasible intervention strategy. Such program could support early rehabilitation and empower patients in self-management to potentially reduce the incidence and severity of lymphedema.

Limitations

Some limitations should be acknowledged in the present study. First, the three-month follow-up period may have been insufficient to fully assess the long-term incidence of lower limb lymphedema, as lymphedema can develop progressively over 1–3 years post-surgery. Future studies should consider extending the follow-up duration to assess the sustained impact of resistance exercise on the development of lower limb lymphedema and its effect on quality of life. Second, the relatively small sample size and potential patient attrition may limit the study's statistical power to draw definitive conclusions regarding the effectiveness of resistance exercise in reducing of the risk of lower limb lymphedema. Increasing the sample size while accounting for patient heterogeneity could strengthen the robustness of future findings. Third, although randomization helped balance group differences, it is essential to acknowledge that individual physiological variability and post-surgical complications may still influence the development of lower limb lymphedema. Factors such as the extent of lymphadenectomy and pre-existing comorbidities could contribute to variations in outcomes. Future studies should consider adjusting for these potential confounding factors to refine the relationship between the effect of the exercise interventions and the prevalence of lower limb lymphedema.

Conclusions

Compared to non-resistance exercise, resistance exercise is not superior in reducing the risk of lower limb lymphedema within the initial three months following gynecological cancer surgery. Both exercise interventions increased the quality of life related to physical and role functions three months after cancer surgery. Resistance exercise in the lower limbs does not exacerbate the adverse effects of lymphedema compared to non-resistance exercise. Therefore, both types of exercises can be recommended to women undergoing gynecological cancer surgery. To further investigate the long-term impact of exercise on lower limb lymphedema in women post-gynecological surgery, future studies should consider extending the duration of intervention and its follow-up period.

CRediT authorship contribution statement

Yu-Yun Hsu: Conceptualization, Methodology Data Curation, Formal Analysis, Funding Acquisition, Writing – Original Draft, Review, Editing. **Cheng-Feng Lin:** Conceptualization, Methodology, Writing – Review & Editing. **Pei-Chi Liang:** Data Curation, Formal Analysis, Visualization. **Tram Thi Bich Nguyen:** Formal Analysis, Visualization, Writing – Review. **Keng-Fu Hsu:** Conceptualization, Methodology, Writing Manuscript Review & Editing. All authors have read and approved the final manuscript.

Ethics statement

The study was approved by the Research Ethics Review Committee of the National Cheng Kung University Hospital (Approval No. B-ER-105-444) and was conducted in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. All participants provided written informed consent.

Data availability statement

The data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available because of privacy or ethical restrictions.

Declaration of generative AI and AI-assisted technologies in the writing process

No AI tools/services were used during the preparation of this work.

Funding

This study was supported by the Ministry of Science and Technology, Taiwan (Grant No. MOST 106-2314-B-006-008), and the National Cheng Kung University (NCKU) within the framework of the Higher Education Sprout Project by the Ministry of Education (MOE) in Taiwan. None of the remaining authors were declared. The funders had no role in considering the study design or in the collection, analysis, interpretation of data, writing of the report, or decision to submit the article for publication.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

The authors would like to acknowledge all the participants in this study. We are grateful to Prof. Chung-Yi Li and Ms. Chih-Hui Hsu from the Biostatistics Consulting Center, Clinical Medicine Research Center, National Cheng Kung University Hospital, for their assistance with data analyses, and to Ms. Yen-Ju Chou and Ms. Miao-Hsin Ko for their data collection. We also thank Dr. Susan Fetzer for editing the manuscript.

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