Original article

The effect of a whole body exercise programme and dragon boat training on arm volume and arm circumference in women treated for breast cancer

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The purpose of this study was to examine the effect of a whole body exercise programme and dragon boat training on changes in arm volume in breast cancer survivors. A total of 16 female breast cancer survivors with no clinical history of lymphoedema volunteered. The 20-week exercise programme consisted of resistance and aerobic exercise with the addition of dragon boat training at week 8. Arm circumference at two sites (CIRC10, CIRC15), arm volume (VOL), and upper body strength (1-RM) were measured at baseline (T1), week 8 (T2), and week 20 (T3). All statistical tests were two-sided ($\alpha \leq 0.05$). No significant differences between the ipsilateral and contralateral upper extremities at any of the three time points were found. All variables significantly increased from T1 to T3 (CIRC10: difference, $d = 0.49$ cm, 95% confidence interval, CI = 0.25–0.73, $P = 0.000$; CIRC15: $d = 1.33$ cm, CI = 0.78–1.88, $P = 0.000$; VOL: $d = 100$ mL, CI = 69–130, $P = 0.000$). As well, 1-RM significantly increased from T1 to T3 ($d = 10.8$ kg, CI = 5.6–16.1; $P = 0.000$). In summary, participation in a whole body exercise programme and dragon boat training resulted in a significant increase in upper extremity volume over time. However, the changes were consistent for both arms and the significant gain in upper body muscular strength likely accounted for the increase in arm volume.

Keywords: breast cancer, lymphoedema, exercise, upper extremity.

INTRODUCTION

Breast cancer related lymphoedema (BCRL) is a chronic swelling that can occur in the ipsilateral hand or arm of women treated for breast cancer (Mortimer 1998). Factors known to increase the risk of developing BCRL include dissection of the axillary lymph nodes, radiotherapy to the breast and axilla, pathological nodal status, obesity and tumour stage (Pain & Purushotham 2000). In fact, there is a 50% probability of women developing BCRL over a 20-year period following treatment (Petrek *et al*. 2001). There is no consistency in when BCRL may develop after treatment or the speed of actual onset. Once BCRL develops, it is essentially incurable; however, treatments such as skin care, manual lymphatic drainage, pneumatic pumping, and compression sleeves exist to contain swelling (Pain & Purushotham 2000; Erickson *et al*. 2001).

There were previous concerns in the medical community that vigorous, upper-body exercise could lead to the development or worsening of BCRL (McKenzie 1998). This view stemmed from the belief that simple axillary obstruction of lymph flow was the primary determinant of

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BCRL. Consequently, if a woman who survived breast cancer engaged in vigorous exercise on a regular basis, then lymph production would increase corresponding to an eventual increase in arm volume. Current research investigating the mechanism of BCRL pathogenesis suggests that its development is multi-factorial and not simply a result of simple axillary obstruction (Pain & Purushotham 2000).

Other studies (Harris & Niesen-Vertommen 2000; McKenzie & Kalda 2003) have not found changes in arm volume and/or circumference in breast cancer survivors with and without lymphoedema due to participation in an exercise programme. However, McKenzie and Kalda only included subjects with BCRL while Harris and Niesen-Vertommen did not statistically analyse the results. Neither study quantified the effects of the prescribed exercise programme. Therefore, the purpose of this study was to examine the effect of a progressive, whole body exercise programme, and dragon boat training on both upper extremity volume and circumference in breast cancer survivors.

PATIENTS AND METHODS

Subjects

Subjects were recruited from the 'Abreast in a Boat' novice dragon boat meeting in January, 2003. A total of 100 women were present at the meeting and of those 18 women signed up to volunteer in the research study. However, two subjects decided not to continue after the pre-test due to medical reasons unrelated to breast cancer, and so, data are presented on 16 female subjects. Prior to testing, informed consent was obtained from each subject and the study was approved by the Clinical Screening Committee for Research and Other Studies Involving Human Subjects at the University of British Columbia.

Subjects had been diagnosed with Stage I–III breast cancer and all had either a lumpectomy and/or mastectomy performed as part of surgical treatment. In the 13 women who had axillary dissections a range of 3–34 nodes were removed (mean = 10.8). Eight-nine per cent of the subjects had received breast or axillary radiation therapy. Table 1 outlines individual details of age, body mass index (BMI), and breast cancer treatment for the 16 subjects who completed the exercise programme. Subjects were eligible for the study if they had completed all treatment for Stage I–III breast cancer over 6 months ago, did not have a 'yes' answer on the Physical Activity Readiness Questionnaire (PAR-Q), could commit to regular exercise and dragon boat training over 20 weeks, and were naïve to dragon boat paddling.

Testing procedures

All subjects were tested prior to the start of the exercise programme (T1), immediately prior to the start of dragon boat training (T2), and at the completion of the dragon boat season (T3) giving a total of three measurements at 0 week, 8 weeks and 20 weeks respectively. Height and weight were measured to the nearest 0.1 cm and 0.1 kg respectively. Arm circumference was determined at two sites – 10 cm proximal to the styloid process of the ulna (CIRC10) and 15 cm proximal to the lateral epicondyle (CIRC15). Subjects were supine on a bench with arms relaxed by their sides and elbows straight for both mea-

Table 1. Individual details of age, body mass index (BMI) and breast cancer treatment for the subjects ($n = 16$)

Subject number	Age (year)	BMI (kg/m^2) at Time 1	Date diagnosed	Tumour stage	Breast surgery	Lymph nodes removed/ number positive	Radiation therapy to axilla
1	58	23.4	October 1999	1	L, M	12/0	Yes
2	59	29.2	December 1998	2	L	3/0	Yes
3	34	23.3	November 2000	3	L	6/0	Yes
4	55	25.1	July 2002	1	L	10/0	Yes
5	57	27.3	August 2002	2	L, M	11/1	Yes
6	52	22.9	March 1993	1	M	11/0	Yes
7	52	24.8	August 2001	1	M	0	Yes
8	47	19.3	September 2000	1	L, M	11/0	Yes
9	52	30.6	December 2001	3	L	13/0	Yes
10	52	22.8	January 2002	3	M	0	Yes
11	59	27.6	March 2001	2	L, M	10/2	Yes
12	64	23.3	May 1985	2	M	0	Yes
13	49	21.3	November 2001	2	L	24/0	Yes
14	50	24.0	October 1997	2	L	0	No
15	48	23.8	January 2001	1	L	10/1	Yes
16	51	22.4	November 1999	1	L	8/0	Yes

L, lumpectomy; M, mastectomy.

surements. The measuring tape was placed around the extremity so that it was not slack but also so that there was no indentation in the tissue. Both arms were measured at each testing date to the nearest 0.1 cm.

Upper extremity volume was measured by water displacement. The arm was kept straight and was slowly immersed into the water, sliding the fingers straight down the inside wall of the volumeter until a marking on their arm at 45 cm proximal to the styloid process of the ulna (VOL). Water was collected from the instant the arm was first immersed until the water was dripping less than once per second. Water was displaced into a graduated cylinder and the volume was read to the nearest 10 mL.

Upper body strength was measured using a supine bench press test. The maximal force exerted in one repetition (1-RM) was predicted using the equation by Lander (1985) (1-RM = 100 × repetition weight/101.3–2.67123 × number of repetitions). Subjects warmed up with light weights and then selected a weight that they could lift 7–10 times.

Exercise programme

The exercise programme consisted of aerobic exercise and resistance training and was performed over the entire duration of the experimental period. Dragon boat training started at week 8, immediately after the test 2 measurement and was performed concurrently with the exercise programme. The specific details of each programme are described below. The aerobic and resistance training sessions were not supervised.

Resistance training was completed three times per week and included six exercises (seated row, bench press, latissimus dorsi pull down, one arm bent-over rowing, triceps extension, and biceps curl). A light weight was used in the early stages of the programme and was progressed to heavier weights as tolerated by each subject. Two sets of 10 repetitions for each exercise were done for the first week, three sets of 10 repetitions thereafter. The resistance training sessions consisted of a 5–7-min period of aerobic warm-up, 5 min of stretching, the strength training programme, followed by a cool-down period.

Aerobic training was done 3 days per week for 30–45 min per session at an intensity of 60% maximal effort. Subjects were given instruction on how to monitor heart rate and were given heart rate training zones for their sessions. They were told to perform aerobic exercise of their choice and to include a 5–7-min period of warm-up, light stretching, and a cool-down period.

The subjects trained in a dragon boat twice per week for 90 min. The training programme began with a 15-min warm-up on land followed by 90 min of intermittent paddling activities. These practices were supervised and involved a progressive increase in frequency, duration and intensity of exercise.

Sample size calculation and statistical analyses

Based on previous research, a minimum of 13 subjects were needed to detect a large standardized effect in upper body strength with a power of 0.80 and a two-tailed alpha less than 0.05. All 18 women who volunteered for the study were invited to participate in order to compensate for subject drop-out.

A 2 × 3 (arm × sessions) MANOVA was completed on the three dependent variables (CIRC10, CIRC15, VOL) using Statistica version 5.1. As well, separate 1 × 3 ANOVAs were conducted on changes in body mass index (BMI) and 1-RM over the 3 testing sessions. Significance was set at $P = 0.05$. *Post hoc* analysis for all main effects was performed using Tukey's test of honest significant differences. Data are reported as mean followed by standard deviation (± SD).

RESULTS

A total of 18 women originally volunteered for the study. Two of the 18 women decided not to participate after the first testing session due to medical reasons unrelated to breast cancer and so were not included in the statistical analyses.

Group characteristics are shown in Table 2. There was no significant change in BMI ($P = 0.377$) over the duration of the experimental period and upper body strength increased significantly from T1 to T3 (difference, $d = 10.8$ kg, 95% confidence interval, CI = 5.6–16.1; $P = 0.000$; Fig. 1). The results of the 2 × 3 MANOVA indicated that there was no significant difference between the contralateral and ipsilateral arms at any of the three time points and only a significant difference across testing sessions for the dependent variables occurred ($P = 0.025$).

Table 2. Physical characteristics of women treated for breast cancer ($n = 16$) who participated in a 20-week exercise programme

	Test 1	Test 2	Test 3
Age (year)	52.4 (± 6.8)		
Height (m)	1.63 (± 0.081)		
Weight (kg)	65.2 (± 9.8)	65.2 (± 9.3)	65.5 (± 9.3)
BMI (kg/m^2)	24.1 (± 2.8)	24.2 (± 2.7)	24.3 (± 2.8)
1-RM (kg)	55.3 (± 13.6)	60.8 (± 9.4)	66.2* (± 9.7)

Values are means (± SD).
BMI, body mass index.
*vs. Test 1; $P = 0.000$.

Post hoc analysis determined that each of the dependent variables – CIRC10, CIRC15 and VOL – showed significant changes across testing sessions.

Upper extremity circumference changes

The mean difference in CIRC10 and CIRC15 (Fig. 2) significantly increased from T1 to T2 (CIRC 10: $d = 0.29$ cm, CI = 0.12–0.46, $P = 0.029$; CIRC15: $d = 0.70$ cm, CI = 0.36–1.03, $P = 0.046$) when only the exercise programme was being performed. As well, both CIRC10 and CIRC15 showed a significant increase from T1 to T3 (CIRC10: $d = 0.49$ cm, CI = 0.25–0.73, $P = 0.000$; CIRC15: $d = 1.33$ cm, CI = 0.78–1.88, $P = 0.000$).

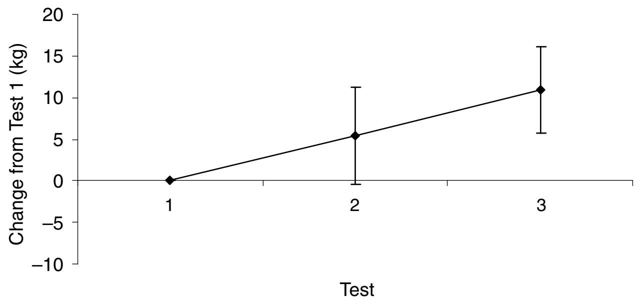

Figure 1. Mean change in upper body strength (kg) compared with baseline (Test 1) in women treated for breast cancer taking part in a whole body exercise programme and dragon boat training.

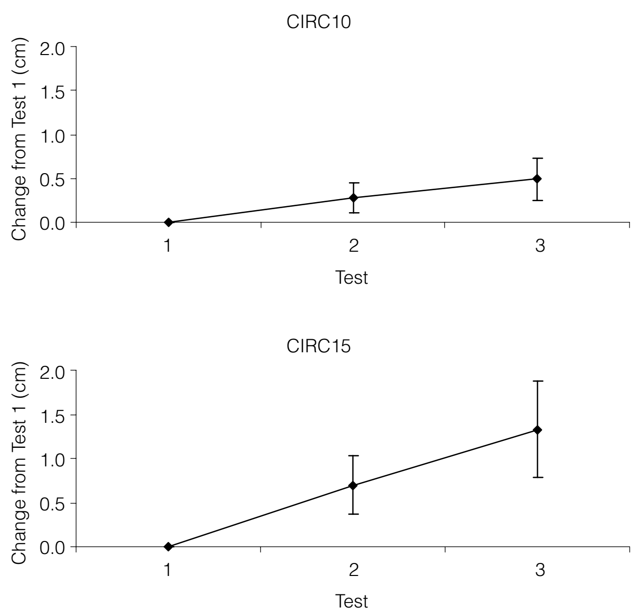

Figure 2. Mean change in arm circumference compared with baseline (Test 1) measured at 10 cm proximal to the styloid process of the ulna (CIRC10) and 15 cm proximal to the lateral epicondyle (CIRC15) in women treated for breast cancer taking part in a whole body exercise programme and dragon boat training.

Upper extremity volume changes

Arm volume (Fig. 3) showed a significant increase from T1 to T3 (VOL: $d = 100$ mL 69–130, $P = 0.000$) and from T2 to T3 ($d = 78$ mL, CI = 48–109, $P = 0.001$).

DISCUSSION

The primary finding of this study is that the prescribed exercise programme and dragon boat training did not result in a significant difference between the ipsilateral and contralateral upper extremities over the course of the experimental period in women treated for breast cancer. Both arms responded similarly to the training programme and showed a significant increase in volume, circumference and strength across testing sessions. Specifically, CIRC10 and CIRC15 (Fig. 2) increased significantly from T1 to T2 when only the exercise programme was being performed and the addition of dragon boat training caused a significant increase in VOL from T2 to T3 (Fig. 3). It should also be noted that the exercise programme and dragon boat training resulted in a significant increase in upper body strength from T1 to T3 (Table 2; Fig. 1).

The increase in arm circumference and arm volume observed over the course of the experimental period may be explained by the effects of both resistance training and dragon boat paddling on the musculoskeletal system. A known adaptation to resistance training is muscle hypertrophy, if the stimulus is of sufficient magnitude. Subjects in the present study completed a 20-week resistance training programme including six upper-body exercises, all of which targeted the shoulder girdle and upper extremity musculature. A significant increase in muscle thickness has been found to occur by 4–6 weeks in both men and

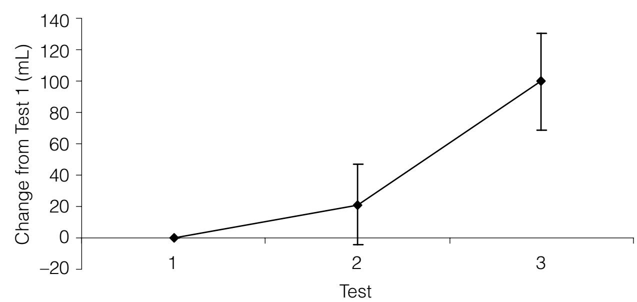

Figure 3. Mean change in arm volume (VOL) compared with baseline (Test 1) in women treated for breast cancer taking part in a whole body exercise programme and dragon boat training.

women performing a resistance training programme of similar exercises three times per week for 12 weeks (Abe *et al*. 2000). Thus, as the resistance programme in the current study was similar to that used by Abe *et al*. gains in muscle mass, and thus, strength would be expected. A significant increase in bench press 1-RM was observed over the experimental period (Table 2).

Dragon boat paddling was added at week 8 and continued for the remaining 12 weeks of the study and during this time subjects participated in twice weekly dragon boat practices as well as twice weekly resistance training sessions. Dragon boat paddling involves strenuous, repetitive, upper body activity that can stimulate musculoskeletal and cardiovascular adaptations (McKenzie 1998). Thus, it would be expected that a 20-week, progressive, upper body strength training programme, as well as 12 weeks of concurrent dragon boat paddling would result in gains in muscle mass reflected by an increase in arm volume and circumference in both arms.

Although it can be postulated that muscle hypertrophy accounted for the increases in upper extremity volume and circumference, measuring anthropometric variables does not give an indication of the specific physiological changes taking place within the arm. For example, an increase in arm volume in women treated for breast cancer may indicate muscle hypertrophy or increases in subcutaneous fat or development of BCRL or a combination of various factors. Using magnetic resonance imaging could help to elucidate the soft tissue changes that may be taking place due to exercise training.

Previous studies by McKenzie and Kalda (2003) and Harris and Niesen-Vertommen (2000) have not shown a significant increase in upper extremity volume and/or circumference due to participation in an exercise programme. Specifically, McKenzie and Kalda monitored the effects of an 8-week, upper-body exercise programme on changes in arm volume and circumference. The exercise programme consisted of both resistance training and aerobic exercise using an upper body ergometer. Although significant increases in either arm volume or circumference were not found, changes in muscular strength were not reported. Eight weeks may not have been of sufficient duration to stimulate strength gains in this population. As well, all subjects in the study by McKenzie and Kalda were chosen because they had unilateral BCRL while none of the subjects in the present study were clinically diagnosed with BCRL. Perhaps, lymphoedema masks the effects of both resistance training and dragon boat paddling on changes in arm composition.

McKenzie and Kalda (2003) reported all arm volume and circumference data as a percentage difference between the ipsilateral and contralateral arms while the present study looked at absolute values for each arm separately. If the data in the current study are statistically analysed using a percentage difference in arm circumference and volume across testing sessions, then no significant increases in any of the dependent variables are found. This again supports the notion that both the exercise programme and dragon boat training affected both arms equally.

Harris and Niesen-Vertommen (2000) measured changes in arm circumference in breast cancer survivors performing an aerobic and resistance training programme as well as dragon boat training. In total ~9 months separated the first and last measurement. Once more, changes in muscular strength were not reported so it is not known if muscle hypertrophy may have occurred. Although statistical analyses were not performed on the arm circumference measurements between the three time points, only two subjects showed a measurably different change defined as >1.27 cm between time 1 and time 3 at any of the four landmarks used. Further, none of the subjects showed a clinically significant difference (>2.54 cm between the ipsilateral and contralateral upper extremities) in arm circumference at time 3. Using the criteria outlined by Harris and Niesen-Vertommen for clinically significant mild lymphoedema (>2.54 cm difference between the ipsilateral and contralateral arms), only one individual in the present study would be classified as having mild lymphoedema at the last testing session. This subject had a difference in her CIRC15 measurement at T3 of 2.9 cm while CIRC10 only differed by 0.8 cm.

A limitation of the above studies (Harris & Niesen-Vertommen 2000; McKenzie & Kalda 2003) and the present study is that the measurement techniques used only provide information on changes in arm volume and circumference and do not provide information on changes in lymphatic function. Although the findings of this study have demonstrated that exercise did not result in the development of lymphoedema, no conclusions can be made about the effects of exercise on lymphatic function.

In summary, this study supports the view that women treated for breast cancer that engage in progressive, upper body activity (aerobic exercise, resistance training, and dragon boat paddling) will not develop BCRL. In fact, there is the potential that chronic exercise could lead to improved lymph flow in the ipsilateral upper extremity and perhaps prevent the development of BCRL; however, this hypothesis needs further research. The propulsion of lymph is dependent on extrinsic (muscular contractions, pulse of nearby arteries, and pressure changes with ventilation) and intrinsic (sympathetic activation of the smooth muscle lining the larger lymphatic vessels) mechanisms (Aukland & Reed 1993). Consequently, physiological changes associated with chronic exercise such as increased sympathetic outflow, increased muscular contractions, and increased ventilation could facilitate lymph return. Exercise may also result in positive lymphatic changes in the affected arm such as lymphangiogenesis and recruitment of dormant lymphatic vessels. Lymphangiogenesis and recruitment of dormant vessels could help to reduce the stress put on the lymphatic vasculature damaged by breast cancer treatment, namely axillary lymph node dissection and radiation to the axilla. Finally, the overall health benefits of regular exercise such as increased quality of life, decreased body fat, increased physical functioning, increase bone mineral density and a reduction in cardiovascular risk factors can not be dismissed. As the survival rate for breast cancer increases, many women will want to use regular physical activity to prevent other lifestyle-related diseases.

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