Effect of Acute Exercise on Upper-Limb Volume in Breast Cancer Survivors: A Pilot Study

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ABSTRACT

Purpose: Strenuous upper-extremity activity and/or exercise have traditionally been prescribed for breast cancer survivors with or at risk of developing lymphedema. The purpose of this study was to assess the effect of an acute bout of exercise on upper-limb volume and symptoms in breast cancer survivors, with the intent to provide pilot data to guide a subsequent larger study.

Methods: Twenty-three women who regularly participated in dragon-boat racing took part in the study. A single exercise bout was performed at a moderate intensity (rating of perceived exertion: 13–14) for 20 continuous minutes on an arm ergometer. The difference between affected and unaffected limb volume was assessed pre- and post-exercise via measurements of limb circumference at five time points.

Results: Although limb volume increased following exercise in both limbs, the difference between the limbs remained stable at each measurement point. Only one participant was found to have an increase in arm-volume difference of >100 ml post intervention, and only four participants reported symptoms of tension and/or heaviness in the affected limb.

Conclusion: The results suggest that limb volume in breast cancer survivors increases after an acute bout of upper-limb exercise but that, for the majority of women, the response is not different between affected and unaffected limbs. Future research using a larger sample and more sensitive measurement methods are recommended.

Key Words: arm, breast neoplasms, exercise, lymphedema, upper extremity

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RÉSUMÉ

Objectif : De l'exercice ou une activité intenses des membres supérieurs ont toujours été déconseillés pour les femmes ayant survécu à un cancer du sein ou risquant de développer un lymphœdème. L'objectif de cette étude était d'évaluer les effets d'un épisode d'exercices intenses sur le volume du membre supérieur ou sur les symptômes chez les survivantes à un cancer du sein, le tout dans le but de fournir des données pilotes pouvant servir de base à une étude ultérieure à plus grande échelle.

Méthodes : En tout, 23 femmes participant régulièrement à la course des bateaux-dragons ont participé à l'étude. Un seul exercice a été effectué, à intensité modérée, durant 20 minutes d'affilée, à l'aide d'un ergomètre pour les bras.

Résultats : Même si après les exercices, les deux membres supérieurs avaient plus de volume, la différence entre les membres supérieurs est demeurée stable à chaque prise de mesure. On a constaté une différence post-intervention dans le volume des bras de l'ordre de >100 ml chez une seule participante et quatre participantes seulement ont signalé des symptômes de tension/une sensation de lourdeur aux membres supérieurs affectés.

Conclusions : Ces résultats suggèrent que le volume des membres supérieurs chez les femmes ayant survécu à un cancer du sein augmente à la suite d'un épisode d'exercices soutenus sollicitant les membres supérieurs, mais également que, pour une majorité de femmes, la réaction des membres touchés n'est pas différente de celle des membres non touchés. Des recherches ultérieures à l'aide d'un échantillon plus important et de méthodes de mesure plus nuancées ou plus sensibles sont recommandées.

Mots clés : bras, exercice, lymphœdème, membres supérieurs, néoplasme, sein, tumeur

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INTRODUCTION

Lymphedema is a chronic progressive condition that can have profound adverse effects on a breast cancer survivor's quality of life and is one of the most feared long-term complications of breast cancer treatment.¹ Numerous lifestyle factors have been implicated in the development of lymphedema, and guidelines for the prevention of lymphedema have been developed.² Vigorous upper-extremity activity and/or exercise have traditionally been proscribed for breast cancer patients and survivors because of the risk of developing lymphedema.^{3,4}

Over the last decade, breast cancer survivors have challenged this long-standing recommendation against upper-extremity activity by participating in dragon-boat racing and upper-extremity strength-training programmes. Early evidence suggests that the majority of breast cancer survivors are able to engage safely in vigorous upper-extremity exercise without developing lymphedema.^{5–8} More recent lymphedema risk-reduction guidelines have been tempered to reflect emerging evidence refuting upper-extremity exercise as a potential factor in the development of lymphedema.³

In the clinical setting, breast cancer survivors often report a transient increase in limb tension, heaviness, and/or swelling with use of the limb for work, functional activities, or exercise.⁹ These symptoms are cause for concern, as periods of transient and/or intermittent swelling often predate the onset of chronic lymphedema¹⁰ and may represent early warning signs of a failing or compromised lymphatic system. For the breast cancer survivor, these symptoms may be a deterrent to activity and exercise. Physiotherapists responsible for educating patients on risk-reduction strategies for lymphedema would benefit from knowing the significance of these symptoms.

The purpose of this study was to assess the effect of an acute bout of exercise on upper-limb volume and symptoms in breast cancer survivors, with the intent to provide pilot data to guide a subsequent larger study.

METHODS

This pilot study enrolled 23 participants. Approval for the study was received from the Research Ethics Committee of the Alberta Cancer Board and from the Health Research Ethics Board of the University of Alberta. Verbal confirmation of participants' interest in the study was obtained at a dragon-boat racing group meeting. Informed consent was obtained from each participant prior to testing.

Eligibility criteria consisted of a diagnosis of early-stage breast cancer, treated with surgical resection of the tumour (lumpectomy or mastectomy) along with sentinel and/or axillary node dissection. Survivors were excluded if they had any known or suspected complications due to breast cancer (e.g., distant metastases, local

cancer recurrence). All participants had completed primary cancer treatments. This patient population was chosen for the pilot study because the women had just completed a 7-month progressive exercise-training programme, including a competitive season of dragon-boat racing, and thus adequate training had occurred to allow for adaptation of the affected limb to exercise. The sample was considered at low risk of acute stress to an untrained or potentially weakened affected limb, which could confound the study results and potentially lead to excessive muscle soreness, injury, or lymphedema.

Acute Exercise Intervention

The independent variable for the study was the acute exercise bout. Following a 2-minute warm-up, exercise was performed for 20 continuous minutes on an arm ergometer (Angio Single Set with programmable control unit; Lode, Groningen, The Netherlands). The arm ergometer was mounted on a table, and the seat position was adjusted to fit each participant. The level of resistance was determined by rating of perceived exertion using the Borg scale.¹¹ Participants were asked to arm cycle at a minimum of 50 revolutions per minute (rpm). A rating of perceived exertion of 13 to 15 ("somewhat hard" to "hard") was used as the target for the experimental exercise bout. Participants who normally wore a compression sleeve while exercising were asked to wear their compression sleeve during the exercise session.

Endpoints

The dependent variable in the study was the difference between affected and unaffected upper-limb volume. Thus, each participant's unaffected limb served as a control. The changes in limb circumference were expressed in centimetres, and lymphedema volume was calculated and expressed in millilitres. A priori, we planned to classify participants into one of two groups (covariate) at baseline:

1. Lymphedema (LE) group: Signs and symptoms indicative of clinically significant lymphedema: >200 mL of fluid difference¹² or a difference of >2 cm at any one measurement point.^{4,12}
2. Breast Cancer (BC) group: No signs or symptoms of lymphedema, but have sustained damage to the lymphatic system through surgical lymph node removal or irradiation.

Measurement Protocol

Participants were assessed at five time points: (1) baseline measures: about 5 minutes prior to exercise; (2) within 5 minutes of completion of the exercise bout; (3) 15 minutes post exercise; (4) 30 minutes post exercise; and (5) 1 hour post exercise. The affected and unaffected limbs were measured and compared at each time point.

For the present study, measurement of circumference was used to calculate limb volume. Circumferential (girth) measurements are simple and efficient and can be performed within the time constraints of recovery from exercise. Measurements were taken of both limbs, starting at the metacarpopharyngeal (MCP) joints, across the hand, including the thumb MCP and wrist. For the purpose of the volumetric calculation, circumference measurements at 4 cm intervals from wrist to axilla were taken. Limb volume was calculated based on the formula for a truncated cone.^{13,14} Using the same measurement technique and formula, the reported correlation between the calculated volume from circumference measurements and the total water displacement volume was $r=0.99$, and the coefficient of determination (r^2) was 0.98.¹³ The reliability of the circumference measurements, expressed as an intra-class correlation coefficient (ICC), varied from 0.96 to 0.99, and the standard error of measurement (SEM) was reported as 0.09–0.20 cm.^{13,15} For the present study, a non-stretch fibreglass tape measure, accurate to 0.1 cm, was used to measure both the circumference and the length of the upper extremity. A single assessor performed the measurements of circumference. A single measurement was taken at each point along the limb. Intrarater reliability was established prior to study initiation (ICC = 0.98; SEM = 0.2 cm). Circumferential measurements were recorded by a research assistant. The assessor was blinded to all prior measurements.

The clinical symptom assessment (heaviness and tension) was performed using a visual analogue scale (VAS). The experiences of tension and heaviness of each limb were scored by the participant on a 100 mm horizontal VAS whose endpoints were described as “no tension” (0 mm) and “worst imaginable tension” (100 mm) and as “no heaviness” (0 mm) and “worst imaginable heaviness” (100 mm). Each participant was asked to record subjective sensations in each limb prior to the exercise and at each of the time points following the exercise.

Analysis

Data were analyzed using SPSS 15.0 (SPSS Inc., Chicago, IL). As this was a pilot study, the purpose of the statistical analyses was to determine point and interval estimates (parameter estimation) to guide future research. We were interested in determining the proportion of participants experiencing an absolute increase in limb-volume difference (*affected limb – unaffected limb*) of > 100 ml^{16,17} or an increase that resulted in a > 200 ml difference between the limbs (i.e., reclassification from BC to LE group). Descriptive analysis included examining individual differences between limbs before and after exercise.

RESULTS

Participants

Twenty-three participants were enrolled and completed the study. Eighteen participants had a baseline limb volume difference (*affected limb volume – unaffected limb volume*) of < 100 ml and did not have any limb circumference measurements that reached or exceed 2 cm for any measurement point. None of these participants reported current or past diagnosis of lymphedema, and they were therefore classified in the BC (breast cancer) group. Five participants were classified into the LE (lymphedema) group. Three LE participants presented with a limb-volume difference of > 200 ml, and two participants presented with > 2 cm circumferential measurement difference at more than one point. In these two participants, the calculated volume difference between the limbs exceeded 95 ml but did not exceed 200 ml. All five LE participants had previously been diagnosed with lymphedema. Participant characteristics are provided in Table 1. All participants completed the exercise regimen as prescribed (see Table 2). No adverse events occurred during or following the exercise intervention.

Table 1 Participant Demographic Information

Variable	Lymphedema (LE) Group (n = 5)	Breast Cancer (BC) Group (n = 18)
Age, mean (min, max), y	55 (48, 62)	52 (48, 56)
Time from diagnosis, mean (min, max), y	5.6 (1.4, 9.7)	6.6 (4.0, 9.1)
BMI, mean (SD), kg/m ²	27.6 (4.3)	27.1 (3.8)
Obese, n	1	4
Disease stage, n		
0-I (T1N0)*	1	7
II (T1N1, T2N0); (T2N1, T3N0)	2	9
III (T1N2, T2N2, T3N1–2)	2	2
Surgical protocol, n		
BCS	3	10
Mastectomy	2	8
Axillary node dissection	5	18
Lymph nodes removed, median (min, max)	8 (4, 13)	9 (0, 22)
Post-surgical complications, n		
Seroma/drainage	3	2
Infection	1	3
Chemotherapy, n	3	9
Radiation therapy, n		
Breast only	2	7
Breast and axillary region	1	6
Breast and supraclavicular region	1	0
Volume difference between limbs, mean (SD), ml**	235 (125)	1 (53)
Symptoms of tension in affected limb, n	1	0
Symptoms of heaviness in affected limb, n	1	1

BMI = body mass index; BCS = breast conservation surgery; *T = tumour, size and extent, rated T0–T4; N = node, presence or absence of lymph-node involvement, rated N0–N3

** $p=0.001$

Table 2 Details on Exercise Regimen Completed

Group	Overall (N = 23)	LE (n = 5)	BC (n = 18)
Total time of continuous exercise, minutes	22	22	22
Watts during exercise bout, mean (min, max)	43 (20, 55)	50 (40, 55)	41 (20, 50)
Revolutions per minute (RPM) (min, max)	71 (50, 90)	73 (59, 81)	70 (50, 90)
Rating of perceived exertion during exercise bout (min, max)	14 (13, 16)	14.6 (13, 16)	14 (13, 15)

LE = Lymphedema group; BC = Breast Cancer group.

Table 3 Mean Limb Volume in Breast Cancer Survivors at Baseline, Immediately Post Exercise, and in the Recovery Period Following Exercise (N = 23)

Group	Limb Volume ml	Baseline Mean (SD)	Post-exercise Mean (SD)	15 Minutes Mean (SD)	30 Minutes Mean (SD)	60 Minutes Mean (SD)
Total Group (N = 23)	Affected limb	2,250 (408)	2,312 (414)	2,270 (413)	2,250 (403)	2,236 (408)
	Unaffected limb	2,199 (367)	2,264 (365)	2,221 (364)	2,205 (358)	2,186 (358)
	Limb-volume difference	58 (130)	51 (138)	57 (146)	52 (133)	54 (149)

Table 4 Mean Arm Volume by Group at Baseline, Immediately Post Exercise, and in the Recovery Period Following Exercise

Group	Limb Volume ml	Baseline Mean (SD)	Post-exercise Mean (SD)	15 Minutes Mean (SD)	30 Minutes Mean (SD)	60 Minutes Mean (SD)
LE Group (n = 5)	Affected limb	2,425 (588)	2,488 (575)	2,449 (604)	2,412 (576)	2,425 (579)
	Unaffected limb	2,190 (483)	2,270 (477)	2,210 (469)	2,190 (464)	2,176 (448)
	Limb-volume difference	235 (125)	218 (130)	239 (157)	222 (140)	249 (164)
BC Group (n = 18)	Affected limb	2,202 (351)	2,263 (363)	2,219 (349)	2,206 (349)	2,183 (351)
	Unaffected limb	2,201 (346)	2,263 (345)	2,223 (345)	2,209 (339)	2,190 (345)
	Limb-volume difference	1 (53)	0 (82)	-3 (69)	-3 (61)	-7 (59)

Limb Volume

Baseline to post-intervention limb-volume measurements are provided in Table 3. Limb volume increased immediately following exercise in both limbs and recovered to slightly below baseline levels by 60 minutes. The difference between the limbs, however, remained stable at each measurement point. The baseline differences between the *affected* and *unaffected* limbs were 1 ± 53 ml for the BC group and 235 ± 124 ml for the LE group (see Table 4). In the BC group, the response to and recovery from exercise were similar in both limbs. In the LE group, there were differences in limb volume between the *affected* and *unaffected* limbs at each time point; however, the difference between the limbs did not change significantly at any time point following the exercise bout. None of the participants in the BC group exceeded the 200 ml cut-point for the difference between limbs post intervention (see Figure 1). Only one participant, in the BC group, had an increase of > 100 ml difference between limbs post intervention (see Figure 2). This participant had undergone a modified radical mastectomy with axillary node dissection on her dominant limb side and had received radiation therapy to the axillary region. Other risk factors for lymphedema in this

participant included a history of postoperative wound infection and current BMI > 30 kg/m².^{2,18}

Symptoms of Tension and Heaviness

None of the participants reported symptoms of tension and/or heaviness in the *unaffected limb* at any time point. Four participants, however, reported symptoms of tension and/or heaviness in the *affected limb* at one or more of the measured time points. One participant (LE group) reported symptoms of tension (5/10 on VAS) and heaviness (5/10 on VAS) in her *affected limb* (non-dominant side) at baseline that were unchanged following exercise. Another participant (BC group) reported symptoms of heaviness (2/10 on VAS) in her *affected limb* (dominant limb) at baseline that were also unchanged following exercise. One participant (BC group) reported the onset of symptoms of tension (3/10 on VAS) and heaviness (4/10 on VAS) in her *affected limb* (dominant limb) following exercise; however, in this participant the affected limb was smaller than the unaffected limb at all time points following exercise. The fourth participant (BC group) with symptoms reported heaviness (2/10 on VAS) in her *affected limb* (dominant limb) following exercise;

Figure 1 Volume difference between affected and unaffected limbs, by participant group, before and after exercise.

Figure 2 Change in limb-volume difference post exercise by participant group.

in this participant, an increase in limb-volume difference (*affected* – *unaffected*) of 58 ml was observed.

Potential Moderators

Three participants wore a compression sleeve during the exercise intervention, and all three were in the LE group. In these participants, a smaller mean increase in

absolute limb volume of 51 ml was observed in the *affected* limb, compared to the mean increase of 84 ml in the *unaffected* limb.

Sample-Size Estimates

The findings of the pilot study were used to determine the sample size for a subsequent study.

Of the 23 participants who took part in the pilot study, only one had an increase of >100 ml between the limbs post exercise. Thus, the proportion of participants with the outcome of interest (>100 ml increase) was approximately 4% (95% CI: -4%, 12%). Assuming an expected proportion of 0.04 and a 95% CI of 0.02–0.07, the required sample size for the subsequent study would be approximately 369 participants. This sample size was calculated for an exact confidence interval based on the binominal distribution.

DISCUSSION

This pilot study is one of the first to examine the effect of acute exercise on limb volume and symptoms of upper-limb tension and heaviness in women with breast cancer. Strengths of the study include the use of a moderate-intensity continuous upper-extremity exercise regimen to assess limb-volume response; this type of exercise was chosen specifically to induce increased blood flow to the limb to allow for assessment of response and recovery in terms of limb volume and symptoms of tension and heaviness. No differences were found in the exercise response between affected and unaffected limbs in our overall sample. Notably, we observed changes between the limbs in both directions and an increase of >100 ml in only one participant. Four participants (one in the LE group, three in the BC group) reported symptoms of tension and/or heaviness at one or more time points, although most reported low levels on the VAS. Thus, for the vast majority of women in the study, exercise did not have a significant impact on upper-limb volume or on symptoms.

The findings of this pilot study are consistent with evidence from the literature that suggests that participation in an exercise programme does not precipitate or exacerbate lymphedema.^{7,8} In theory, exercise should be beneficial for lymphatic function, as skeletal muscle contraction, which can be facilitated by exercise, is a primary force propelling lymph fluid by direct compression of the collecting lymphatic vessels.¹⁹ Thus, exercise may potentially enhance the “muscle pump” effect on the lymphatic system. Exercise can also improve lymphatic flow by increasing heart rate and arterial pulsations and by inducing changes in intrathoracic pressure via deep breathing.⁹ Moreover, exercise can improve soft-tissue and joint mobility, thereby reducing any potential impact of tissue fibrosis on venous and lymphatic flow.^{20,21}

Lane et al. examined the effect of an acute bout of intermittent exercise on lymphatic function.²² The study participants were breast cancer survivors with lymphedema (BCRL: $n=10$), breast cancer survivors without lymphedema (BC: $n=10$), and a control group of healthy age-matched women (Control: $n=10$). The authors reported that the BCRL group had similar clearance

from the hand during exercise but reduced accumulation of radiopharmaceutical colloid reaching the axillary lymph nodes on the affected side. Moreover, the BCRL group was found to have greater activity in the forearm region, suggesting dermal backflow that worsened with exercise. The authors also reported a variable response from exercise in the BC group, suggesting that some participants may have been at risk for developing lymphedema. In our pilot study, we did not observe a significant between-limb difference in the response to exercise for the overall group. However, we examined limb volume as a method to reflect a change in lymphatic function. This method does not provide information on the components that may contribute to an increase or decrease in limb volume and, furthermore, cannot detect subtle (sub-clinical) changes in lymphatic function that may be visualized through imaging techniques such as lymphoscintigraphy, used in the Lane study. Finally, our sample was composed of women who regularly took part in high-intensity exercise, while only two participants with BCRL in the Lane study reported regular exercise. Regular participation in an upper-body exercise-training programme may have allowed for adaptation of the lymphatic system, such that the acute exercise bout did not have a large impact. Thus, regular participation in dragon-boat racing by women in this study may have provided a level of protection that would not otherwise be experienced by breast cancer survivors not accustomed to upper-limb exercise.

An interesting finding of the pilot study was that only three participants reported wearing a compression sleeve for exercise, despite recommendations for the use of compression garments by survivors with or at high risk for lymphedema (e.g., patients who have undergone an axillary node dissection and radiation therapy).³ Interestingly, the three participants who wore a compression sleeve during the acute bout of exercise were found to have a smaller increase in affected limb volume than in unaffected limb volume. Although an observational finding, this is suggestive of a potential protective effect from the garment. Johansson et al., who examined the acute effect of low-intensity resistance exercise on lymphedema volume in 31 breast cancer survivors with or without a compression sleeve,²³ found a significant increase in *affected* limb volume ($p<0.01$) and a borderline significant increase in lymphedema volume ($p=0.07$) (i.e., *affected limb volume* – *unaffected limb volume*) in the affected limb immediately following exercise for both conditions (sleeve or no sleeve), which resolved over 24 hours. In contrast to our findings, Johansson et al. reported a non-significant increase in limb lymphedema volume when participants wore a compression sleeve during exercise, suggesting no benefit from use of the sleeve. One explanation for the disparity in findings is that the exercise bout in our study resulted in a larger overall increase in limb volume

bilaterally relative to the Johansson study. Moreover, we examined the effect of a moderate-intensity, continuous bout of aerobic exercise, whereas Johansson et al. examined low-intensity resistance exercise. Thus, the benefit of wearing a compression sleeve during exercise may be related to the type (aerobic vs. resistance) and intensity (moderate vs. low) of exercise; this point is worthy of further investigation.

The main limitation of the present pilot study was that it was underpowered to detect changes between the groups, as it was undertaken with the intent to inform future work. A future study with a larger sample would allow for evaluation of within-subject factors (e.g., obesity) and treatment-related factors (e.g., radiation therapy to the axilla) that are associated with increased risk of lymphedema.

In this study, a minority of women (22%) presented with lymphedema, using limb volume and limb circumference as the criteria; however, the percentage in the sample would be consistent with the reported incidence in the breast cancer population.¹⁸ The sample consisted of women who regularly participated in vigorous upper-limb exercise, and thus the findings are not generalizable to breast cancer survivors who do not regularly perform this type of exercise.

A further limitation of the pilot study was the choice of measurement outcome. Measurement of circumference was used in the pilot study because it is a simple and quick measurement method. Water-displacement volumetry, however, is considered the gold standard. Water-displacement volumetry was not chosen for the pilot study because it would not allow for measurements to be performed within the time constraints of exercise recovery. An alternative method to reduce error associated with limb-circumference measurements would be to use an opto-electrical volumetric system²⁴ such as the Perometer (Juzo, USA, Inc., Cuyahoga Falls, OH). The Perometer allows for measurement of the limb within a few seconds, has been shown to be highly reliable, and has been validated by comparison with circumferential and water-volume measurements.²⁴ Bioimpedance spectroscopy (BIS) is an alternative method that measures the impedance, or opposition to flow, of an electric current through body fluids and is used to assess extracellular, intracellular, and total-body water.²⁵ More recent evidence has demonstrated that BIS directly measures lymphedema with greater sensitivity and specificity than the indirect measures of limb circumference and limb volume.²⁵ BIS is able to quantify differences in fluid levels between the affected and unaffected limbs prior to detectable changes in limb volume and circumference.²⁵ The use of the Perometer in conjunction with BIS would allow for measurement of both limb volume and extracellular fluid within the time constraints of exercise recovery. Further validation of findings could be achieved through the addition of imaging techniques,

such as magnetic resonance or lymphoscintigraphy, that would allow for visualization of the effect of exercise on the structure and function of the lymphatic system.

A final limitation of the pilot study was that the exercise intensity for the study was determined by asking participants to select an exercise intensity based on an RPE (13 to 15, "somewhat hard" to "hard"). In a future study, it would be important to ensure a more consistent intensity of exercise across participants by monitoring objective physiologic measures such as heart rate.

CONCLUSIONS

The study findings suggest that the response to acute exercise in terms of changes in upper-limb volume is similar between affected and unaffected limbs in women with breast cancer who regularly engage in upper-limb exercise. The number of individuals potentially experiencing a transient increase in limb volume from an acute bout of moderate-intensity upper-limb endurance exercise appears to be low. Further research with a larger sample is needed to allow for appropriate evaluation of the effect of exercise on the lymphatic system and to explore the relationship between exercise response and known factors associated with increased risk of lymphedema.

KEY MESSAGES

What Is Already Known on This Subject

Lymphedema is a chronic progressive condition that can have profound adverse effects on a breast cancer survivor's quality of life. Preliminary research evidence suggests that participation in an exercise programme does not precipitate or exacerbate lymphedema. In the clinical setting, however, transient increases in arm swelling and/or symptoms of tension and heaviness are often reported to occur following acute upper-limb exercise or activity. The significance of these symptoms is unclear.

What This Study Adds

The findings of this pilot study suggest that the response to acute upper-extremity exercise in terms of upper-limb volume and symptoms is similar between affected and unaffected limbs in women with breast cancer who perform regular upper-extremity exercise. This study provides preliminary data that can be used to design future investigations on this topic.

REFERENCES

1. Erickson VS, Pearson ML, Ganz PA, Adams J, Kahn KL. Arm edema in breast cancer patients. *J Nat Cancer Inst.* 2001;93:96-111.

2. Ridner SH. Breast cancer lymphedema: pathophysiology and risk reduction guidelines. *Oncol Nurs Forum*. 2002;29:1285–93.
3. NLN Medical Advisory Committee. Position statement of the National Lymphedema Network: exercise [Internet]. Oakland, CA: The Network; 2008 [cited 2008 Oct 1]. Available from: www.lymphnet.org/pdfDocs/nlnexercise.pdf.
4. Harris SR, Hugi MR, Olivotto IA, Levine M, Steering Committee for Clinical Practice Guidelines for the Care and Treatment of Breast Cancer. Clinical practice guidelines for the care and treatment of breast cancer: 11. Lymphedema. *Can Med Assoc J*. 2001;164:191–9.
5. Harris SR, Niesen-Vertommen SL. Challenging the myth of exercise-induced lymphedema following breast cancer: a series of case reports. *J Surg Oncol*. 2000;74:95–8; discussion 98–9.
6. McKenzie DC, Kalda AL. Effect of upper extremity exercise on secondary lymphedema in breast cancer patients: a pilot study. *J Clin Oncol*. 2003;21:463–6.
7. Ahmed RL, Thomas W, Yee D, Schmitz KH. Randomized controlled trial of weight training and lymphedema in breast cancer survivors. *J Clin Oncol*. 2006;24:2765–72.
8. Courneya KS, Segal R, Mackey JR, Gelmon K, Reid RD, Friedenreich CM, *et al*. Effects of aerobic and resistance exercise in breast cancer patients receiving adjuvant chemotherapy: a multicenter randomized controlled trial. *J Clin Oncol*. 2007;25:1–9.
9. Miller L. Lymphedema: unlocking the doors to successful treatment. *Innov Oncol Nurs*. 1994;10:58–62.
10. Mortimer P, Badger C. Lymphoedema. In: Doyle D, editor. *Oxford textbook of palliative medicine*. 3rd edn. New York: Oxford University Press; 1998. p. 657–65.
11. Borg GAV. *Borg's Perceived Exertion and Pain Scales*. London: Human Kinetics; 1998.
12. Stanton AW, Badger C, Sitzia J. Non-invasive assessment of the lymphedematous limb. *Lymphology*. 2000;33:122–35.
13. Karges JR, Mark BE, Stikeleather SJ, Worrell TW. Concurrent validity of upper-extremity volume estimates: comparison of calculated volume derived from girth measurements and water displacement volume. *Phys Ther*. 2003;83:134–45.
14. Sander AP, Hajer NM, Hemenway K, Miller AC. Upper-extremity volume measurements in women with lymphedema: a comparison of measurements obtained via water displacement with geometrically determined volume. *Phys Ther*. 2002;82:1201–12.
15. Karges J. Assessing the relationship between water displacement and circumferential measurements in determining upper extremity volume in women with lymphedema [thesis]. Indianapolis: University of Indianapolis; 1996.
16. Williams AF, Franks PJ, Moffatt CJ. Lymphoedema: estimating the size of the problem. *Palliat Med*. 2005;19:300–313.
17. Stout Gergich NL, Pfalzer LA, McGarvey C, Springer B, Gerber LH, Soballe P. Preoperative assessment enables the early diagnosis and successful treatment of lymphedema. *Cancer*. 2008;112:2809–19.
18. Lawenda BD, Mondry TE, Johnstone PA. Lymphedema: a primer on the identification and management of a chronic condition in oncologic treatment. *CA Cancer J Clin*. 2009;59:8–24.
19. Loscalzo J, Creager MA, Dzau VJ. *Vascular medicine*. Boston: Little: Brown; 1992. p. 1099–104.
20. Brennan MJ, Miller LT. Overview of treatment options and review of the current role and use of compression garments, intermittent pumps, and exercise in the management of lymphedema. *Cancer*. 1998;28:2821–7.
21. Mortimer PS. Managing lymphoedema. *Clin Exp Dermatol*. 1995;20:98–106.
22. Lane KN, Dolan LB, Worsley D, McKenzie DC. Upper extremity lymphatic function at rest and during exercise in breast cancer survivors with and without lymphedema compared with healthy controls. *J Appl Physiol*. 2007;103:917–25.
23. Johansson K, Tibe K, Weibull A, Newton RC. Low intensity resistance exercise for breast cancer patients with arm lymphedema with or without compression sleeve. *Lymphology*. 2005;38:167–80.
24. Stanton AW, Northfield JW, Holroyd B, Mortimer PS, Levick JR. Validation of an optoelectronic limb volumeter (Perometer). *Lymphology*. 1997;30:77–97.
25. Cornish BH, Chapman M, Hirst C, Mirolo B, Bunce IH, Ward LC, *et al*. Early diagnosis of lymphedema using multiple frequency bioimpedance. *Lymphology*. 2001;34:2–11.