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EFFECTS OF COMPRESSION ON LYMPHEDEMA DURING RESISTANCE EXERCISE IN WOMEN WITH BREAST CANCER-RELATED LYMPHEDEMA: A RANDOMIZED, CROSS-OVER TRIAL

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ABSTRACT

The use of compression garments during exercise is recommended for women with breast cancer-related lymphedema, but the evidence behind this clinical recommendation is unclear. The aim of this randomized, cross-over trial was to compare the acute effects of wearing versus not wearing compression during a single bout of moderate-load resistance exercise on lymphedema status and its associated symptoms in women with breast cancer-related lymphedema (BCRL). Twenty-five women with clinically diagnosed, stable unilateral breast cancer-related lymphedema completed two resistance exercise sessions, one with compression and one without, in a randomized order separated by a minimum 6 day wash-out period. The resistance exercise session consisted of six upper-body exercises, with each exercise performed for three sets at a moderate-load (10-12 repetition maximum). Primary outcome was lymphedema, assessed using bioimpedance spectroscopy (L-Dex score). Secondary outcomes were lymphedema as assessed by arm circumferences (percent inter-limb difference and sum-of-circumferences), and symptom severity for pain, heaviness and tightness, measured using visual analogue scales. Measurements were taken pre-, immediately post- and 24 hours post-exercise. There was no difference in lymphedema status (i.e., L-Dex scores) pre- and post-exercise sessions or between the compression and non-compression condition [Mean (SD) for compression pre-, immediately post- and 24 hours post-exercise: 17.7 (21.5), 12.7 (16.2) and 14.1 (16.7), respectively; no compression: 15.3 (18.3), 15.3 (17.8), and 13.4 (16.1), respectively]. Circumference values and symptom severity were stable across time and treatment condition. An acute bout of moderate-load, upper-body resistance exercise performed in the absence of compression does not exacerbate lymphedema in women with BCRL.

Keywords: Lymphedema, breast cancer, compression, exercise, randomized crossover trial

Arm lymphedema occurs in 20% of

women following breast cancer (1). Lymphedema is characterized by protein-rich fluid accumulating within the interstitial spaces as a consequence of an imbalance between lymph load and transport capacity (2,3). Clinically, breast cancer-related lymphedema (BCRL) presents as swelling of the arm and/or trunk region on the affected side. It contributes to upper-body morbidity including the presence of pain, heaviness, tightness, weakness, and poor range of movement of the arm and shoulder, as well as psychosocial concerns including reduced self-esteem, depression and anxiety (4-8). It is a feared breast cancer treatment sequelae, deserving of preventive, early diagnosis, and management efforts.

A growing and compelling body of literature has been used to inform breast cancer survivorship guidelines, with these guidelines highlighting the importance of participating in regular, moderate-load exercise post-breast cancer. Exercise leads to improvements in physical and psychosocial well-being, overall quality of life, and has been linked with prevention of future chronic disease and improvements in disease-specific and overall-survival post-breast cancer (9-14). Specifically in relation to lymphedema, participation in regular resistance exercise has been linked with reducing the risk of lymphedema, in particular for those who have ≥ 5 axillary nodes removed as part of their surgical treatment for breast cancer, as well as effective management of the condition and its associated symptoms (10,11,15,16).

The current clinical recommendation for individuals with lymphedema is to wear compression sleeves while exercising (17), but the evidence behind these clinical recommendations is unclear (18). It may simply be because daily compression of the lymphedematous limb is the most common form of lymphedema treatment (19) and that it is possible to exercise while wearing compression (that is, individuals can continue with prescribed treatment even when exercising), or that the pressure from the compression garment against the contracting muscle may promote lymph flow and/or doesn't allow the tissue to extend further. Current guidelines may also be influenced by previous landmark studies (16,20) in which all participants wore compression during exercise. Although of note, guidelines informed the protocol regarding garment wear in these studies. Alternatively, the use of compression during exercise has been associated with enhanced blood circulation, reduced blood lactate concentrations during exercise and facilitation of lactate removal following exercise, reductions in swelling and perceptions of pain, enhanced warm-up, improved exercise performance and reduced effects of delayed onset muscle soreness (21-27). These effects may be perceived as desirable for those with an impaired lymphatic system, such as those with lymphedema. However, the necessity to wear compression is a major concern described by women with BCRL, resulting in negative effects on body image and function (28-30). Women with BCRL have reported exercise to be 'harder' when compression is worn while exercising (31). Compression use can cause discomfort, impede mobility, impair with heat transfer mechanisms (23,26,30-32), and may present as a barrier to regular exercise participation for women with BCRL (32). Thus, scientifically evaluating the need for the clinical guideline is warranted.

Two studies, conducted by Johansson et al (31,33), provide preliminary evidence regarding the need, or lack thereof, for compression during exercise for those with BCRL. The first study involved 31 women with unilateral BCRL, undertaking an acute, low-intensity resistance exercise session with or without compression (31). Order of compression and no compression session was randomized and sessions were performed on different days. Transient increases in total arm volume (water displacement), immediately post-exercise were observed for the compression session, but not the session undertaken without compression, and there

was a tendency towards reduced lymphedema 24 hours post-exercise, irrespective of whether compression was worn. In a subsequent study, which also involved the assessment of lymphedema pre-, post- and 24 hours post- a moderate-to-high intensity (reported as >15 on the Borg Ratings of Perceived Exertion scale (34)) resistance exercise session in the absence of compression (there was no compression condition for comparison purposes), similar findings to the original study were observed (33). That is, lymphedema remained stable between pre- and immediately post-exercise, while there was suggestion of a decline in arm volume by 24 hours post-exercise. However, assessment of lymphedema in both these studies was through measurement of arm volume, which is insensitive to subtle changes in extracellular fluid, which could differ between compression and no compression exercise sessions. Therefore, we sought to advance understanding in this area by evaluating the acute response in those with BCRL to a bout of moderate-load resistance exercise [the load now routinely recommended to women following breast cancer (35)], with and without compression, by evaluating exercise effect on lymphedema status, (through measurement of extracellular fluid and arm size), as well as lymphedema-associated symptoms. It was hypothesized that performing moderate-load resistance exercise in the absence of compression will not exacerbate lymphedema.

METHODS

Study Design

The present study used a multicenter, randomized, cross-over design. Participants completed two moderate-load resistance exercise sessions: 1) wearing compression (COMP); and 2) without compression (noCOMP). Randomization (computer-generated by a research assistant) occurred in a 1:1 ratio, with participants allocated into their first resistance exercise session following baseline assessment. To be eligible for study involvement, participants: (i) must have been diagnosed with unilateral breast cancer between 1-15 years ago, (ii) were currently cancer-free and/or have completed active breast cancer treatment (excluding hormone therapy), (iii) must have received a clinical diagnosis of BCRL, and (iv) have stable lymphedema. Stable lymphedema was defined as the absence of therapist-delivered treatment and no arm infections requiring antibiotics in the previous three months. A clinical diagnosis of BCRL was defined as an inter-limb difference of ≥10% in volume or circumference, or >5 cm difference in the sum of circumference between the affected and non-affected side (16). Participants were excluded from participating if they were: (i) over 70 years old; or (ii) diagnosed with any musculoskeletal, cardiovascular or neurological disorder that may limit their ability to safely exercise.

Following ethical approval, potentially eligible women were identified using databases held by study researchers (n=126) and were sent study information packages between August 2011 and February 2012. Of these, 23 were ineligible, 58 declined to participate (e.g., for reasons primarily due to travel and time constraints), and 17 could not be contacted to discuss the study further. This left a convenience sample of 28 women with clinician-diagnosed, unilateral BCRL providing consent to participate in the study (*Fig. 1*). Written informed consent for study participation was also obtained from each woman's general practitioner. All participants were advised to maintain their normal lymphedema self-management strategies, activities of daily living including physical activity patterns, and dietary behaviors during study participation.

Data collection and exercise sessions

All data collection and exercise sessions were conducted by Accredited Exercise

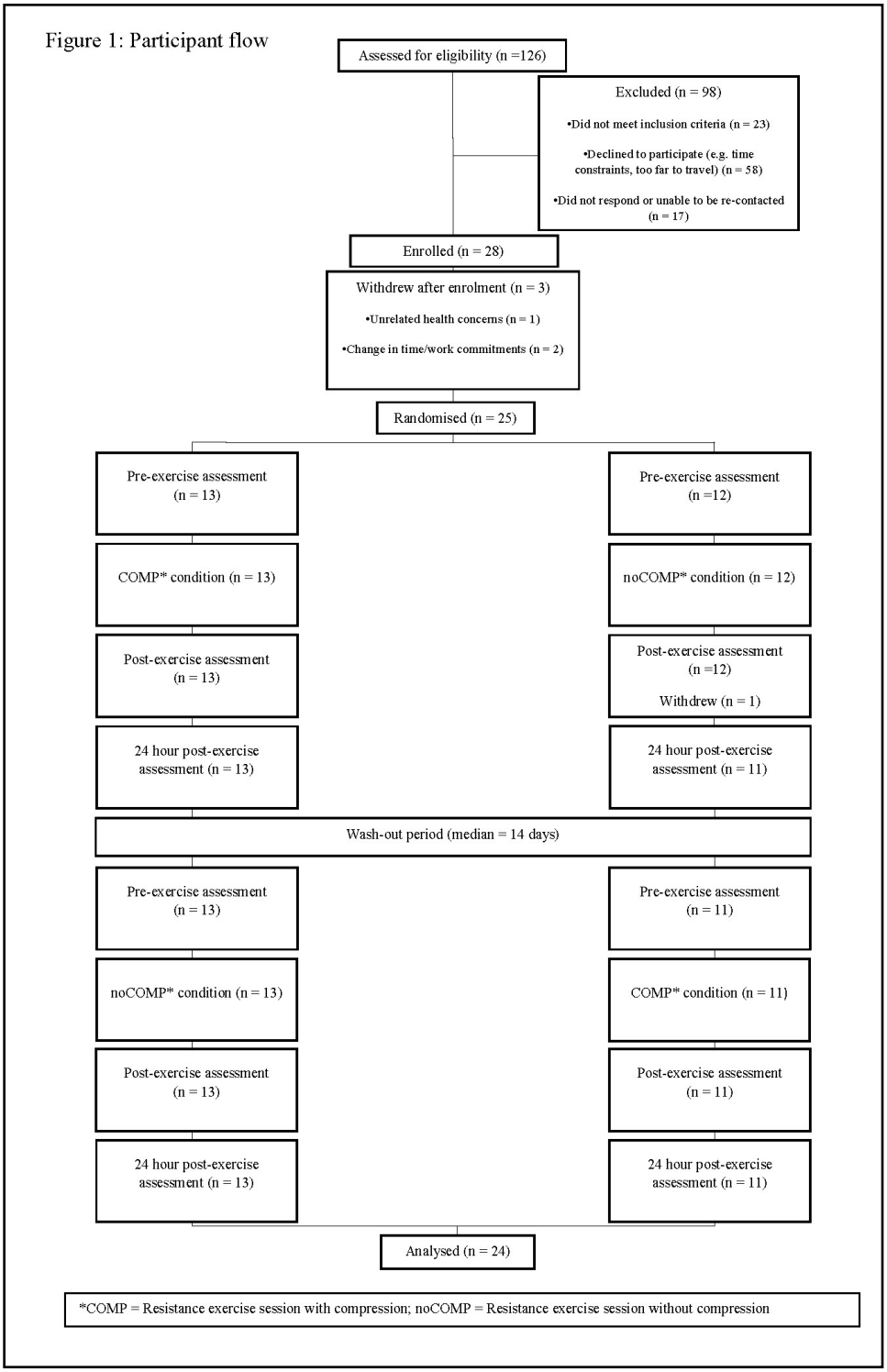

Fig. 1. Participant flow

Physiologists with experience in exercise prescription for women with breast cancer. Neither the participants nor the exercise physiologist conducting outcome assessments were blinded to the exercise condition. The testing protocol, including data collection and testing sessions is outlined in *Fig. 1*. The participants completed four familiarization visits, over a period of two weeks, prior to the experimental exercise sessions. During these sessions, participants were instructed on the correct technique of six resistance exercises, targeting all major upper-body muscle groups. Intensity of these familiarization sessions progressed from very light (two sets of 15-20 repetitions with minimal weight) during the first session, through to moderate load resistance (three sets of 10-12 repetitions) by the final familiarization session. The weight lifted for each set was adjusted so that 10-12 repetitions could be completed per set with the final repetition in each set requiring near maximal effort for a successful lift. Resistance exercises undertaken during familiarization and testing sessions included chest press, bent-over row, biceps curl, triceps extension, lateral raise, and wrist curl. Data collection sessions occurred immediately before, after, and 24 hours post-exercise testing sessions (*Fig. 1*). Regular compression sleeve use prior to the first testing exercise session (i.e., outside the study) was kept consistent for the second session. Participants were asked to remove their garments (when relevant) at the beginning of all data collection sessions, and then reapplied the garment on completion of the data collection session (unless they were about to participate in the COMP exercise session). For the exercise sessions, three sets of six exercises were performed with two minutes rest between each set and between each exercise. Each set was performed with a load corresponding to the maximum amount of repetitions that could be performed 10-12 times (i.e., 10-12 RM (36)). Familiarization and testing sessions included an appropriate warm-up and cool-down period, which involved 5-10 minutes of low-intensity aerobic exercise (walking or stationary cycling) and static stretching of all major upper-body muscle groups. The two experimental exercise sessions (COMP and noCOMP) were separated by at least a 6 day wash-out period. When available, participants wore their own compression garment during the COMP condition (n=20), or were provided with a personally-fitted compression sleeve (n=5; Venosan 7002 (23-32 mmHg)).

Outcomes of interest

Arm lymphedema was assessed with standard objective methods including bioimpedance spectroscopy [BIS (SFB7, Impedimed, Brisbane, Australia), primary outcome] to assess extracellular fluid and measurements of arm circumferences (37-40) to assess arm size. Bioimpedance spectroscopy is a previously well-described, reliable, sensitive, objective method to assess pitting and/or subclinical lymphedema (39,41-43). It is used to measure the impedance of the extracellular fluid for each limb, with the ratio of these values, comparing the affected and non-affected limbs then calculated (SFB7, Impedimed, Brisbane, Australia). The ratio of impedance values is then converted to an L-Dex score; lymphedema is present when L-Dex is >10, and lymphedema has worsened (that is, extracellular fluid has increased in the affected limb) when the L-Dex score increases by ≥ 10 (equivalent to a 10% increase in the impedance ratio).

Secondary outcomes were lymphedema assessed by arm size using arm circumferences, and symptom severity. Arm circumference measurements are a reliable technique for assessing lymphedema (38). Circumference measurements were performed as per Australasian Lymphology Association protocols (44), with participants seated upright with their arm positioned at 90° abduction, rested on a measuring board (Jobst, North Carolina, USA). Participants maintained their shoulders straight and level, with legs uncrossed. A set-square was used

to ensure accurate and reproducible marking of the limb (44). The locations of the tip of the third finger, the mid-point of the ulnar and radial metacarpo-phalangeal joints and the ulnar styloid process were recorded and a set-square was used to mark 5-cm increments from the ulnar styloid mark up to the participant's axillary fold. Measurements were taken using a constant tension measuring tape. Arm circumference measures were reported as the sum-of-circumferences (centimeters) of the affected arm and the percentage difference in the sum-of-circumferences between the affected and non-affected arms. The severity of lymphedema-associated symptoms including pain, heaviness and tightness were assessed using a visual analogue scale (VAS) of 0 (corresponding to no pain, heaviness, or tightness) to 10 (severe/worst pain, heaviness, or tightness). During the immediate post-exercise data collection session, a rating of perceived exertion (RPE) for the session just completed was recorded [scale: 6 to 20 (34)], and participants were asked to rate the extent to which they agree to the statement 'I have found this exercise session to be tolerable' (1=strongly disagree; 7=strongly agree).

Statistical Analyses

Data were analyzed using SPSS Statistics for Windows, Version 21 (IBM SPSS, Chicago, IL). Descriptive statistics for baseline characteristics included means and standard deviations (SD) for continuous variables, or counts and percentages for categorical variables. Normally distributed continuous outcomes were analyzed using repeated measures analyses of variance to determine statistically significant condition (COMP and noCOMP) x time (pre-exercise, immediately post-exercise, and 24 hours post-exercise) interactions, while Bonferroni post-hoc tests were used to identify where these differences lie. All available data were used in analyses, with no imputation of data generated. All tests were 2-tailed with a criterion α level of 0.05. Sample size calculations indicated that to detect a change in L-Dex score of 10 units as statistically significant, with power and significance set at 80% and 5% (two-tailed), respectively, approximately 22 participants were required.

RESULTS

Participant Characteristics and Retention

Flow of participants through the study is presented in *Fig. 1*. Three of the 28 participants who consented to participate and provided baseline information withdrew prior to completing any experimental exercise sessions. Reasons included unrelated health concerns (n=1), change in work commitments (n=1) and unable to commit time as initially intended (n=1). There was no discernible difference in their demographic or lymphedema-related characteristics compared with the remaining sample (*Table 1*). Participants were on average aged 61 years and had lymphedema for a mean of 8 years (*Table 1*). The majority (84%) were overweight or obese. There were no minor or major adverse events during the study. Mean (SD) RPE for both exercise conditions was similar [COMP = 12.5 (2.1) and noCOMP = 12.7 (1.9)] and corresponded to moderate-intensity. Participants rated both exercise conditions as being tolerable [COMP = 6.3 (0.9) and noCOMP = 6.0 (1.5)] with exercise tolerance not influenced by compression. Missing data were minimal (BIS measures could not be taken from one participant due the presence of a titanium knee insert and one participant completed the noCOMP condition only and withdrew prior to the 24 hour post-exercise data collection session).

Outcomes of Interest

A statistically significant condition x time interaction was identified for lymphedema assessed using BIS (*Table 2*), with post-hoc analysis demonstrating a reduction in L-Dex

TABLE 1
Personal, Diagnostic and Physical Activity Characteristics of the Sample (n = 25)

Characteristics	Mean (SD) or n (%)
Age (years)	61.5 (9.2)
Weight (kg)	79.9 (15.6)
Body mass index (kg/m^2)	30.9 (5.7)
Underweight (<18.5)	0 (0%)
Normal (18.5–24.9)	4 (16%)
Overweight (25–29.9)	10 (40%)
Obese (≥30)	11 (44%)
Presence of comorbidities[1]	
0	10 (35%)
1	6 (21%)
2	8 (29%)
3+	4 (15%)
Time since cancer diagnosis (years)	9.3 (9.0)
Cancer stage	
I	5 (20%)
II	5 (20%)
III	5 (20%)
IV	2 (4%)
Missing	9 (36%)
Adjuvant treatment (yes)	
Radiotherapy	21 (84%)
Chemotherapy	19 (76%)
Hormone therapy (currently and/or previously)	14 (56%)
Surgery (yes)	24 (96%)
Full axillary clearance (yes)	19 (76%)
Number of lymph nodes dissected	16 (8.1)
Years since lymphedema diagnosis	7.8 (8.4)
Lymphedema treatment in previous 3 months (yes)	8 (32%)
Currently physically active[2] (yes)	19 (76%)

[1]Comorbidities include hypertension/ high blood pressure, high cholesterol, Cardiovascular disease or heart disease, diabetes, and osteoporosis
[2]Physically active defined as meeting the Australian national physical activity guidelines (52)

score immediately following participation in the COMP exercise session (p-value <0.01). There was no statistically significant or clinically relevant difference over time or between testing conditions for all other outcomes of interest, including lymphedema assessed with circumferences (*Table 2*) and symptom severity (*Table 3*). Pre-COMP and noCOMP condition, between 38-58% of participants reported no pain, heaviness or tightness (that is, marked 0 on the 0-10 VAS scale) and between 13-29% reported the severity of either their pain, heaviness or tightness as being ≥1. The mean (SD) for those reporting symptom severity as ≥1 for pain (n=4), heaviness (n=5) or tightness (n=5) pre-COMP was 2.7 (1.4), 3.5 (1.7), and 3.5 (1.7), respectively, and the mean scores pre-noCOMP for those reporting pain (n=3), heaviness (n=9) or tightness (n=8) severity as

TABLE 2
Lymphedema Status, as Measured by Bioimpedance Spectroscopy and Circumference Measurements, for Compression and No Compression Conditions Pre-Exercise, Immediately Post-Exercise, and 24 Hours Post-Exercise

	Compression Mean (SD)	No Compression Mean (SD)	p-value[2]
BIS (L-Dex score)[1] (n=23)			<0.01
Pre-exercise	17.7 (21.5)	15.3 (18.3)	
Immediately post-exercise	12.7 (16.2)*	15.3 (17.8)	
24 hours post-exercise	14.1 (16.7)	13.4 (16.1)	
Percentage difference between affected and unaffected limb (%)[3] (n = 24)			0.89
Pre-exercise	6.8 (6.1)	7.9 (7.3)	
Immediately post-exercise	6.6 (5.8)	7.8 (7.7)	
24 hours post-exercise	6.9 (5.7)	6.9 (6.0)	
Total circumference on affected limb (cm) (n = 24)			0.99
Pre-exercise	279.1 (51.5)	281.0 (50.8)	
Immediately post-exercise	280.3 (51.7)	282.3 (51.4)	
24 hours post-exercise	278.9 (51.1)	278.8 (51.2)	

BIS: Bioimpedance spectroscopy
[1]Bioimpedance spectroscopy L-Dex score ≥ 10 indicates lymphedema. An increase in L-Dex represents a worsening of lymphedema
[2]p-values represent an overall time (pre-exercise, immediately post-exercise, and 24 hours post-exercise) × condition (compression and no compression) value
[3]Represents the percentage difference of the sum of circumferences of affected and unaffected limb
*Statistically significant difference between pre-exercise and immediately post-exercise (p = 0.03)

TABLE 3
Number of Participants Reporting a Change in Symptom Severity of ≥2 Units in VAS Scores for Pain, Heaviness and Tightness from Pre-Exercise to Immediately Post-Exercise, and from Pre-Exercise to 24 Hours Post-Exercise

	COMP	noCOMP
Pain		
Δ Post-exercise	↑ (n=0); ↓ (n=1)	↑ (n=1); ↓ (n=0)
Δ 24 hours post-exercise	↑ (n=0); ↓ (n=1)	↑ (n=0); ↓ (n=0)
Heaviness		
Δ Post-exercise	↑ (n=0); ↓ (n=0)	↑ (n=2); ↓ (n=1)
Δ 24 hours post-exercise	↑ (n=1); ↓ (n=1)	↑ (n=0); ↓ (n=0)
Tightness		
Δ Post-exercise	↑ (n=0); ↓ (n=0)	↑ (n=1); ↓ (n=1)
Δ 24 hours post-exercise	↑ (n=0); ↓ (n=2)	↑ (n=2); ↓ (n=1)

Δ Post-exercise indicates change from pre-exercise to immediately post-exercise
Δ 24 hours post-exercise indicates change from pre-exercise to 24 hours post-exercise
↑ Number of participants reporting an ≥2 unit increase in VAS score
↓ Number of participants reporting an ≥2 unit reduction in VAS score

≥1 was 2.4 (2.1), 2.6 (2.2) and 2.8 (2.4), respectively. Mean change in sensations over time within the COMP and noCOMP condition was minimal [mean change for pain, heaviness and tightness between pre-exercise to 24 hour post-COMP condition: -0.1 (0.8), 0.1 (1.2) and -0.1 (0.8), and pre-exercise and 24 hour post-noCOMP condition: 0.1 (0.4), -0.1 (0.6) and 0.0 (1.1), respectively]. There was also no significant change in the proportions of women reporting pain, heaviness and tightness severity as ≥1 after exercise. Nonetheless, as shown in *Table 3*, there were three individuals who reported increases in severity of symptoms by 2 or more units for heaviness (n=1, COMP) or tightness (n=2, noCOMP) from pre-exercise to 24 hours post-exercise (range: 2.3 to 4.6) and five individuals who reported reductions in severity of symptoms by 2 or more units for pain (n=1, COMP), heaviness (n=1, COMP) or tightness (n=2/1, COMP/noCOMP) from pre-exercise to 24 hours post-exercise (range: 2.1 to 2.5).

DISCUSSION

The key findings from this study are that arm lymphedema and lymphedema-associated symptoms were not exacerbated in the short-term when moderate-load resistance exercise was undertaken without compression, and a single bout of moderate-load resistance exercise was well tolerated by all participants, irrespective of whether compression was worn during exercise.

In this study we showed a statistically significant decrease in lymphedema (as assessed by BIS) following moderate-load resistance exercise when compression is worn. However, the clinical relevance of the magnitude of this change is questionable and was transient. Interestingly though and in contrast to the findings from our study, Johansson et al's work (31) indicated that lymphedema increased, albeit of a small magnitude, immediately following low-load resistance exercise with compression (as assessed by limb volume change). The differences in study findings are likely explained by the different exercise protocols (i.e., resistance loads evaluated) and the difference in the method of lymphedema assessment (arm volume measurements versus extracellular fluid measures). When assessing lymphedema status through measurement of volume, it is unclear whether any increases observed are a consequence of increases in intracellular fluid (e.g., through blood flow increases, which is the normal physiological response to exercise), extracellular fluid (which would reflect an increase in lymphedema), or a combination of the two. Measures of lymphedema using BIS provide a more specific assessment of extracellular fluid. When exercising while wearing compression it seems more likely that extracellular fluid would decrease rather than increase when compared with exercise without compression. This is because compression has been shown to be an effective form of lymphedema treatment, and the muscle pump represents one of the main ways in which lymph is transported (45). Of clinical relevance though, irrespective of the manner by which lymphedema status was assessed [both in this study and prior work by Johansson et al. (31)], is that the magnitude of change observed in lymphedema immediately following a bout of resistance exercise was modest and transient.

Findings from this study are in line with previous studies which query the necessity of compression use during resistance exercise and reported no exacerbation of lymphedema when performing resistance exercise without compression (31,33). Previous studies have demonstrated that low-intensity resistance exercise performed in the absence of compression does not exacerbate lymphedema in the short-term, and the current work extends this to include resistance exercise of a moderate-load. Moreover, irrespective of whether compression was worn, a single bout of moderate-load resistance exercise was well tolerated by all participants. Previous work

suggests that compression may act as a form of perceived support during exercise (31). However, our study failed to show that resistance exercise was more tolerable when wearing compression.

Johansson et al's work reported reductions in pain and heaviness up to 24 hours post-exercise without compression (31,33). Findings from our work cannot be used to either confirm or refute these findings. Most of the women in our convenience sample reported either no, or low levels of symptom severity (i.e., pain, heaviness or tightness) prior to exercise, which limited our ability to see improvements in these self-reported outcomes. Conversely though, symptom characteristics of the sample would have improved the ability to observe an adverse effect. There was a slight trend suggesting more participants reported an increase in pain, heaviness or tightness immediately after or 24 hours after the noCOMP condition compared with the COMP condition. However, given the proportion of participants reporting an increase and the magnitude of the change, caution needs to be applied before drawing strong conclusions about the clinical relevance of these data.

Compression use during exercise and recovery in non-clinical settings has been implicated in facilitating the clearance of muscle metabolites and reducing post-exercise swelling and delayed onset muscle soreness (21,23,26). In such cases, compression is suggested to influence physiological mechanisms by augmenting local blood flow, reducing the magnitude of inflammation-associated swelling and assisting in the clearance of myocellular proteins and inflammatory mediators (21,23,26). This may be considered desirable, particularly for women with BCRL, given the presence of lymphedema is an indicator of an impaired lymphatic system. While no acute benefits of compression use during a resistance exercise session with respect to declines in lymphedema were observed in the current study, future research that measures inflammatory biomarkers may help substantiate or refute this potential physiological rationale for compression use during exercise.

There are possible adverse consequences for suggesting that compression use is necessary for safe participation in exercise for these women. Women experience declines in physical activity levels following diagnosis of BCRL (32), and as such, clinical practice guidelines need to assist women to stay or become appropriately active following BCRL. Unfortunately, the need to wear compression during exercise has been identified as a barrier to regular exercise participation (32). Issues associated with wearing compression garments during exercise include discomfort and irritation, mobility restrictions, interference with heat transfer mechanisms, difficulties in applying and/or removing a garment before and after exercise, as well as negative effects relating to body image and self-esteem (29,32,46-51). For some, there are also access and affordability issues in acquiring specialist-prescribed and fitted garments.

Limitations of this present study include a lack of participant and assessor blinding, as well as recruitment of a sample which experienced few and mild lymphedema-associated symptoms. Nonetheless, the objective assessment of outcomes, using standardized procedures reduced the risk of measurement bias, and while sample characteristics reduced the ability to detect improvements in symptoms, the ability to detect adverse changes in symptoms was improved. In summary, findings from this randomized, cross-over designed study suggest that failure to wear compression during an acute bout of moderate-load resistance exercise does not exacerbate lymphedema or its associated symptoms. Future research is now required to quantify the longer-term effects of exercise in the absence of compression. Until such time as these results become available, the recommendation to wear or not wear compression during exercise should be considered on an individual basis, taking into

consideration patient preferences and adherence issues regarding compression use.

Ethical Approval: Ethical approval was received by Queensland University of Technology's and Edith Cowan University's human research ethics committees.

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RUN and SCH led the work undertaken at Edith Cowan University and Queensland University of Technology, respectively.

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