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Exercise-Based Cancer Rehabilitation Program Improves Phase Angle in Breast Cancer Survivors

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ABSTRACT

International Journal of Exercise Science 15(3): 1444-1456, 2022. Phase angle (PhA) is an index of cell membrane integrity and prognostic indicator of survival and quality of life in cancer survivors. The efficacy of exercise-based cancer rehabilitation programs (ExCR) on PhA is unknown. To assess the effect of ExCR on PhA in breast cancer survivors. Fifty-nine female breast cancer survivors (61 ± 9 years) were referred to the ExCR by their oncologist and participated in one-on-one exercise-based training for 90 minutes, 3 times a week, for 12 weeks. Training sessions included 45 minutes of resistance training at intensities between 40-85% of 1-repetition maximum with a rate of perceived exertion (RPE) between 3-8, 30 minutes of cardiorespiratory training at intensities between 40-85% of heart rate reserve with an RPE between 3-8, and 15 minutes of flexibility training. Participants completed pre- and post-measurements of body composition, cardiorespiratory endurance, flexibility, muscular endurance, muscular strength, and PhA (Inbody 770). PhA significantly increased ($p < 0.05$) after ExCR ($PhA_{pre} = 4.56$; $PhA_{post} = 4.64$; $\Delta = 1.8\%$). Changes in measures of muscular strength have a weak but significant positive relationship ($r = 0.20\text{-}0.39$; $p < 0.05$) with changes in PhA. There was no relationship between changes in PhA and changes in cardiorespiratory endurance or muscular endurance. A 12-week ExCR significantly improves PhA in breast cancer survivors. Training muscular strength may be an integral component of ExCR with the objective of improving PhA.

KEY WORDS: Cancer survivorship, bioimpedance, muscular strength

INTRODUCTION

Advances in cancer screening, treatments, and supportive care has led to a decrease in cancer mortality rates, which indicates the number of cancer survivors is likely to increase rapidly (41, 42). However, cancer treatments cause toxicities that may increase mortality and decrease quality of life (3). Exercise is an effective tool that can combat the negative effects of cancer and treatment, but additional research is needed to improve clinical practice (12).

Bioelectrical impedance analysis derived phase angle (PhA) is considered a prognostic indicator of survival (21) and quality of life (19) in cancer survivors. PhA is produced by the correlation between the resistance (R) of the electrolyte containing total body water, and reactance (Xc) that is present due to cell membranes acting as capacitors (17). Low PhA values indicate a low Xc and high R, or poor membrane integrity and malnutrition respectively (38). In contrast, high PhA values result from high Xc and low R, or intact cell membranes and higher levels of electrolytes and total body water (32). Thus, nutritional programs which increase electrolyte-containing water may decrease R (14), whereas exercise may increase Xc (43). Furthermore, PhA is affected by changes in the capacitive behavior of the tissues, cell size and mass, cell membrane permeability, and intracellular composition (15, 32).

The average PhA of cancer survivors is significantly lower than their healthy age-matched counterparts (4, 8, 29). The effects of cancer and cancer-related treatments (e.g., chemotherapy and radiation) are likely to decrease PhA by damaging cell membranes, causing inflammation and cancer-related cachexia. Cancer itself is known to alter the composition of cell membranes, causing deformation and increased rigidness (30). During eccentric contractions, rigid cell membranes are likely to tear, resulting in breaches that will influence the integrity of the cell membrane (1). Radiation, inflammation, and oxidative stress from toxic cancer-related therapies will also affect cell membrane integrity (1). Furthermore, cancer-related therapies result in cachexia that decreases body cell mass (7), which is known to decrease PhA (18, 45). Fortunately, exercise can reverse damage to cell membranes (1), which results in adaptations that improve cell membrane integrity (11, 46), and ultimately Xc (36). A PhA of 5.6° has been established as a cutoff value as a marker of the health status and functional capacity in breast cancer survivors (26). Therefore, the development of ExCR specifically designed to increase PhA in cancer survivors may be essential to improve survival and quality of life.

The effect of an exercise-based cancer rehabilitation program (ExCR) on PhA in cancer survivors is unclear (27). Evidence suggests that the use of resistance and/or endurance training has the potential to improve PhA in cancer survivors (27). A systematic review of PhA in athletes suggests that muscle strengthening causes a greater increase in PhA compared to endurance training (15). Although PhA has been shown to be a marker of muscular strength in breast cancer survivors (28), the superiority of any exercise program (e.g., resistance, or aerobic) in improving PhA in cancer survivors is unclear (27). The American College of Sports Medicine recommends that a concurrent model (resistance + aerobic + flexibility) should be prescribed for individuals with cancer (5). Therefore, the purpose of this study is to (1) examine the effects of a concurrent ExCR on PhA in breast cancer survivors, and (2) evaluate the relationship between changes in PhA and changes in muscular strength, muscular endurance, cardiorespiratory endurance, flexibility, and body composition. We hypothesize that ExCR will improve PhA, and that improvements in PhA will be correlated with improvements in cardiorespiratory endurance, muscular endurance, and muscular strength.

METHODS

Participants

Sample size was calculated while considering a medium (d = 0.5) Cohen's d effect size, with a 5% type I error, and 80% power. The estimated sample size was 35 participants. A medium effect size of 0.5 was used as previous work showed that a 6-month exercise intervention resulted in a 6% improvement in PhA, concomitant with a medium effect (Cohen's d = 0.4)(44). Fifty-nine female breast cancer survivors (61 ± 9 years) were recruited to participate in this study. Subjects were invited to participate through cancer survivor groups, oncologist referrals, and word-of-mouth. Subject's demographic data was collected during the initial intake, where both the time since diagnosis and the time since the last round of cancer treatment were self-reported. Participants' cancer rehabilitation phase (2) was assigned at the conclusion of the initial measurements. Participant characteristics can be found in Table 1. Inclusion criteria consisted of a breast cancer diagnosis, medical clearance to participate in an exercise-based intervention, literacy in English, and a minimum age of 18 years. Informed consent was obtained from all subjects included in the study. The study was conducted in accordance with the Declaration of Helsinki and approved by the University of Hawaiʻi Institutional Review Board (#2017-00979) for studies involving humans. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (31).

Table 1. General Subject Characteristics (mean ± SD)

Breast Cancer Survivors	*N*	59
Age	(years ± SD)	61 ± 9
Weight	(kg ± SD)	67.7 ± 18.7
Height	(cm ± SD)	158.9 ± 8.5
Time Since Cancer Dx	(months ± SD)	59 ± 37
Time Since Last Treatment	(months ± SD)	49 ± 29

Protocol

A prospective cohort study was carried out over a 16-week period. Measurements were performed during weeks 1-2 and 15-16 in the following order: anthropometrics, body composition, flexibility, muscular strength, muscular endurance, and cardiorespiratory endurance. Weeks 3-14 were dedicated to the ExCR intervention (aerobic + resistance + flexibility training). Post-training measurements were performed with at least 72 hours of rest after the final training session to avoid acute effects on performance. Participants completed 1:1 training sessions for 90 minutes, 3 times per week, for 12 weeks. Individualized exercise programs were prescribed based on participants' cancer rehabilitation stage and baseline assessments. All measurements were conducted at the same location, in a temperature-controlled room (22-24 °C), by the same evaluators.

Vitals were measured to ensure subject safety both before and after the fitness assessment. Blood pressure was measured manually using a stethoscope and sphygmomanometer (American Diagnostic Corporation, Hauppauge, NY, USA). The subject's oxygen saturation was measured on the index finger with a pulse oximeter (Santa Medical, Tustin, CA, USA). Height was measured with a stadiometer, and weight was measured with a triple beam balance scale (Bertec, Columbus, OH, USA). Before fitness evaluations, a resting 12-lead electrocardiogram (EKG) was used to screen the electrical activity of the heart, while a chest-based heart rate monitor was used to measure the heart rate response during exercise (Polar Electro H10, Kempele, Finland). The same administrator performed both the initial and follow-up assessments.

Body composition and whole-body PhA was obtained from a multifrequency BIA device (InBody 770, Cerritos, CA, USA) which estimated percent body fat, fat-free mass, and PhA. PhA is calculated as the arc-tangent (Xc/R) x 180°/π. Participants were instructed to stand on the Inbody 770 platform barefoot with their feet in contact with the electrodes. Subjects then wrapped their hand around the electrode handles of the unit with their thumb and fingers in contact with the electrodes throughout the measurement (~ 1-2 minutes). InBody Tissues (damp towelettes) were used to increase the electrical conductivity between the hands and feet with the hand and foot electrodes. Participants were instructed to refrain from physical activity 24 hours prior to the assessment and be well hydrated. Subjects removed jewelry to account for the potential influence on conductivity. BIA measurements were completed prior to any exercise evaluations to account for exercise-induced shifts of fluid between compartments. Furthermore, subjects were asked to stand for 15 minutes before BIA measurement to account for fluid shifts due to posture.

1-repetition maximum (1-RM) testing was completed for leg extension, leg curl, leg press, incline bench press, seated cable row, and latissimus dorsi pulldown. 1-RM tests were completed using machine weights, except for the incline bench press which utilized a barbell. A warm-up of 6 to 10 repetitions with 40-60% of participants' body weight was used prior to each exercise. After 2 minutes of rest, three attempts of 1-RM were performed. If the participant completed more than 1 repetition during the third 1-RM attempt, the Brzycki equation was used to predict 1-RM (10). A minimum of two test administrators monitored and standardized lifting technique and provided spotting to ensure participant safety. Dominant hand grip strength was assessed with a hand dynamometer (Jamar, JLW Instruments, Chicago, IL, USA), where the best of 3 scores were recorded.

The chair squat to stand the test was used to measure muscular endurance. Participants completed as many squats as possible on the chair in 1 minute, or until fatigue. The same chair was utilized for the initial and post-assessment to standardize squat depth, and test administrators ensured that the bottom contacted the chair during each repetition.

Flexibility was assessed prior to testing fitness-related components, as they are likely to detrimentally influence flexibility measurements. The best score of three trials for the modified sit-and-reach test was used to measure the flexibility of the hamstrings. Range of motion in the shoulder and elbow was measured using the back-scratch test, with the best of three scores being recorded.

Participants completed a cancer population-specific VO2 peak test on a treadmill (40). The final stage speed and grade were utilized to predict VO2 peak. To ensure participant safety, the VO2 peak test was terminated due to patient volitional fatigue, upon patient request, or the occurrence of indications to end exercise testing (5), and a 4-lead EKG was used to monitor the electrical activity of the heart by a trained specialist.

The protocol was based on a standard care model (9) and ACSM's recommendations to improve fitness in breast cancer survivors (5). Concurrent ExCR was performed at the hospital by trained personnel. Training sessions were performed three times per week, with 48 hours of rest between sessions. Each 90-minute training session included 45 minutes of resistance training, 30 minutes of steady-state cardiorespiratory training, and 15 minutes of flexibility training. Resistance training was performed with a combination of free weights and machines. To increase adherence to the protocol and keep participants engaged in the training, a variety of strength training exercises were used including bodyweight exercises (i.e., squats, push-ups), exercises that utilized Therabands (Theraband, Akron, OH, USA), and isometric exercises. To ensure the Principle of Specificity was applied, participants engaged in the same 7 exercises used to test 1-RM every 2 weeks (latissimus dorsi pull-down, shoulder press, chest press, seated row, leg press, leg curl, and leg extension). Exercise intensity was determined based upon participants baseline strength (1-RM) and cancer rehabilitation stage (9). Participants in stages 1, 2, and 3 trained at 30-40%, 40-60%, and 60-85% of their 1-RM respectively. The prescribed resistances ensured patients could complete 2-3 sets of 8-10 repetitions to fatigue. Steady-state aerobic training was performed on a treadmill, stationary cycle, or elliptical within prescribed target heart rate zones. Participants in stages 1, 2, and 3 trained at 30-45%, 40-60%, and 60-85% of their heart rate reserve (HRR), respectively.

Statistical Analysis

Normality of the data was verified by the Shapiro-Wilk test. Paired t-tests were performed to compare pre- to post-ExCR measures. Pearson's correlation coefficients and simple linear regression were used to examine the relationship between changes in phase angle and changes in health-related fitness variables. All statistical analyses significance was set at $p < 0.05$. A Cohen's d of 0.2, 0.5, and 0.8 were categorized as a small, medium, or large effect size (23). An R2 of 0.02, 0.13, and 0.26 were classified as small, medium, or large effect sizes (13). Data were analyzed using GraphPad Prism (Version 9.2 for MacOS, GraphPad Software, San Diego, CA, USA).

RESULTS

Participants' average cancer stage at diagnosis was 1.36 ± 0.78 (mean ± SD). Medical histories indicate that subjects performed radiation, surgery, chemotherapy, CAR T-cell therapy, and bone-marrow transplants as treatment. Thirty-six (61%) of the individuals that participated in this study were diagnosed with lymphedema. Pre- to post-ExCR measures of phase angle, body composition, muscular strength, muscular endurance, flexibility, and cardiorespiratory endurance can be found in Table 2. Significant improvements in measures of muscular strength (incline bench press, seated cable row, latissimus dorsi pulldown, leg press, leg curl, leg extension, and grip strength), muscular endurance (chair squat test), cardiorespiratory endurance (VO2peak), flexibility (sit and reach), and phase angle were found (Table 2, $p < 0.05$).

Table 2. Muscular strength, muscular endurance, flexibility, cardiorespiratory endurance, and body composition values at pre- and post- training in breast cancer survivors (n= 59)

Variable	Pre-training	Post-training	Mean Δ%	P	Effect Size (Cohen's d)
Phase Angle (degrees)	4.56 ± 0.52	4.64 ± 0.59	1.80%	0.0196 *	0.13
Muscular Strength					
Incline Bench Press 1-RM (kg)	21.55 ± 5.29	25.56 ± 5.97	18.60%	<0.0001*	0.71
Seated Cable Row 1-RM (kg)	27.65 ± 5.87	32.02 ± 5.81	15.80%	<0.0001*	0.75
Lat Pull Down 1-RM (kg)	30.98 ± 5.95	34.70 ± 6.17	12.00%	<0.0001*	0.61
Leg Press 1-RM (kg)	90.71 ± 28.15	112.71 ± 38.18	24.25%	<0.0001*	0.66
Leg Curl 1-RM (kg)	35.93 ± 10.63	40.98 ± 11.32	14.05%	<0.0001*	0.46
Leg Extension 1-RM (kg)	35.49 ± 13.06	42.92 ± 14.44	20.93%	<0.0001*	0.54
Grip Strength (kg)	24.86 ± 6.23	25.75 ± 6.08	3.58%	0.0479 *	0.14
Muscular Endurance					
Chair Test (repetitions)	33 ± 15	44 ± 20	33.33%	<0.0001 *	0.60
Flexibility					
Sit and Reach Test (cm)	28.42 ± 9.01	31.21 ± 8.68	9.81%	<0.0001 *	0.32
Back Scratch Test Right (cm)	-6.75 ± 10.56	-6.22 ± 11.12	-7.80%	0.561	0.05
Back Scratch Test Left (cm)	-11.15 ± 10.87	-10.28 ± 10.86	7.80%	0.2879	0.08
Cardiorespiratory endurance					
VO2 Peak (ml/kg/min)	27.06 ± 8.17	32.05 ± 8.76	18.44%	<0.0001 *	0.59
Body Composition					
Reactance (ohms)	50.84 ± 9.04	51.74 ± 9.42	1.80%	0.0976	0.10
Resistance (ohms)	637.40 ± 96.06	638.3 ± 91.55	0.14%	0.8331	0.01
Body Weight	149.80 ± 41.91	149.70 ± 40.69	0%	0.8376	-0.002
Lean Body Mass	90.23 ± 15.80	89.78 ± 14.60	-0.04%	0.3604	-0.03
Body Fat %	37.94 ± 8.51	38.45 ± 8.51	1.43%	0.0166 *	0.06
Intracellular Water (L)	40.24 ± 7.33	40.36 ± 6.55	0.29%	0.6998	0.02
Extracellular Water (L)	25.97 ± 5.31	26.42 ± 7.33	1.73%	0.5859	0.07
ECW/TBW	0.38 ± 0.01	0.38 ± 0.04	0%	0.1903	-0.31

Data are expressed as mean ± standard deviation. Mean Δ% = (Post - Pre)/Pre. 1-RM = predicted 1 repetition maximum predicted by the Brzycki equation (10). ECW/TBW = extracellular water / total body water. * = significant ($p < 0.05$)

Table 3 displays correlations between relative changes (Δ) in health-related fitness components and Δ PhA. Changes in measures of muscular strength (seated cable row, latissimus dorsi pull down, and leg extension), and extracellular water (ECW) has a weak significant positive relationship (r = 0.2-0.39; $p < 0.05$) with ΔPhA, while ΔXc has a strong significant positive relationship (r = 0.6-0.8; $p < 0.05$) with ΔPhA. No relationship between changes in measures of cardiorespiratory endurance, or muscular endurance and Δ PhA were observed ($p > 0.05$).

Table 3. Pearson correlation analysis and simple linear regression between Δ phase angle and Δ health-related fitness components after exercise training in breast cancer survivors (n= 59)

Variable	r	R^2	P
Muscular Strength			
Incline Bench Press 1-RM	0.19	0.04	0.1424
Seated Cable Row 1-RM	0.3	0.09	0.0221 *
Lat Pull Down 1-RM	0.29	0.09	0.0258 *
Leg Press 1-RM	0.01	0.0001	0.9386
Leg Curl 1-RM	0.25	0.05	0.0582
Leg Extension 1-RM	0.3	0.09	0.0232 *
Grip Strength	-0.1	0.01	0.4393
Muscular Endurance			
Chair Test	0.08	0.01	0.2534
Flexibility			
Sit and Reach Test	0.23	0.05	0.0754
Back Scratch Test Right	0	0	0.9622
Back Scratch Test Left	0.2	0.04	0.1327
Cardiorespiratory endurance			
VO2 Peak	0.05	0.002	0.722
Body Composition			
Body Weight	0.25	0.06	0.05
Lean Body Mass	0.06	0.004	0.6028
Body Fat %	0.17	0.03	0.1847
Intracellular Water (L)	0.03	0.004	0.8247
Extracellular Water (L)	0.3	0.09	0.0215 *
ECW/TBW	-0.07	0.004	0.604
Resistance (ohms)	0.05	0.002	0.7123
Reactance (ohms)	0.68	0.47	<0.0001 *

Data are expressed as mean ± standard deviation. Mean Δ% = (Post - Pre)/Pre. 1-RM = predicted 1 repetition maximum calculated using the Brzycki equation (10). ECW/TBW = extracellular water / total body water. * = significant ($p < 0.05$).

DISCUSSION

The main finding of our study was that a 12-week concurrent ExCR program significantly improved PhA in breast cancer survivors. Results also suggest that improvements in Xc (and not R) account for improvements in PhA following an ExCR in breast cancer survivors. Changes in PhA were significantly and positively associated with changes in measures of muscular strength, but not measures of muscular endurance and cardiorespiratory endurance in breast cancer survivors.

To our knowledge, this is the first study to show significant improvements in the PhA of breast cancer survivors after an ExCR (27). A study by O'Neill et al. (33) evaluated the efficacy of a 12-week program including exercise training, dietary counseling, and multidisciplinary education on PhA in esophagogastric cancer survivors, and found no change in PhA. The previous study asked subjects to perform ExCR for 20-35 minutes, 2-6 times per week, for 12 weeks and included aerobic training at 30-60% HRR and resistance training including 2-6 sets of 12-17 repetitions to failure (33). The primary differences in training protocols between the current study and the O'Neill et al. study (33) are the duration of training sessions (90 vs. 20-35 minutes) and training intensity (8-10 vs. 12-17 repetitions to fatigue; 40-85% HRR vs. 30-60% HRR). Higher loads of training volume and intensity are important drivers of hypertrophy and metabolic stress (37), which may place larger stress on cell membranes resulting in improved membrane integrity, ultimately improving Xc and PhA (11, 34, 36, 39). Thus, our findings may have been significant due to differences in training volume and intensity.

A recent review by Martins et al. (27) found that to date, no exercise intervention performed by a group of cancer patients undergoing surgery or treatment has significantly improved PhA. This makes sense as cancer and cancer-related treatments affect cell membrane integrity, decreasing Xc thereby blunting the ability to improve PhA (1, 30, 36). Caveolae, a component of the cell membrane that allows stretching during eccentric muscular contractions (24), can be affected by cancer (25) and cancer-related treatments (1), which potentially increases the risk of membrane tears and reduces membrane integrity. Additionally, alterations in membrane integrity affect action potential propagation through t-tubules (24), which disrupt neuromuscular function (34) and impair performance. In theory, decrements in the ability to produce muscular force or sustain submaximal contractions would negatively influence an individual's capacity to induce exercise stimuli that result in positive neuromuscular adaptations.

The superiority of resistance or endurance training in improving PhA in cancer survivors remains elusive (27). Our data indicate that changes in PhA have significant and positive relationships with changes in measures of muscular strength, but not muscular endurance or cardiorespiratory endurance (Table 3) in breast cancer survivors. In support of our findings, a recent systematic review compared PhA in bodybuilders to those of cyclists and marathon runners, indicating that hypertrophy-type resistance training may result in larger PhA values when compared to endurance training (15). Furthermore, hypertrophy-type resistance training produces increases in body cell mass (37), which has been shown to increase PhA in young men and women (35). However, no significant change in lean body mass or intracellular water was found in our study ($p > 0.05$), indicating that other mechanisms may be responsible for changes in PhA (i.e., improved cellular membrane integrity). Other factors that could potentially explain interindividual changes in PhA following ExCR include changes in fluid distribution within tissues (extracellular water to total body water ratio), intracellular composition (intracellular water), and membrane integrity (20). In the current study, there were no significant differences in intracellular water, extracellular water, or the extracellular water to total body water ratio from pre-post ExCR ($p > 0.05$). Thus, differences in PhA in our study may be due to changes in membrane integrity. Resistance exercise likely causes greater eccentric stress to cell membranes than low-moderate intensity aerobic exercise, which may result in adaptations of larger magnitudes in measures of cell membrane integrity (16, 20, 21). Support for this hypothesis can be found in results from Souza et al. (43), in which significant improvements in Xc (proxy of membrane integrity) and PhA were found following a resistance training program in older women. Although increases in Xc were not significant in our study ($p > 0.05$; Xc increased 1.8% while R increased 0.14%), we found that ΔXc had a strong significant positive relationship ($r = 0.68$, $p < 0.0001$) with ΔPhA, while ΔR were not associated with ΔPhA ($r = 0.05$, $p = 0.7123$). Since high PhA values indicate high Xc and low R, our data suggest that increases in Xc are responsible for the increase in PhA of breast cancer survivors following an ExCR. Furthermore, improvements in muscular strength are associated with specific neural adaptations, including improved neuromuscular transmission efficacy (6). Therefore, changes in muscular strength may have been associated with changes in PhA due to alterations in neuromuscular function, which may reflect the restoration of damaged cell membranes from cancer and cancer-related treatments (1, 16).

This study had several limitations. Our findings can not be extrapolated to populations other than breast cancer survivors. Although exercise prescription followed current recommendations, day-to-day intensities prescribed to participants differed based on daily fluctuations in patients' energy levels (9). Each subject served as her own control; there was not a sedentary condition (27, 43). Lastly, dietary intake and physical activity outside of sessions were not monitored, limiting our ability to identify changes in nutrition or physical activity that may have occurred throughout the study.

Concurrent ExCR significantly improves muscular strength, muscular endurance, flexibility, cardiorespiratory endurance, and PhA in breast cancer survivors. This research provides preliminary evidence for proof of the principle that ExCR in breast cancer survivors can improve PhA. Data from our study indicates that training muscular strength may be a superior method for improving PhA than training cardiorespiratory endurance and muscular endurance. However, future research is needed to clearly delineate the effects of different types of training (aerobic or resistance) on PhA, Xc, and R in this population. Furthermore, exploration of training styles within aerobic training (i.e., high intensity interval training or steady state) and resistance training (i.e., power, strength, hypertrophy, endurance) may provide more insight into the optimal exercise prescription for improving the PhA of breast cancer survivors. Still, the effectiveness and safety of a wide range of exercise protocols for the cancer population must be examined before we can evaluate the effect of different training programs on PhA. Work in this area has already begun, as high-intensity interval training is being explored as a possible exercise model for this population (22). Alternatively, preliminary studies may be needed in healthy populations to provide insights into adaptations of PhA to different exercise stimuli prior to attempting specific training protocols in cancer survivors.

In summary, our findings indicate that the PhA of breast cancer survivors may improve following a 12-week ExCR that includes cardiorespiratory endurance training, resistance training, and flexibility training. The improvements in PhA following ExCR are likely due to improved Xc, rather than R, which may represent the restoration or improved function of damaged cell membranes. Lastly, changes in the PhA of breast cancer survivors are significantly and positively associated with changes in measures of muscular strength, but not measures of muscular endurance and cardiorespiratory endurance. Training muscular strength may be an integral component of an ExCR with the objective of improving PhA.

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