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RESEARCH REPORT

Effect of a six-month yoga exercise intervention on fitness outcomes for breast cancer survivors

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Abstract

Yoga-based exercise has proven to be beneficial for practitioners, including cancer survivors. This study reports on the improvements in physical fitness for 20 breast cancer survivors who participated in a six-month yoga-based exercise program (YE). Results are compared to a comprehensive exercise (CE) program group and a comparison (C) exercise group who chose their own exercises. ''Pre'' and ''post'' fitness assessments included measures of anthropometrics, cardiorespiratory capacity, strength and flexibility. Descriptive statistics, effect size (*d*), dependent sample '*t*' tests for all outcome measures were calculated for the YE group. Significant improvements included: decreased % body fat (-3.00%, $d = -0.44$, $p < 0.001$); increased sit to stand leg strength repetitions (2.05, $d = 0.48$, $p = 0.003$); forward reach (3.59 cm, $d = 0.61$, $p = 0.01$); and right arm sagittal range of motion (6.50°, $d = 0.92$, $p = 0.05$). To compare YE outcomes with the other two groups, a one-way analysis of variance (ANOVA) was used. YE participants significantly outperformed C participants on ''forward reach'' (3.59 cm gained versus -2.44 cm lost), ($p = 0.009$) and outperformed CE participants (3.59 cm gained versus 1.35 cm gained), but not statistically significant. Our results support yoga-based exercise modified for breast cancer survivors as safe and effective.

Keywords

Cancer survivors, fitness, yoga

History

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Introduction

Each year, over 226 000 new women are diagnosed with breast cancer (American Cancer Society, 2012). Breast cancer remains the most prevalent cancer for women, and for Latina women, it is still the number one cancer killer (American Cancer Society, 2009). A growing body of research documents the benefits of exercise for breast cancer survivors, including improvements in fitness, physical functioning, fatigue and emotional well-being (Courneya 2003; Courneya et al, 2003; Pinto, Frierson, Trunzo, and Marcus 2005; Schmitz et al, 2010b; Segal et al, 2001). Indeed, cohort studies have shown a decreased risk of breast cancer recurrence and lowered breast cancer mortality for those breast cancer survivors who are more physically active (Ballard-Barbash et al, 2012; Holmes et al, 2005; Irwin et al, 2011; Patterson, Cadmus, Emond, and Pierce 2010). Thus, engaging in exercise activities is an important behavior for breast cancer survivors (Courneya, Mackey, and Jones 2000; Schmitz et al, 2010b).

Although these benefits have been well documented, only a minority of breast cancer survivors are active at levels consistent with public health guidelines (Schmitz et al, 2010b). Like others who experience cancer, many breast cancer survivors who were not active before diagnosis will stay inactive; and, those who were active often do not return to their previous level of activity (Schmitz et al, 2010b). Specifically, approximately four out of every five breast cancer survivors do not meet national exercise recommendations at 10 years post diagnosis (Mason et al, 2013).

For centuries, yoga has been recognized as a form of exercise that can yield increased flexibility, weight management, strength and endurance for regular practitioners (Agte, Jahagirdar, and Tarwadi, 2011; Gordon et al, 2008; Olivo, 2009; Phoosuwan, Kritpet, and Yuktanandana, 2009; Pullen et al, 2008; Ulger and Yagli, 2011). Yoga-based exercise is also emerging as an important practice to be used for cancer survivors and shown to improve cancer survivors self-reported quality of life (QOL) (Banasik et al, 2011; Bower et al, 2012; Buffart et al, 2012; Culos-Reed, Carlson, Daroux, and Hately-Aldous, 2006; Danhauer et al, 2009; DiStasio, 2008; Kiecolt-Glaser et al, 2014; Lengacher et al, 2012; Moadel et al, 2007; Mustian et al, 2013; Ulger and Yagli, 2010; Van Puymbroeck et al, 2013).

Though most randomized trials using yoga-based exercise have looked at QOL parameters as primary outcomes (Buffart et al, 2012), several studies have looked at physical fitness and physical functioning outcomes specific for breast cancer survivors (Bower et al, 2012; Culos-Reed, Carlson, Daroux, and Hately-Aldous, 2006; Littman et al, 2012). Based on these initial studies that provide strong evidence on the benefits of purposeful yoga-based exercise and to better understand the effects of different modalities of exercise on a comprehensive array of fitness outcomes, we sought to conduct a six-month randomized trial comparing yoga-based exercise with ''conventional'' exercise and with exercise of individual's own choosing. We randomized 94

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post-treatment breast cancer survivors either to a yoga-based exercise program (YE), a ''conventional'' comprehensive exercise (CE) program (aerobic, resistance, flexibility) consistent with public health guidelines for physical activity for U.S. adults (United States Department of Health and Human Services 2008), or to a comparison group (C) where participants chose their own exercise activities. Here we detail the methodology and the fitness outcomes for the YE group and compare the results to the other two groups. We expected that the YE group would have equal to or better outcomes when compared to the CE group and both the CE and YE groups would have better outcomes than the C group.

Methods

Recruitment

After obtaining approval from the Institutional Review Board at the University of Texas Health Science Center at San Antonio (UTHSCSA), and the Cancer Therapy and Research Center Protocol Review Committee, participants were recruited with assistance from the ThriveWell® Cancer Foundation's DIVA (Deriving Inspiration and Vitality through Activity) program, a self-referral program that offers support services for breast cancer survivors. Potential participants who called in to register for DIVA services or expressed interest in response to study flyers, radio and TV advertisements were screened for eligibility by research staff. Inclusion criteria were: age 18 or older; previous diagnosis of invasive breast cancer or ductal carcinoma *in-situ*; being at least two months post-treatment (surgery, chemotherapy, radiation, or any combination thereof); able to provide informed consent; and free of any absolute contraindications for exercise testing as stated in the American College of Sports Medicine (ACSM) Guidelines for Exercise Testing (American College of Sports Medicine, 2013). If interested in participating in the research, participants were asked over the phone to complete the Physical Activity Readiness Questionnaire (PAR-Q), as detailed in the ACSM's Guidelines for Exercise Testing and Prescription (American College of Sports Medicine, 2013). Physician's clearance was required for all participants that answered ''yes'' to any of the seven questions listed on the PAR-Q prior to scheduling them for baseline appointments. Participants who answered ''no'' to all questions or had received physician's clearance were scheduled for a comprehensive fitness baseline assessment. Participants were asked to provide a detailed list of all current medications at baseline assessment; any participants who were on maintenance therapies (e.g. Tamoxifen) were allowed to participate in the study.

Study design

Of the 130 women who expressed interest in the study, 121 met the inclusion criteria, and 94 of those completed baseline fitness assessments (Figure 1). Informed consent was obtained with the baseline assessments conducted at a cancer treatment center in the San Antonio, Texas area. Using a minimization adaptive randomization technique, participant covariates of age, body mass index (BMI), and cardiorespiratory capacity (estimated VO_2max) were used to assign 94 participants either to: (1) a yoga-based exercise program (YE) group, $n = 31$; 2) a comprehensive, individualized exercise program (CE) group, $n = 31$; or 3) a comparison group (C), in which participants performed exercises of their choice, $n = 32$. Here we detail the results of the YE group and compare their results to the CE and C groups. Of the 31 participants randomized to the YE group, 20 completed the six-month trial and completed ''post'' fitness assessments. In the other two groups, a total of 11 participants dropped out, resulting in 26 participants in both the CE group and the C group completing the study, respectively. There were no reported injuries in any group related to the exercise programs.

Specifically designed yoga exercise classes were taught to the participants in a local yoga studio. YE participants were asked to attend three 1-hour yoga classes per week. Participants were neither encouraged nor discouraged from seeking other forms of exercise but were highly encouraged to attend the yoga classes offered. In addition, an audio CD and an instruction booklet for the specific protocol were provided to the participants for use at home when class attendance was not feasible. For the CE group individualized exercise programs were prescribed by an ACSM certified Clinical Exercise Physiologist®. The program components were based on the participants' individual baseline fitness results, following ACSM guidelines (American College of Sports Medicine, 2013), and consistent with the levels of activity as described in the public health guidelines for physical activity for adults (United States Department of Health and Human Services, 2008). The exercise programs included components of aerobic, resistance and flexibility training focused on three 1-hour sessions per week. C group participants were asked to participate in three hours of exercise of their own choosing, though they were given a DIVA class schedule and encouraged to attend DIVA activity classes. The DIVA program provides classes at five different locations across the city of San Antonio. More than 30 exercise classes are held every week and the class offerings include aerobics, strength training, yoga, Tai Chi, Zumba, water aerobics and belly dancing. CE and C participants were asked to log their activities. Similar to the YE group, CE and C participants were neither encouraged nor discouraged from seeking other forms of exercise beside those prescribed. An assigned research staff member called all participants every two weeks to answer any questions, monitor possible safety concerns, and encourage program participation.

Procedures

Fitness assessment summary

The fitness assessments included tests for cardiorespiratory capacity, muscular strength, flexibility and body composition. For cardiorespiratory capacity, a ramped sub-maximal cycle ergometer test was used with a metabolic cart for capturing expired respiratory gases and used to estimate VO_2max (mlO_2/kg/min) based on a linear heart rate (HR) response to increased VO2 uptake. Arm, shoulder and torso muscular strength were tested using a strength dynamometer. For leg strength, participants performed a timed ''sit-to-stand'' test. Hip and lower back flexibility were measured using a ''sit-and-reach'' flexibility box. Upper body flexibility and balance were assessed using a ''forward reach'' functional task. Shoulder flexion range of motion (ROM) in the sagittal and lateral planes was measured using an inclinometer. Body composition was assessed calculating body mass index (BMI) (kg/m^2) and conducting a three-site skinfold assessment (triceps, suprailium, and quadriceps). Arm volume for both arms was measured using water volume displacement. Participants received a $25 gift card as compensation upon completion of the assessments.

Yoga program specifics

A structured Hatha yoga exercise program was developed specifically for this study. The program took into account the potential limitations of limb movement, higher body fatness, and the lower aerobic and strength conditioning characteristic of post-treatment breast cancer survivors (Schmitz et al, 2010b). The protocol was developed by an experienced yoga instructor and a licensed clinically trained physical therapist with extensive

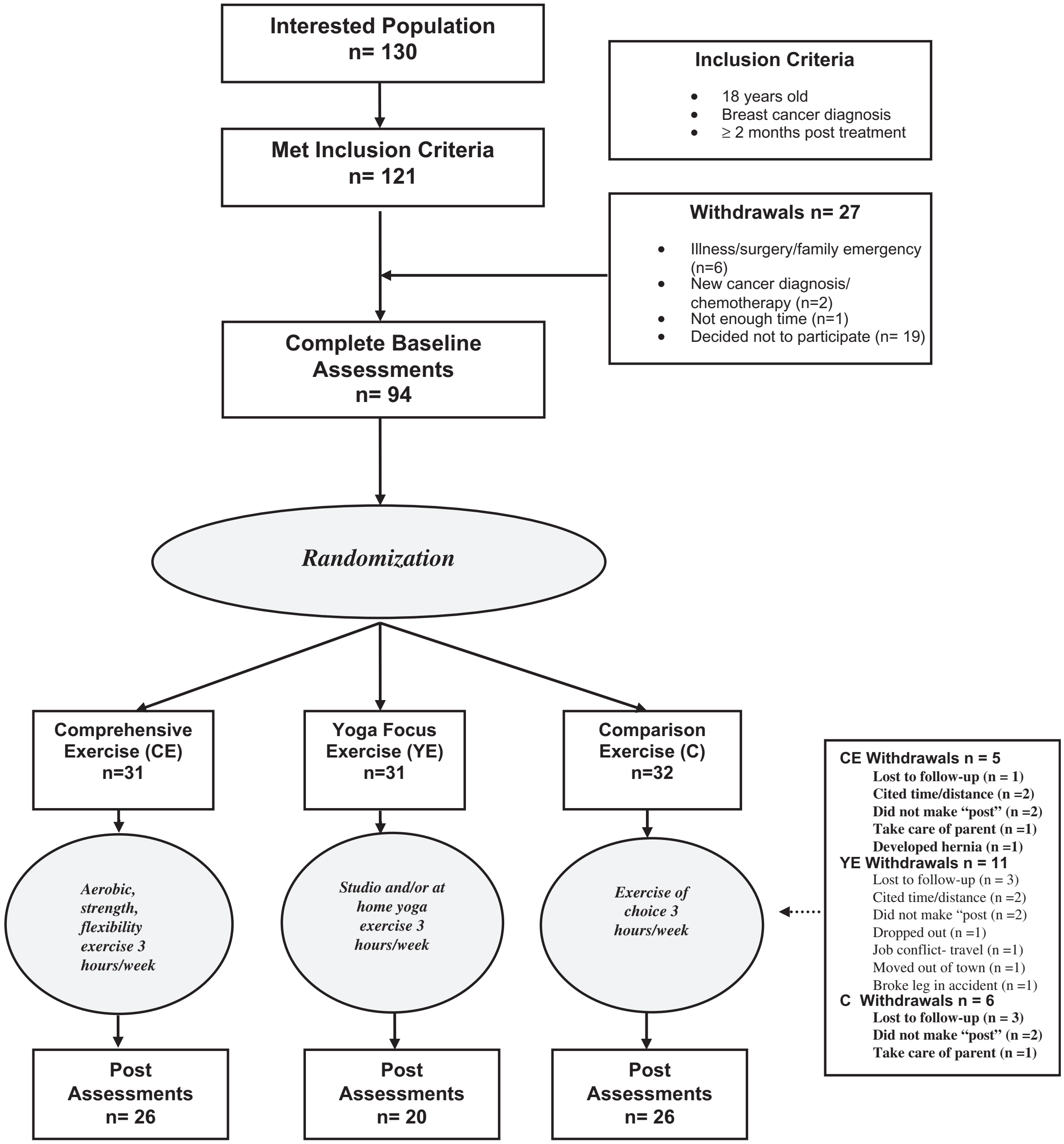

Figure 1. Study flow diagram.

experience in hospital, outpatient, home health, private and community education settings, including working with closely with cancer survivors.

The program included: an emphasis on breath awareness and practice (pranayama); a modified Sun Salutation; standing, seated, quadruped, twisting/rotation, prone, supine postures and the transition used between postures; modified inversion; and guided relaxation and resting postures. The protocol and sequencing of postures were designed with a great deal of specificity to guarantee that the subjects would receive the same instructions and perform the same routine, regardless of the instructor or class attended. Modifications were developed for each posture to accommodate the limitations that might be encountered within this population. The instructors that led the classes for the study participants received training in specific language to be used, as well as timing/pacing for the class to ensure consistency for the 60-min program used throughout the duration of the research study. Breathwork was cued and directed through the entire asana practice. Asana practice was set for 50 min with guided savasana and closing for the final 10 min. A total of five instructors were available to deliver six classes per week at set times on six days per week (Monday–Saturday) to allow for morning, evening and weekend access for participants. Four of the five instructors were 200-h certified yoga instructors receiving 50 h of direct training in the pertinent components for the actual class to be taught (specific language to be used, timing, modifications, specific cues, appropriate delivery style including voice quality and pace of instruction given). In addition, the instructors were required to practice individually and in groups teaching each other for an additional 20 h. The physical therapist who designed the class and provided the training served as the fifth instructor.

Measures

Co-morbidity index

From the medical history information, a co-morbidity index was calculated with a sum score of the number of a possible 17 items endorsed: (1) diagnosis of a heart attack; (2) heart failure; (3) heart condition; (4) circulation problems; (5) blood clots;

(6) hypertension; (7) stroke; (8) lung problems; (9) diabetes; (10) kidney problems; (11) rheumatoid arthritis; (12) osteoarthritis; (13) anemia; (14) thyroid problems; (15) neuropathy; (16) fibromyalgia; and (17) hepatitis.

Resting hemodynamics (resting heart rate, resting blood pressure)

Before resting heart rate (RHR) resting systolic (SBP) and diastolic blood pressure (DBP) were taken, the participant was asked to rest in a seated position for at least five minutes. Resting blood pressures (SBP and DBP) were taken manually using a sphygmomanometer and a stethoscope via the right arm, (or in case of participants with lymphedema – an unaffected limb), using the first and fifth Korotkoff sounds as indicated of SBP and DBP, respectively according to ACSM guidelines for blood pressure testing (American College of Sports Medicine, 2013). Participants had their RHR measured via a pulse oximeter attached on the opposite finger/hand.

Cardiorespiratory capacity

For cardiorespiratory capacity, a ramped cycle ergometer test based on ACSM Guidelines for submaximal exercise testing (American College of Sports Medicine, 2013) was conducted to obtain estimated VO_2max (mlO_2/kg/min). A Lode Corival Cycle (Groningen, Netherlands) and a ParvoMedics TrueOne® 2400 metabolic cart (ParvoMedics, Sandy, UT) were used. A specific protocol for this population was developed by the lead author, an ACSM certified Clinical Exercise Physiologist®, which has been used previously in studies with endometrial cancer survivors (Hughes et al, 2010; Basen-Engquist et al, 2011).

In detail, participants began by pedaling with no resistance for 60 s, followed by a warm-up stage of 2 minutes at 20 watts (W). During the exercise stage, resistance increased until the participant reached either: 85% of their age-predicted maximum heart rate (HR); a sustained respiratory exchange ratio (RER) > 1.0; or signaled that they wished to stop. During the exercise phase, blood pressure, HR and Rating of Perceived Exertion (RPE) using the Borg scale (Borg, 1998) were recorded every 2 min, and every minute during the subsequent recovery stage. Real-time breath-by-breath gas exchange data were obtained and included measurements of VO_2 (mlO2/kg/min), VCO_2 (L), and RER (VCO_2/VO_2).

As this was a submaximal test, in order to obtain more accurate estimates of VO_2max, one of either three calculations was performed depending on participant characteristics. (1) VO_2max was estimated by linear regression analysis, regressing HR against corresponding VO2 uptake (ml O2/kg/min) levels during the period from the beginning of the exercise phase (resistance > 21 W) to the exercise phase ''termination point'' of either: RER $\geq$ 1.0 or a HR of 85% of age-predicted maximum rate. To smooth out the inherently noisy breath-by-breath data, 15-s average HR and VO_2 uptake levels were used in the regression analysis. The linear relationship was then extrapolated to the participants' age-predicted maximum HR (220 – current age), and the estimated VO_2max level was then determined by the regression equation. (2) For participants who reported taking beta-blocker type medications, a regression equation based on RPE was used since HR response to increasing workload could be suppressed with this class of medications. In these cases, the RPE level was regressed on VO_2 levels during the period from the beginning of the exercise phase (resistance greater than 21 W) to the ''termination point''. The RPE was then extrapolated to a ''maximum'' RPE of 19, and the estimated VO_2max level was determined on the basis of a linear relationship between VO_2 and RPE. An RPE of 19 was used as the maximum point, as previous studies have indicated this value is more realistic for assessing maximum effort during exercise testing than an RPE level of 20 (Faulkner, Parfitt, and Eston, 2007). (3) For participants who had difficulty wearing the face mask or preferred to not use the mask, an alternative protocol was used. Briefly, research staff set the cycle ergometer to record W. Recording began after a 2-min warm-up with the participant cycling at 20 W. Every 2 min resistance was increased by 20 W or 30 W depending on participants' response to increased work level. W and corresponding HR were recorded every 2 minutes up to each participant's voluntary level of tolerance (usually RPE levels of 14–16). Work rate (kg-m/min) was obtained by multiplying W by the conversion factor 6.12, and VO2 uptake was calculated using the formula based on ACSM-recommended calculations for estimation of energy expenditure – Table 7.3 (American College of Sports Medicine, 2013): VO2 uptake = 3.5(resting component) + 3.5 (horizontal component) + ((1.8 X work rate)/body mass (kg)). Estimated VO_{2max} was then calculated by linear regression of VO2 uptake on HR using the same linear regression methods as detailed above. For those participants that expressed the desire to ''push on'' during exercise testing and reached an RER > 1.1 for at least 30 s, the corresponding VO_2 uptake was designated as their estimated VO_2max and no regression equations were used.

Strength

Arm strength was tested using a Takei 5002 pull dynamometer system (Takei Scientific Instruments, Niigata City, Japan). Participants stood on top of the dynamometer platform and were asked to hold a handle bar chained to the sensor with wrists in a supinated position, activating the biceps, at an approximate 30° angle. Keeping their back vertically aligned, participants pulled with voluntary maximum effort for 5 s, rested 15 s and repeated the task. Peak force (kg) was noted for each trial and the larger value was recorded.

Shoulder strength was tested similarly; except the participants switched their wrists to a pronated position, activating the deltoids. Torso strength was assessed in a similar fashion. Participants were instructed to hold the handle bar with wrists in a pronated position with arms extended flexing their trunk at approximately 30° to activate the torso. Participants were instructed to pull back with maximal force. The higher value (kg) of two trails was recorded.

For leg strength, participants were asked to perform a timed ''sit-to-stand'' test. Research staff demonstrated the proper technique and then prompted the participants to begin. The number of times the participant stood fully erect and sat down in a 30-s time period was recorded.

Flexibility

For flexibility, participants performed a ''sit-and-reach'' test, a ''forward reach'' test and had passive arm range of motion (PROM) measured using an inclinometer. Hip and lower back flexibility were measured using a ''sit-and-reach'' task (Canadian Society for Exercise Physiology, 2003) with a Lafayette model 01285B sit and reach flexibility box (Lafayette Instruments, Lafayette IN). Participants were instructed to sit on the floor, with feet completely flat on the box and legs fully extended. Participants were asked to extend their arms forward with one hand on top of the other, in a controlled motion while gently exhaling. The maximal distance reached (cm) in three trials was recorded.

Upper body flexibility and balance were assessed using a functional forward reach assessment task (Duncan, Weiner, Chandler, and Studenski, 1990). Participants stood adjacent to a meter stick on a wall with arm horizontal and parallel to the floor with the palm of the hand facing downward. Without moving their feet, participants reached forward as far as possible. The maximal distance reached (cm) in two trials was recorded.

Arm flexion PROM in the sagittal and lateral planes was measured using an inclinometer. Participants were asked to point their thumbs forward in the direction of a vertical line while standing on pre-marked floor squares. The participants' arm was placed in a neutral resting position to the side and the inclinometer was placed across the elbow, PROM occurred in the sagittal plane until resistance was felt at the shoulder girdle, avoiding compensation (e.g. shoulder hiking). PROM measurement (°) with the inclinometer was recorded at the point compensation was noted. When measuring in the lateral plane, participants were asked to point their thumbs along a horizontal line of the floor square employing the identical procedure.

Anthropometrics

Anthropometric measures included BMI (kg/m^2) calculated from height (cm) and weight (kg), body fat estimates from three-site skinfold measures and arm volume by water displacement. Height (cm) and weight (kg) were measured using a wall-mounted Stadiometer (Seca 644 Handrail Scale). For body fat estimate, three-site (triceps, supra-ilium, and quadriceps) skinfold assessments were performed according to ACSM guidelines (American College of Sports Medicine, 2013). Calipers (Lafayette Instruments, Lafayette IN) measured the skinfold tissue in mm with duplicate measurements taken at each site. Unless contraindicated by lymphedema, recent surgery, or participant preference, all measurements were taken on the right side of the body. Skin fold measurements were summed. Body density (Db) and % body fat were calculated using ACSM-recommended formulas (Table 4.4) (American College of Sports Medicine, 2013):

$$\text{Db} = 1.099421 - 0.0009929\,(\text{skinfold sum}) + 0.0000023\,(\text{skinfold sum})^2 - 0.0001392\,(\text{age})$$

$$\%\text{body fat} = (4.96/\text{Db}) - 4.51$$

Arm volume was measured with a water displacement volumeter. Participants sat next to an arm volumeter (7'' × 7'' × 30'') and slowly lowered their arm. The displaced water was collected and measured to calculate arm volume (ml). In addition, Norman lymphedema self-report measures (Norman et al, 2001) were completed at baseline, every four weeks during the intervention, and at the end of the intervention. Participants were encouraged to immediately report any injuries incurred during exercise as well as any symptoms of hand, arm, and limb change from the Norman self-report to the research staff and if necessary seek medical attention.

Treatment of data

All the analyses were performed using Statistical Package for the Social Sciences (version 21.0; IBM Corp., Armonk, NY). Descriptive statistics were performed on all variables (range, mean, standard deviation). Paired-sample ''t-tests'' were performed to compare ''pre'' and ''post'' values. Because we were also interested in the magnitude of change for the YE participants, in addition to statistical significance, we calculated effect size as ES = (m1–m2)/s1 where m1 = ''pre'' mean, m2 = ''post'' mean and s1 = ''pre'' standard deviation. Our original sample size estimate was determined by logistics in how many participants could be managed in each of the study arms given resource limitations. Our primary outcome variable was body composition change (% body fat), as increased adiposity is associated with breast cancer risk in post-menopausal women (McTiernan et al, 2006; Chen et al, 2010). Effect sizes were defined as: small (0.2); medium (0.5); or large (0.8) (Cohen, 1988). To compare YE participant outcomes with the other two groups, we used a one-way analysis of variance (ANOVA). Bonferroni post hoc tests were applied when the difference was significant ($p < 0.05$) according to the results of the ANOVA.

Results

Participant baseline characteristics are shown in Table 1. Prior to randomization, our participants averaged 56.2 years of age, had moderate levels of co-morbidities (2.3), were overweight (BMI = 28.8 kg/m^2) and presented with very low cardiorespiratory capacity (19.8 ml O2/kg/min). This low level of cardiorespiratory capacity is less than the 10^{th} percentile for age and gender as reported by ACSM fitness categories (American College of Sports Medicine, 2013). Our participants' ethnicity was one third Hispanic (32%), and race was predominately white (80%). Our participants were highly educated with 60% having obtained at least a bachelor's degree. Approximately half of our participants (49%) were fully employed and 36% reported as either retired or home-maker.

There were no significant differences between groups in baseline characteristics. However, in a comparison between participants that completed the study and those that dropped out, those that completed had higher ''sit and reach'' scores (29.7 versus 25.4, $p = 0.046$), (data not shown). This overall group difference in flexibility was consistent for the YE participants that completed versus those that dropped out, (28.7 versus 21.7, $p = 0.009$). For the CE group ''sit and reach'' was not different; however, lower BMI (28.1 versus 34.2, $p = 0.041$), better ''forward reach'' (38.4 versus 33, $p = 0.023$), and higher left arm lateral ROM (170.0 versus 145.6, $p = 0.030$) were different between those that completed and those that did not. For the C group, there were no differences.

Descriptive results, tests for mean differences (''pre'' and ''post'') and effect sizes specific to the YE group are shown in Table 2. Participants improved in all outcome measures in the expected direction with the exception of weight, cardiorespiratory capacity and systolic blood, with essentially no change in these outcomes. Though weight remained essentially the same (+0.23 kg), significant improvements were seen in body composition with a reduction of % body fat, (−3.00%, $d = -0.44$, $p = 0.001$). Participants also improved in sit to stand leg strength repetitions (2.05, $d = 0.48$, $p = 0.003$); forward reach (3.59 cm, $d = 0.61$, $p = 0.01$); and right arm sagittal PROM (6.50°, $d = 0.92$, $p = 0.05$). Although not statistically significant, favorable small to moderate effect sizes occurred for diastolic blood pressure ($d = -0.20$); arm strength ($d = 0.33$); torso strength ($d = 0.28$); right arm lateral PROM ($d = 0.49$); and left arm sagittal PROM ($d = 0.33$).

As can be seen in Table 3, when compared to the other groups, ''forward reach'' (a test of flexibility and balance) was significantly different with YE participants outperforming C participants (3.59 cm gained versus −2.44 cm lost), ($p = 0.009$) and outperforming CE participants (3.59 cm gained versus 1.35 cm gained), but not statistically significant. Though not statistically significant, other comparisons are noteworthy. All participants lost body fat; however, the YE group lost the most with an average of 3.00% with the CE group and C group losing 2.46% and 1.97% respectively. Interestingly, though while losing the most % body fat, the YE group gained mass (0.23 kg), indicative of favorable changes in body composition when compared to the other groups. The CE group, which had a specific aerobic training component increased the most in VO2 (2.01%) while the YE group and C group virtually maintained the same levels (−0.77% and 1.01%

Table 1. Participant characteristics at baseline, mean standard deviation or n (%).

Baseline characteristic	All ($N = 94$)	YE ($n = 31$)	CE ($n = 31$)	C ($n = 32$)	p
Age	56.2 (7.9)	56.7 (9.6)	57.6 (6.6)	54.4 (7.0)	0.266
Comorbidity	2.3 (1.7)	2.1 (1.7)	2.1 (1.5)	2.7 (1.8)	0.323
BMI	28.8 (6.7)	29.1 (6.7)	29.1 (6.2)	28.1 (7.3)	0.810
VO2max	19.8 (5.1)	20.2 (5.6)	19.2 (4.9)	19.9 (5.0)	0.737
Lymphedema					
Yes	19 (20%)	5 (16%)	6 (19%)	8 (25%)	
No	72 (77%)	25 (81%)	25 (81%)	22 (69%)	
Missing	3 (37%)	1 (3%)	1 (3%)	2 (6%)	
Ethnicity					
Hispanic	30 (32%)	10 (32%)	7 (23%)	13 (41%)	
Non-hispanic	63 (67%)	21 (68%)	24 (77%)	18 (56%)	
Missing	1 (1%)			1 (1%)	
Race					
White	75 (79%)	26 (84%)	25 (81%)	24 (75%)	
African American	5 (5%)	–	2 (6%)	3 (9%)	
Asian	1 (5%)	1 (5%)	–	–	
Other	11 (11%)	4 (13%)	3 (10%)	4 (12%)	
Missing	2 (2%)	–	1 (3%)	1 (3%)	
Education					
High school diploma	8 (8%)	3 (10%)	2 (6%)	3 (9%)	
Technical	3 (3%)	3 (10%)	–	–	
Some college	23 (25%)	7 (23%)	7 (23%)	9 (28%)	
Bachelor's degree	26 (28%)	10 (32%)	9 (29%)	7 (22%)	
Master's degree	28 (30%)	6 (19%)	10 (32%)	12 (38%)	
Terminal degree (e.g. MD, PhD)	4 (4%)	2 (6%)	2 (6%)	–	
Missing	2 (2%)	–	1 (3%)	1 (3%)	
Employment status					
Employed full time	46 (49%)	14 (45%)	15 (48%)	17 (53%)	
Employed part time	8 (8%)	1 (3%)	5 (16%)	2 (6%)	
Not working but seeking	2 (2%)	2 (6%)	–	–	
Not working not seeking	1 (1%)	–	–	1 (3%)	
Retired	22 (23%)	8 (26%)	8 (26%)	6 (19%)	
Homemaker	13 (13%)	6 (19%)	3 (10%)	4 (13%)	
Volunteer	1 (1%)	–	–	1 (3%)	
Missing	1 (1%)	–	–	1 (3%)	

Total % may not add up to 100% due to rounding. YE = Yoga-based exercise group; CE = Comprehensive exercise group; C = Comparison group.

Table 2. Descriptive statistics for yoga group physical fitness/functioning outcomes, $n = 20$.

Fitness/Functioning	Pre range	Pre mean (SD)	Post range	Post mean (SD)	Expected direction	p	Change score	(95%CI)* change	ES**
Weight (kg)	54.6–102.1	74.6 (14.8)	55.8–97.8	74.8 (14.8)	Decrease	0.766	0.23	(−1.34, 1.79)	0.02
BMI (kg/m^2)	19.9–40.5	28.8 (6.5)	20.1–39.9	28.8 (6.0)	Decrease	0.942	0.03	(−0.79, 0.85)	0.00
Body adiposity (% body fat)	18.1–43.4	34.0 (6.8)	18.1–41.2	31.0 (6.5)	Decrease	<0.001	−3.00	(−4.50, −1.50)	−0.44
Resting heart rate (bpm)	51.0–99.0	68.6 (13.0)	43.0–118.0	70.0 (17.6)	Decrease	0.718	1.35	(−6.36, 9.06)	0.10
Systolic blood pressure (mm Hg)	110.0–160.0	126.6 (14.8)	108.0–152.0	127.6 (13.3)	Decrease	0.978	0.11	(−7.87, 8.08)	0.01
Diastolic blood pressure (mm Hg)	62.0–108.0	81.4 (9.8)	60.0–108.0	79.8 (10.3)	Decrease	0.551	−1.95	(−8.67, 4.78)	−0.20
Predicted VO2max (mlO2/kg/min)	10.4–33.6	21.9 (6.1)	15.9–26.2	21.2 (3.4)	Increase	0.530	−0.77	(−3.31, 1.77)	−0.13
Arm strength (kg)	13.0–39.0	22.2 (7.0)	12.0–46.0	24.7 (7.7)	Increase	0.208	2.31	(−1.42, 6.03)	0.33
Shoulder strength (kg)	26.0–47.0	33.0 (5.7)	14.0–46.0	32.4 (7.7)	Increase	0.651	−0.78	(−4.34, 2.79)	−0.14
Torso strength (kg)	32.0–64.0	46.4 (8.9)	21.0–68.0	49.7 (14.2)	Increase	0.515	2.53	(−5.60, 10.67)	0.28
Sit to stand (repetitions)	8.0–25.0	13.7 (4.3)	11.0–27.0	15.8 (3.9)	Increase	0.003	2.05	(0.79, 3.31)	0.48
Sit and reach (cm)	17.5–37.5	28.7 (6.0)	13.0–45.0	29.1 (7.8)	Increase	0.313	0.85	(−0.87, 2.56)	0.14
Forward reach (cm)	24.5–48.0	34.6 (5.9)	25.5–54.0	38.2 (6.7)	Increase	0.011	3.59	(0.92, 6.26)	0.61
Arm range of motion									
Right arm sagittal	160.0–182.0	171.4 (7.1)	160.0–196.0	177.8 (11.1)	Increase	0.05	6.50	(−0.22, 13.22)	0.92
Right arm lateral	146.0–190.0	167.8 (11.3)	140.0–190.0	173.4 (12.3)	Increase	0.10	5.55	(−1.17, 12.27)	0.49
Left arm sagittal	150.0–180.0	167.8 (8.8)	150.0–188.0	170.4 (10.1)	Increase	0.293	2.90	(−2.71, 8.51)	0.33
Left arm lateral	150.0–180.0	168.0 (9.0)	138.0–186.0	167.2 (13.5)	Increase	0.809	−0.70	(−6.69, 5.29)	−0.08
Arm volume									
Right arm	1390–3080	1917.4 (470.9)	1360–2840	1942.2 (395.0)	–	0.771	24.8	(−151.2, 200.8)	0.05
Left arm	1240–3190	1915.5 (513.9)	1230–2930	1992.4 (514.1)	–	0.173	76.8	(−36.7, 190.5)	0.15

*95% Confidence interval of the mean change score.

**ES = effect size = (''post'' mean - ''pre'' mean)/standard deviation of ''pre'' score.

Table 3. Differences between groups change score (post minus pre) ANOVA.

Fitness/Functioning	All ($n = 72$) Mean (SD)	YE ($n = 20$) Mean (SD)	CE ($n = 26$) Mean (SD)	C ($n = 26$) Mean (SD)	Expected direction	p	Post-hoc
Weight (kg)	−0.09 (2.83)	0.23 (3.35)	−0.65 (2.91)	0.20 (2.29)	Decrease	0.479	
BMI (kg/m^2)	−0.02 (1.30)	0.03 (1.75)	−0.14 (1.27)	0.06 (0.91)	Decrease	0.838	
Body adiposity (% body fat)	−2.43 (3.11)	−3.00 (3.21)	−2.46 (3.05)	−1.97 (3.14)	Decrease	0.540	
Resting heart rate (bpm)	3.83 (12.33)	1.35 (16.46)	4.80 (10.32)	4.81 (10.50)	Decrease	0.576	
Systolic blood pressure (mm Hg)	0.43 (14.95)	0.11 (16.56)	−2.46 (11.54)	3.35 (16.48)	Decrease	0.394	
Diastolic blood pressure (mm Hg)	−0.17 (9.92)	−1.95 (13.95)	2.38 (8.96)	−1.23 (6.60)	Decrease	0.292	
Predicted VO2max (mlO2/kg/min)	0.87 (4.56)	−0.77 (5.11)	2.01 (3.45)	1.01 (4.85)	Increase	0.151	
Arm strength (kg)	1.71 (9.91)	2.31 (7.48)	2.57 (11.95)	0.54 (9.65)	Increase	0.747	
Shoulder strength (kg)	−0.03 (7.02)	−0.78 (7.17)	0.96 (5.92)	−0.38 (7.93)	Increase	0.702	
Torso strength (kg)	2.81 (16.58)	2.53 (14.69)	−0.09 (15.41)	5.42 (18.63)	Increase	0.524	
Sit to stand (repetitions)	2.45 (3.16)	2.05 (2.68)	2.70 (3.22)	2.54 (3.51)	Increase	0.792	
Sit and reach (cm)	1.11 (3.54)	0.85 (3.56)	1.66 (3.50)	0.79 (3.64)	Increase	0.649	
Forward reach (cm)	0.58 (6.93)	3.59 (5.71)	1.35 (6.75)	−2.44 (6.97)	Increase	0.009	YE > C
Arm range of motion							
Right arm sagittal	5.56 (12.55)	6.50 (14.35)	6.04 (10.78)	4.38 (12.98)	Increase	0.833	
Right arm lateral	4.06 (13.09)	5.55 (13.09)	3.04 (12.93)	3.85 (12.64)	Increase	0.819	
Left arm sagittal	5.51 (13.58)	2.90 (12.00)	9.08 (15.92)	4.23 (12.13)	Increase	0.272	
Left arm lateral	0.51 (13.09)	−0.70 (12.79)	−0.70 (13.49)	2.50 (13.21)	Increase	0.623	
Arm volume							
Right arm	70.2 (292.9)	24.8 (376.1)	94.0 (233.1)	82.31 (279.7)	—	0.714	
Left arm	46.2 (269.0)	76.8 (242.7)	16.7 (302.2)	50.96 (261.7)	—	0.758	

YE = Yoga-based exercise group; CE = Comprehensive exercise group; C = Comparison group.

respectively), although the differences were not statistically significant.

Discussion

Overwhelming evidence continues to demonstrate the benefits of exercise on reducing morbidity and mortality while improving individual quality of life and overall health (Blair et al, 1989; Haskell et al, 2007; Lichtenstein et al, 2006; Schmitz et al, 2010b; United States Department of Health and Human Services, 1996; United States Department of Health and Human Services, 2008). These benefits apply to cancer survivors as well (Beasley et al, 2012; Doyle et al, 2006; Holmes et al, 2005; Schmitz et al, 2010b; Speck et al, 2010). Adopting and maintaining a physically active lifestyle improves cancer survivors' well-being (Courneya, 2003), and reduces their risk of: cardiovascular disease (LaCroix et al, 1996); noninsulin-dependent diabetes mellitus (Helmrich, Ragland, Leung, and Paffenbarger, 1991); osteoporosis (Devogelaer and de Deuxchaisnes, 1993); and recurrent cancers (Friedenreich and Rohan 1995; Giovannucci et al, 1995). However, cancer survivors tend to decrease their level of physical activity after diagnosis and mostly never regain their former levels after treatment (Courneya and Friedenreich, 1997; Irwin et al, 2003; Irwin et al, 2004).

Thus, the need for exercise activities that engage breast cancer survivors is urgent. Moreover, the design of exercise activities specifically modified for the often compromised physical functioning of post-treatment breast cancer survivors is critical. The specificity of the design of a program could offer the potential to optimize the outcomes. In addition to aerobic and/or resistance exercise programs, yoga-based programs are starting to be used for the welfare of this population. Here we reported on the successful fitness and physical functioning results of 20 post-treatment breast cancer survivors who safely completed a six-month structured Hatha yoga-based exercise trial and compared their results to groups randomized to 'conventional' comprehensive exercise (aerobic, resistance, flexibility) or a comparison group who chose their form of exercise. The yoga-based program took into account the potential limitations of limb movement, higher body fatness, and the lower aerobic and strength conditioning characteristic of post-treatment breast cancer survivors.

Consistent with other studies with yoga and breast cancer survivors, we saw improvements in physical functioning (Bower et al, 2012; Chandwani et al, 2010; Culos-Reed, Carlson, Daroux, and Hately-Aldous, 2006; Littman et al, 2012; Van Puymbroeck, Schmid, Shinew, and Hsieh, 2011) for the YE group. Participation in the trial was also associated with improvements in body composition (body fat loss of 3%) for the YE group, who of the three groups had the most favorable change in body composition. This is consistent with Littman et al. (2012) six-month study where yoga participants had a significant favorable change in waist circumference compared to a wait list control. Similar to our results, these participants also did not lose weight (Littman et al, 2012). The change in body composition for our participants is important to note as obesity and obesity-associated endocrine output has been associated with breast cancer recurrence risk (Chen et al, 2010; Demark-Wahnefried et al, 2012; Gilbert and Slingerland, 2013; Morimoto et al, 2002; Simpson and Brown, 2013). Some studies suggest that the association of the physical activities' effect on biological markers associated with breast cancer risk may not only be the direct effect from activity but also the result of a favorable effect on managing/reducing obesity (Ballard-Barbash et al, 2012; Irwin et al, 2005; Irwin et al, 2011; McTiernan, 2008; McTiernan et al, 2003a 2003b; McTiernan et al, 2006). Since the weight stayed virtually the same in our YE participants (+ 0.23 kg), the loss in body fat probably translated to a gain in lean mass, though without better assessment techniques (e.g. dual-energy x-ray absorptiometry) we cannot be certain.

Our protocol specifically used participants' body weight for resistance training so the YE participants also performed resistance training though probably not in the same manner as the other groups. This mixed results in strength outcomes between groups we observed is consistent with results from Van Puymbroeck et al. (2011) where in 8 weeks of yoga, yoga participants increased upper and lower body strength and flexibility while a 'light exercise' group improved in abdominal strength. As we expected

YE participants performed better than the other groups in the ''forward reach'' task, which is a test of flexibility and balance (Duncan, Weiner, Chandler, and Studenski, 1990).

This study has certain limitations and strengths that should be noted. First, interpretation of our results should be guarded. The small number of participants who completed the study in each arm may have impacted our results in detecting statistical significance in differences between groups for our outcome variables. As mentioned, a relatively small sample size ($n = 20$) of YE participants completed our trial. As noted in Figure 1 we had 11 participants drop in our study for various reasons; a relative high attrition rate, the same as the other two groups combined. A contributory factor could be that participants were asked to attend a singular specific yoga studio at specific times. Though we offered several times and dates to accommodate schedules, this constraint may have become a significant barrier to participation. Secondly, outside of those participants that attended the yoga studio classes we have no exact knowledge of the quality of yoga, if any, that our participants practiced outside of class. As mentioned, we did give participants a set of instructions and an audio CD with which to practice the specific protocol outside of the studio. Participants may or may not have done the yoga routine as instructed; moreover, any of the participants could have participated in other activities without our knowledge. Future efforts will include in improving access to the yoga-based exercise.

Nonetheless, our study has strengths as well. Most exercise studies that involve exercise and cancer survivorship to date do not include the comprehensive array of fitness and physical functioning assessments that we employed in our study (Galvao and Newton, 2005; Schmitz et al, 2010b). Moreover, though some exercise studies with breast cancer survivors have employed some of the fitness assessments we did, such as body composition, VO2 uptake with respiratory gases, and strength (Demark-Wahnefried et al, 2014; Friedenreich et al, 2011; Schmitz et al, 2009; Schmitz et al, 2010a); ours is the only study we are aware of to simultaneously compare three different exercise modalities over a six-month randomized trial that includes yoga-based exercise specifically designed for post-treatment breast cancer survivors.

Our results taken together support the hypothesis that yoga-based exercise is as safe and effective for post-treatment breast cancer survivors as individually designed exercise programs that incorporate aerobic, resistance and flexibility training or participants choosing their own forms of exercise. Larger-scale studies that incorporate yoga-based exercise are warranted to determine optimal exercise protocols for specific cancer survivor populations.

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Declaration of interest

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Cancer Institute, the National Institutes of Health or Susan G. Komen®.

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References

Agte VV, Jahagirdar MU, Tarwadi KV 2011 The effects of Sudarshan Kriya Yoga on some physiological and biochemical parameters in mild hypertensive patients. Indian Journal of Physiology and Pharmacology. 55: 183–187.

American Cancer Society 2009 Cancer Facts and Figures for Hispanics/Latinos, 2009–2011, Atlanta, GA, American Cancer Society.

American Cancer Society 2012 Cancer Facts and Figures, 2012, Atlanta, GA, American Cancer Society.

American College of Sports Medicine 2013 ACSM's Guidelines for Exercise Testing and Prescription, 9th ed. Philadelphia. PA, Lippincott Williams & Wilkins.

Ballard-Barbash R, Friedenreich CM, Courneya KS, Siddiqi SM, McTiernan A, Alfano CM 2012 Physical activity, biomarkers, and disease outcomes in cancer survivors: A systematic review. Journal of the National Cancer Institute 104: 815–840.

Banasik J, Williams H, Haberman M, Blank SE, Bendel R 2011 Effect of Iyengar yoga practice on fatigue and diurnal salivary cortisol concentration in breast cancer survivors. Journal of the American Academy of Nurse Practitioners 23: 135–142.

Basen-Engquist K, Carmack CL, Perkins H, Hughes D, Serice S, Scruggs S, Pinto B, Waters A 2011 Design of the steps to health study of physical activity in survivors of endometrial cancer: Testing a social cognitive theory model. Psychology of Sport and Exercise 12: 27–35.

Beasley JM, Kwan ML, Chen WY, Weltzien EK, Kroenke CH, Lu W, Nechuta SJ, Cadmus-Bertram L, Patterson RE, Sternfeld B, Shu XO, Pierce JP, Caan BJ 2012 Meeting the physical activity guidelines and survival after breast cancer: Findings from the after breast cancer pooling project. Breast Cancer Research and Treatment 131: 637–643.

Blair SN, Kohl HW, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW 1989 Physical fitness and all-cause mortality. A prospective study of healthy men and women. JAMA 262: 2395–2401.

Borg G 1998 Borg's Perceived Exertion and Pain Scales. Champaign, IL, Human Kinetics.

Bower JE, Garet D, Sternlieb B, Ganz PA, Irwin MR, Olmstead R, Greendale G 2012. Yoga for persistent fatigue in breast cancer survivors: A randomized controlled trial. Cancer 118: 3766–3775.

Buffart LM, van Uffelen JG, Riphagen, II, Brug J, van Mechelen W, Brown WJ, Chinapaw MJ 2012 Physical and psychosocial benefits of yoga in cancer patients and survivors, a systematic review and meta-analysis of randomized controlled trials. BMC Cancer 12: 559.

Canadian Society for Exercise Physiology 2003 Canadian Physical Activity, Fitness and Lifestyle Approach: CSEP-Health and Fitness Program's Appraisal and Counseling Strategy, 3rd ed. Ottawa, ON, Canadian Society for Exercise Physiology.

Chandwani KD, Thornton B, Perkins GH, Arun B, Raghuram NV, Nagendra HR, Wei Q, Cohen L 2010 Yoga improves quality of life and benefit finding in women undergoing radiotherapy for breast cancer. Journal for the Society of Integrative Oncology 8: 43–55.

Chen X, Lu W, Zheng W, Gu K, Chen Z, Zheng Y, Shu XO 2010 Obesity and weight change in relation to breast cancer survival. Breast Cancer Research and Treatment 122: 823–833.

Cohen J 1988 Statistical Power Analysis for the Behavioral Sciences, 2nd ed. Hillsdale, NJ, Lawrence Erlbaum Associates, Inc.

Courneya KS 2003 Exercise in cancer survivors: An overview of research. Medicine and Science in Sports and Exercise 35: 1846–1852.

Courneya KS, Friedenreich CM 1997 Relationship between exercise pattern across the cancer experience and current quality of life in colorectal cancer survivors. Journal of Alternative and Complementary Medicine 3: 215–226.

Courneya KS, Mackey JR, Bell GJ, Jones LW, Field CJ, Fairey AS 2003 Randomized controlled trial of exercise training in postmenopausal breast cancer survivors: Cardiopulmonary and quality of life outcomes. Journal of Clinical Oncology 21: 1660–1668.

Courneya KS, Mackey JR, Jones LW 2000 Coping with cancer: Can exercise help? Physician and SportsMedicine 28: 49–73.

Culos-Reed SN, Carlson LE, Daroux LM, Hately-Aldous S 2006 A pilot study of yoga for breast cancer survivors: Physical and psychological benefits. Psychooncology 15: 891–897.

Danhauer SC, Mihalko SL, Russell GB, Campbell CR, Felder L, Daley K, Levine EA 2009 Restorative yoga for women with breast cancer: Findings from a randomized pilot study. Psychooncology 18: 360–368.

Demark-Wahnefried W, Jones LW, Snyder DC, Sloane RJ, Kimmick GG, Hughes DC, Badr HJ, Miller PE, Burke LE, Lipkus IM 2014 Daughters and Mothers Against Breast Cancer (DAMES): Main outcomes of a

randomized controlled trial of weight loss in overweight mothers with breast cancer and their overweight daughters. Cancer 120: 2522–2534.
Demark-Wahnefried W, Platz EA, Ligibel JA, Blair CK, Courneya KS, Meyerhardt JA, Ganz PA, Rock CL, Schmitz KH, Wadden T, Philip EJ, Wolfe B, Gapstur SM, Ballard-Barbash R, McTiernan A, Minasian L, Nebeling L, Goodwin PJ 2012 The role of obesity in cancer survival and recurrence. Cancer Epidemiology Biomarkers and Prevention 21: 1244–1259.
Devogelaer JP, de Deuxchaisnes CN 1993 Therapy and the 1990s: Osteoporosis. British Journal of Rheumatology 32: 48–55.
DiStasio SA 2008 Integrating yoga into cancer care. Clinical Journal of Oncolohy Nursing 12: 125–130.
Doyle C, Kushi LH, Byers T, Courneya KS, Demark-Wahnefried W, Grant B, McTiernan A, Rock CL, Thompson C, Gansler T, Andrews KS 2006 Nutrition and physical activity during and after cancer treatment: An American Cancer Society guide for informed choices. CA: A Cancer Journal for Clinicians. 56: 323–353.
Duncan PW, Weiner DK, Chandler J, Studenski S 1990 Functional reach: a new clinical measure of balance. Journal of Gerontology 45: M192–197.
Faulkner J, Parfitt, Eston R 2007 Prediction of maximal oxygen uptake from the ratings of perceived exertion and heart rate during a perceptually-regulated sub-maximal exercise test in active and sedentary participants. European Journal of Applied Physiology 101: 397–407.
Friedenreich CM, Rohan TE 1995 Physical activity and risk of breast cancer. European Journal of Cancer Prevention 4: 145–151.
Friedenreich CM, Woolcott CG, McTiernan A, Terry T, Brant R, Ballard-Barbash R, Irwin ML, Jones CA, Boyd NF, Yaffe MJ, Campbell KL, McNeely ML, Karvinen KH, Courneya KS 2011 Adiposity changes after a 1-year aerobic exercise intervention among postmenopausal women: A randomized controlled trial. International Journal of Obesity 35: 427–435.
Galvao DA, Newton RU 2005 Review of exercise intervention studies in cancer patients. Journal of Clinical Oncology 23: 899–909.
Gilbert CA, Slingerland JM 2013 Cytokines, obesity, and cancer: New insights on mechanisms linking obesity to cancer risk and progression. Annual Review of Medicine 64: 45–57.
Giovannucci E, Ascherio A, Rimm EB, Colditz GA, Stampfer M, Willett WC. 1995. Physical activity, obesity, and risk for colon cancer and adenoma in men. Annals of Internal Medicine 122: 327–334.
Gordon LA, Morrison EY, McGrowder DA, Young R, Fraser YT, Zamora EM, Alexander-Lindo RL, Irving RR 2008 Effect of exercise therapy on lipid profile and oxidative stress indicators in patients with type 2 diabetes. BMC Complementary and Alternative Medicine 8: 21.
Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A 2007 Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Medicine and Science in Sports and Exercise 39: 1423–1434.
Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS 1991 Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. New England Journal of Medicine 325: 147–152.
Holmes MD, Chen WY, Feskanich D, Kroenke CH, Colditz GA 2005 Physical activity and survival after breast cancer diagnosis. JAMA 293: 2479–2486.
Hughes D, Baum G, Jovanovic J, Carmack C, Greisinger A, Basen-Engquist K 2010 An acute exercise session increases self-efficacy in sedentary endometrial cancer survivors and controls. Journal of Physical Activity and Health 7: 784–793.
Irwin ML, Crumley D, McTiernan A, Bernstein L, Baumgartner R, Gilliland FD, Kriska A, Ballard-Barbash R 2003 Physical activity levels before and after a diagnosis of breast carcinoma: The Health, Eating, Activity, and Lifestyle (HEAL) study. Cancer 97: 1746–1757.
Irwin ML, McTiernan A, Bernstein L, Gilliland FD, Baumgartner R, Baumgartner K, Ballard-Barbash R 2004 Physical activity levels among breast cancer survivors. Medicine and Science in Sports and Exercise 36: 1484–1491.
Irwin ML, McTiernan A, Bernstein L, Gilliland FD, Baumgartner R, Baumgartner K, Ballard-Barbash R 2005 Relationship of obesity and physical activity with C-peptide, leptin, and insulin-like growth factors in breast cancer survivors. Cancer Epidemiology Biomarkers and Prevention 14: 2881–2888.
Irwin ML, McTiernan A, Manson JE, Thomson CA, Sternfeld B, Stefanick ML, Wactawski-Wende J, Craft L, Lane D, Martin LW, Chlebowski R 2011 Physical activity and survival in postmenopausal women with breast cancer: Results from the women's health initiative. Cancer Prevention Research 4: 522–529.
Kiecolt-Glaser JK, Bennett JM, Andridge R, Peng J, Shapiro CL, Malarkey WB, Emery CF, Layman R, Mrozek EE, Glaser R 2014 Yoga's impact on inflammation, mood, and fatigue in breast cancer survivors: A randomized controlled trial. Journal of Clinical Oncology 32: 1040–1049.
LaCroix AZ, Leveille SG, Hecht JA, Grothaus LC, Wagner EH 1996 Does walking decrease the risk of cardiovascular disease hospitalizations and death in older adults? Journal of the American Geriatrics Society 44: 113–120.
Lengacher CA, Reich RR, Post-White J, Moscoso M, Shelton MM, Barta M, Le N, Budhrani P 2012 Mindfulness based stress reduction in post-treatment breast cancer patients: An examination of symptoms and symptom clusters. Jiurnal of Behavioral Medicine 35: 86–94.
Lichtenstein AH, Appel LJ, Brands M, Carnethon M, Daniels S, Franch HA, Franklin B, Kris-Etherton P, Harris WS, Howard B, Karanja N, Lefevre M, Rudel L, Sacks F, Van Horn L, Winston M, Wylie-Rosett J 2006 Diet and lifestyle recommendations revision 2006: A scientific statement from the American Heart Association Nutrition Committee. Circulation 114: 82–96.
Littman AJ, Bertram LC, Ceballos R, Ulrich CM, Ramaprasad J, McGregor B, McTiernan A 2012 Randomized controlled pilot trial of yoga in overweight and obese breast cancer survivors: Effects on quality of life and anthropometric measures. Supportive Care in Cancer 20: 267–277.
Mason C, Alfano CM, Smith AW, Wang CY, Neuhouser ML, Duggan C, Bernstein L, Baumgartner KB, Baumgartner RN, Ballard-Barbash R, McTiernan A 2013 Long-term physical activity trends in breast cancer survivors. Cancer Epidemiology Biomarkers and Prevention 22: 1153–1161.
McTiernan A 2008 Mechanisms linking physical activity with cancer. Nature reviews. Cancer 8: 205–211.
McTiernan A, Kooperberg C, White E, Wilcox S, Coates R, Adams-Campbell LL, Woods N, Ockene J 2003a Recreational physical activity and the risk of breast cancer in postmenopausal women: The Women's Health Initiative Cohort Study. JAMA 290: 1331–1336.
McTiernan A, Rajan KB, Tworoger SS, Irwin M, Bernstein L, Baumgartner R, Gilliland F, Stanczyk FZ, Yasui Y, Ballard-Barbash R 2003b Adiposity and sex hormones in postmenopausal breast cancer survivors. Journal of Clinical Oncology 21: 1961–1966.
McTiernan A, Wu L, Chen C, Chlebowski R, Mossavar-Rahmani Y, Modugno F, Perri MG, Stanczyk FZ, Van Horn L, Wang CY 2006 Relation of BMI and physical activity to sex hormones in post-menopausal women. Obesity 14: 1662–1677.
Moadel AB, Shah C, Wylie-Rosett J, Harris MS, Patel SR, Hall CB, Sparano JA 2007 Randomized controlled trial of yoga among a multiethnic sample of breast cancer patients: Effects on quality of life. Journal of Clinical Oncology 25: 4387–4395.
Morimoto LM, White E, Chen Z, Chlebowski RT, Hays J, Kuller L, Lopez AM, Manson J, Margolis KL, Muti PC, Stefanick ML, McTiernan A 2002 Obesity, body size, and risk of postmenopausal breast cancer: The Women's Health Initiative (United States). Cancer Causes and Control 13: 741–751.
Mustian KM, Sprod LK, Janelsins M, Peppone LJ, Palesh OG, Chandwani K, Reddy PS, Melnik MK, Heckler C, Morrow GR 2013 Multicenter, randomized controlled trial of yoga for sleep quality among cancer survivors. Journal of Clinical Oncology 31: 3233–3241.
Norman SA, Miller LT, Erikson HB, Norman MF, McCorkle R 2001 Development and validation of a telephone questionnaire to characterize lymphedema in women treated for breast cancer. Physical Therapy 81: 1192–1205.
Olivo EL 2009 Protection throughout the life span: The psychoneuroimmunologic impact of Indo-Tibetan meditative and yogic practices. Annals of the New York Academy of Sciences 1172: 163–171.
Patterson RE, Cadmus LA, Emond JA, Pierce JP 2010 Physical activity, diet, adiposity and female breast cancer prognosis: A review of the epidemiologic literature. Maturitas 66: 5–15.
Phoosuwan M, Kritpet T, Yuktanandana P 2009 The effects of weight bearing yoga training on the bone resorption markers of the postmenopausal women. Journal of the Medical Assoiation of Thailand 92 Suppl 5: S102–S108.
Pinto BM, Frierson GM, Trunzo JJ, Marcus BH. 2005. Home-based physical activity intervention for breast cancer patients. Journal of Clinical Oncology 23: 3577–3587.

Pullen PR, Nagamia SH, Mehta PK, Thompson WR, Benardot D, Hammoud R, Parrott JM, Sola S, Khan BV 2008 Effects of yoga on inflammation and exercise capacity in patients with chronic heart failure. Journal of Cardiac Failure 14: 407–413.

Schmitz KH, Ahmed RL, Troxel AB, Cheville A, Lewis-Grant L, Smith R, Bryan CJ, Williams-Smith CT, Chittams J 2010a Weight lifting for women at risk for breast cancer-related lymphedema: a randomized trial. JAMA 304: 2699–2705.

Schmitz KH, Courneya KS, Matthews C, Demark-Wahnefried W, Galvao DA, Pinto BM, Irwin ML, Wolin KY, Segal RJ, Lucia A, Schneider CM, von Gruenigen VE, Schwartz AL 2010b American College of Sports Medicine roundtable on exercise guidelines for cancer survivors. Medicine and Science in Sports and Exercise 42: 1409–1426.

Schmitz KH, Troxel AB, Cheville A, Grant LL, Bryan CJ, Gross CR, Lytle LA, Ahmed RL. 2009. Physical Activity and Lymphedema (the PAL trial): Assessing the safety of progressive strength training in breast cancer survivors. Contemporary Clinical Trials 30: 233–245.

Segal R, Evans W, Johnson D, Smith J, Colletta S, Gayton J, Woodard S, Wells G, Reid R 2001 Structured exercise improves physical functioning in women with stages I and II breast cancer: Results of a randomized controlled trial. Journal of Clinical Oncology 19: 657–665.

Simpson ER, Brown KA 2013 Minireview: Obesity and breast cancer: A tale of inflammation and dysregulated metabolism. Molecular Endocrinolology 27: 715–725.

Speck RM, Courneya KS, Masse LC, Duval S, Schmitz KH 2010 An update of controlled physical activity trials in cancer survivors: A systematic review and meta-analysis. Journal of Cancer Survivorship 4: 87–100.

Ulger O, Yagli NV 2010 Effects of yoga on the quality of life in cancer patients. Complementary Therapies in Clinical Practice 16: 60–63.

Ulger O, Yagli NV 2011 Effects of yoga on balance and gait properties in women with musculoskeletal problems: A pilot study. Complementary Therapies in Clinical Practice 17: 13–15.

United States Department of Health and Human Services 1996 Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA.

United States Department of Health and Human Services 2008 Physical Activity Guidelines for Americans. Atlanta, GA.

Van Puymbroeck M, Burk BN, Shinew KJ, Cronan Kuhlenschmidt M, Schmid AA 2013 Perceived health benefits from yoga among breast cancer survivors. American Journal of Health Promotion 27: 308–315.

Van Puymbroeck M, Schmid A, Shinew KJ, Hsieh PC 2011 Influence of Hatha yoga on physical activity constraints, physical fitness, and body image of breast cancer survivors: A pilot study. International Journal of Yoga Therapapy 21: 49–60.