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Comparison of Upper Extremity Function in Women With and Women Without a History of Breast Cancer

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Background. Breast cancer treatments often result in upper extremity functional limitations in both the short and long term. Current evidence makes comparisons against a baseline or contralateral limb, but does not consider changes in function associated with aging.

Objective. The objective of this study was to compare upper extremity function between women treated for breast cancer more than 12 months in the past and women without cancer.

Design. This was an observational cross-sectional study.

Methods. Women who were diagnosed with breast cancer and had a mean post–surgical treatment time of 51 months (range = 12–336 months) were compared with women who did not have breast cancer (CTRL group). Self-reported upper extremity function using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and shoulder range of motion, strength, and muscular endurance were measured. Participants were divided into 3 groups: breast cancer involving the nondominant limb (BC-ND), breast cancer involving the dominant limb (BC-DOM), and CTRL.

Results. A total of 59 women in the CTRL group, 23 women in the BC-ND group, and 28 women in the BC-DOM group completed measures. Mean DASH scores in women with breast cancer were higher than those of women in the CTRL group, regardless of the limb on which cancer occurred (Cohen d = 1.13; CI_{95} = 2.20 to 16.21). Range of motion for the BC-ND group was significantly less for flexion (Cohen d =1.19, CI_{95} = -13.08 to -0.11) and external rotation (Cohen d =1.11, CI_{95} = -18.62 to -1.98) compared with the CTRL group**.** Strength in the BC-ND group was 23% to 25% lower in the CTRL group for external (Cohen's d =0.89, CI_{95} = 0.09 to 0.12) and internal rotation (Cohen d =0.92, CI_{95} = 0.10 to 0.13). Endurance was not significantly different in the 3 groups.

Limitations. Some participants had rehabilitation, which may have skewed results. The range of post–surgical treatment times was broad, making it difficult to determine when function returned. Muscular endurance measures demonstrated a ceiling effect and large variance, limiting the ability to distinguish differences among participants. These results may not be generalizable to the subset of women who were treated with lumpectomy, sentinel node biopsy, or chest wall radiation alone or who underwent a contralateral prophylactic mastectomy.

Conclusion. In the long term, women with breast cancer have lower self-reported shoulder function than women without breast cancer. Motion and strength are lower among women who have experienced cancer on the nondominant limb.

With the 5-year survival rate of breast cancer at nearly 90%, currently over 3 million women are living after a diagnosis of breast cancer.[1] Upper extremity functional deficits following surgical and radiation treatments persist beyond the first year.[2-4] Declines in upper extremity function compared with a precancer level are self-reported in 21% to 35% of women treated for breast cancer up to 6 years following diagnosis.[5,6] The more involved the treatment, the greater risk of upper extremity morbidity. In women surgically treated with mastectomy and axillary lymph node dissection (ALND) and in women who undergo axillary radiation, upper extremity deficits in function are reported at greater levels than in women with lumpectomy and/or sentinel node dissection surgeries.[7] The extent of these reported deficits and whether they can be attributed to breast cancer surgery and treatment or to normal aging have not been examined adequately.

Functional performance of the upper extremity includes adequate levels of arm motion, strength, and muscular endurance. Declines in motion are reported among women treated for breast cancer in the long term, with one study reporting >10% decline in flexion more than 5 years following treatment for breast cancer,[8] and another study identifying that losses of ≥20degrees of motion were present 7 years after surgical treatment.[9] Upper extremity strength declines of 10% to 15% are reported 1 to 5 years after treatment for breast cancer.[10] Muscular endurance, the ability to sustain an activity over time, has been minimally examined among women with breast cancer but conflicting results from no deficits[11] to a 20% deficit in muscular endurance are reported.[12,13] To date, studies on upper extremity functional performance in women with breast cancer have primarily used self-reported measures or measured changes relative to the contralateral limb, assuming this limb is without deficit and functions similarly. Direct comparisons to a group of women with similar ages without breast cancer have not been reported for women who have been diagnosed with breast cancer long term. Furthermore, range of motion (ROM) and strength among women who are healthy is dependent on limb dominance[14,15]; therefore, involved limb dominance should be considered when making comparisons between these groups.

Deficits in self-reported and objective measures of upper extremity function among long-term survivors of breast cancer may be in part a result of changes seen with normal aging. Direct comparisons of upper extremity function measured by self-report, ROM, strength, and muscular endurance between women with BC and women who are healthy are important to determine whether existing deficits are due to treatment or normal aging. The purpose of this study was to compare upper extremity function of long-term survivors of breast cancer to a population of women without breast cancer.

[H1] Methods

[H2] Participants

A convenience sample of 59 women who were healthy (CTRL group), 25 women with breast cancer on the nondominant limb (BC-ND group), and 29 women with breast cancer on the dominant limb (BC-DOM group) recruited via word-of-mouth, flyers, and email agreed to participate. All participants were between 40 and 69 years. The CTRL group had no history of breast cancer, while the BC groups underwent at least 1 of the following treatments a minimum of 12 months prior to participation: mastectomy, ALND, axillary radiation. Participants were excluded if they had any history of shoulder, cervical, or thoracic spine pathology diagnosed by a physician within the previous 6 months or any history of shoulder, cervical, or thoracic surgery so as to not confound findings. Women with prophylactic contralateral mastectomies were also excluded to be able to clearly measure involved versus uninvolved sides. One participant with breast cancer was excluded after screening revealed she had undergone rotator cuff surgery on her involved side prior to the cancer diagnosis. Two other participants with breast cancer were excluded after clarification that the radiation received was local to the tumor site and not the axilla. The final analyses included 23 women in the BC-ND group and 28 women in the BC-DOM group.

Sample size was based *a priori* on a study examining self-reported function between women with and without breast cancer. Using the mean Disabilities of the Arm, Shoulder, and Hand (DASH) scores and flexion ROM measures between women with breast cancer 6 months after treatment and healthy controls,[16] the power calculation resulted in an estimated 14 to 16 participants per group required to meet a power of 90%. The study procedures were explained to all participants, and, after questions were answered, each completed consent prior to data collection. This study was approved by the Institutional Review Boards of the University of

Kentucky, Lexington, Kentucky, the University of Dayton and Miami Valley Hospital, Dayton, Ohio.

Procedures

On a single visit, each participant's objective upper extremity function was measured by a battery of tests--bilateral shoulder ROM and strength in 3 planes, and muscular endurance using the Functional Impairment Test–Hand and Neck, Shoulder, Arm (FIT-HaNSA)--by 1 of 3 trained investigators.[17] Participants completed a demographic questionnaire, the International Physical Activity Questionnaire (IPAQ), and the DASH prior to completing other components of testing. Demographic variables of age and arm dominance were recorded, and height and weight were measured to determine body mass index.

[H2] Participant-Reported Measures

Activity level was measured by the 7-item IPAQ, which has good test-retest reliability (Spearman r = 0.70–0.90).[18] Self-reported upper extremity function was measured by the DASH, a 30-item disability scale scored 0 to 100; lower scores denote less disability. Construct and convergent validity have been established with other shoulder functional scales, and the test-retest reliability within the breast cancer population is excellent (ICC = 0.97).[19-22]

[H2] Objective Clinical Measures

Range of motion. Bilateral active ROM of shoulder flexion, external rotation (ER), and hand behind back (HBB) were measured by taking photographs of the participant completing each motion. The HBB motion was chosen as a representation of a functional measure of internal rotation, often utilized clinically. Degrees of motion were calculated using ImageJ (National Institutes of Health, Washington, DC, USA) by the primary investigator. The ICC for intrarater reliability of digital measurement of ROM was consistently >0.95, with a standard error of measurement <2 degrees.

Shoulder flexion and ER measurements were taken by placing markers along the axes of motion as described by Norkin and White[23]; the marker for the HBB measure was placed at the level of the C7 spinous process.[24,25] Shoulder flexion measurements were taken in standing; ER was taken with the participant's upper arm supported on 2 towels while the participant was lying supine with the arm at 90 degrees of abduction and 90 degrees of elbow flexion. Participants were instructed to complete the motion as far as possible, and a photograph was taken at this end range. This procedure was repeated twice bilaterally with the mean of the 2 measurements used for analysis.[23] The shoulder flexion angle was the intersection of 2 lines, one representing the shoulder and the other the thorax (Fig. 1a). The shoulder ER angle was formed by a line drawn through the shaft of the ulna and a line perpendicular to the plinth (Fig. 1b). To measure the HBB distance, a 10-cm reference was placed in the same plane as the participant to provide a spatial scale of the image for accurate measurement.[26] The distance in centimeters from the C7 spinous process to the spinous process in line with the tip of the thumb was recorded (Fig. 1c).[24] A lower value indicates greater motion. Interrater reliability of the ROM procedures was established in pilot testing of 8 female adults who were healthy prior to data collection (ICCs = 0.90-0.99).

[H2] Strength. The strength of the shoulder flexors, internal rotators, and external rotators was measured by handheld dynamometry (Lafayette Manual Muscle Test System, Lafayette Instruments, Lafayette, IN, USA) using standard testing positions.[27] An inelastic nylon strap (~5 cm [2 in] wide) was placed around the participant's limb and the tester's body for each motion to provide a consistent, immovable resistance for the handheld dynamometer (Fig. 2).[28-30] Each participant was instructed to generate force to a maximal level over 5 seconds in each direction of testing.[31,32] Two submaximal practice trials were completed prior to testing, followed by 3 trials with 10 seconds rest in between. The average strength in kilograms (kg) of the 3 trials was used for statistical analysis.[33] Strength was normalized to body weight and is presented as a percentage of body weight (kilograms of force/body weight in kilograms). Shoulder flexion was measured with the participant seated, arm elevated to 90 degrees (Fig. 2a).[27] To measure IR and ER, the upper arm was supported on 2 towels while the participant was lying supine with the arm at 90 degrees of abduction and 90 degrees of elbow flexion (Fig. 2b, 2c).[27] In pilot testing with 8 participants, the ICCs for interrater reliability for strength measures ranged from 0.78 to 0.80, and the standard error of measurement was consistently below 1.2% of body weight.

[H2] Muscular endurance. Upper extremity muscular endurance was measured by the FIT-HaNSA subtests 2 and 3 following a previously established protocol for performance and termination of testing.[17] The FIT-HaNSA challenges muscular endurance through the completion of a series of repetitive tasks involving lifting 1 kg from eye level down 25 cm, and a sustained manipulation task with nuts and bolts above the head (Fig. 3a, 3b). The FIT-HaNSA demonstrates good-excellent test-retest reliability (ICC = 0.79–0.97), and moderate concurrent validity (r = 0.71–0.76) with self-reported upper extremity functional scales (Fig. 3 and 4).[17,27]

[H2] Data Analysis

Participants with breast cancer were divided into groups based on which side the cancer occurred: dominant (BC-DOM group) or nondominant (BC-ND group). For comparison analyses, the same limb was used for both the CTRL and BC groups: BC-DOM was compared to the dominant limb of the CTRL group, whereas BC-ND was compared to the nondominant limb of the CTRL group For analyses that did not depend on laterality, the full BC group (ie, both the BC-DOM group and the BC-ND group) was compared to the CTRL group.

Descriptive statistics were calculated for all variables. Data were examined for assumptions of normality using Kolmogorov-Smirnov test. All data were normally distributed (p <.05) except for the DASH and FIT-HaNSA scores. Because the sample size is robust and the variance small, the DASH and FIT-HaNSA were evaluated with parametric tests, consistent with other literature in this area.[5,17] Participant demographics of age, body mass index, activity level, and DASH scores were compared using a 1-way analysis of variance (ANOVA). Separate multivariate analyses of variance (MANOVA) were used to analyze all ROM, strength, and muscular endurance measures. For each MANOVA, Box Tests of Equality of Covariance Matrices were used to test assumptions of homogeneity. When significance was found on the ANOVA and MANOVA, Games-Howell *post hoc* testing determined the direction of significance based on unequal group sizes with unequal variances.[34] Cohen d was used to calculate effect sizes. Significance was established *a priori* at $P \leq 05$. All data were analyzed using IBM SPSS Statistics 23 (Chicago, IL, USA).

[H1] Results

The ANOVA revealed no significant differences in potential confounders of age (P = .23), body mass index (P =.59), and activity levels (P =.78) among the 3 groups. Among participants with breast cancer, the median duration since surgical treatment was 51 months (range = 12–336); 34 (66.7%) underwent a mastectomy, 17 (33.3%) underwent ALND, and 12 (23.5%) had axillary radiation. Of these, 23 (45.1%) underwent a mastectomy alone, 5 (9.8%) had both a mastectomy and ALND, 6 (11.8%) underwent an ALND and axillary radiation, and 6

(11.8%) underwent all 3 procedures. Of the 34 women who underwent a mastectomy, data on reconstruction status were available from 26 (76.5%), with 11 (42.3%) women not having reconstructive surgery, 12 (46.2%) having implant reconstruction, 2 (7.7%) having transverse rectus abdominis myocutaneous (TRAM) flap reconstruction, and 1 (3.8%) %) having latissimus reconstruction. More than half of the participants (60%) who answered the question about prior rehabilitation intervention for their shoulder did not have previous treatment. Of those who received rehabilitation, the majority received lymphedema treatment and education, with a small portion receiving exercise to improve motion. Enrolled participants came from a broad geographic area including 5 counties encompassing urban, suburban, and rural locales. Participant demographics are detailed in Table 1.

The ANOVA for the DASH resulted in statistically significant differences between both BC groups and controls. Tukey *post hoc* testing revealed significant differences among the BC-DOM and CTRL groups ($P \leq .001$) and the BC-ND and CTRL groups ($P = .008$) (Tab. 2). The Box Test of Equality of Covariance Matrices was not significant ($P > .01$) for ROM, strength, or muscular endurance, indicating that the covariance matrices of the dependent variables were equal across groups. The MANOVA for ROM measures revealed statistically significant differences between the BC-ND and CTRL groups ($P \leq .001$). Games-Howell p*ost hoc* testing indicated that the BC-ND group had statistically significantly less flexion ($P = .006$) and ER ($P = .009$) motion than the CTRL group (Tab. 2). Strength was significantly less in the BC-ND group for shoulder internal ($P \leq .001$) and external rotation ($P = .003$) than for the CTRL group (Tab. 2). FIT-HaNSA testing resulted in no statistically significant differences between groups ($P > .05$).

[H1] Discussion

This unique study directly compared DASH scores and shoulder ROM, strength, and muscular endurance between women with BC and healthy controls, while considering involved limb dominance. To our knowledge ,these comparisons have not been investigated among long-term survivors of breast cancer. The results suggest that persistent deficits may be a result of breast cancer treatment and are not due to aging. Women treated for breast cancer report higher DASH scores (disability) regardless of which limb is involved. Those with cancer affecting their nondominant limb demonstrate less upper extremity ROM and strength than a control sample of women without breast cancer. Based on these findings, clinical interventions may need to be different based on the side affected by breast cancer.

DASH scores were statistically significantly higher among women with breast cancer compared with levels reported by the healthy sample, implying lower levels of overall upper extremity function. Caution should be exercised, however, as this level of perceived function may not be clinically relevant when compared to DASH values in a larger population. The mean DASH score of a general population sample of 1706 adults was 10.1 (SD = 14.7),[35] and among 327 women aged 18 to 65 years, the mean DASH score was 14.3 (SD = 14.9).[36] That the control population in this study reported DASH scores much lower than the general population is likely due to study criteria for participation that included no current shoulder dysfunction. In a comparison of our results (mean score = 12.0–12.3) to a general population, our sample of women with breast cancer who were on average 4 years posttreatment reported similar levels of function. These findings indicate that women with breast cancer can expect recovery of function similar to the population as a whole with adequate time. Yet months to years after treatment, over 20% of women treated for breast cancer score >20 on the DASH.[5] Given the large effect sizes of the results, the findings in our study may suggest that the diagnosis of cancer can overlay the reality of recovery and that women treated for breast cancer continue to perceive that recovery is incomplete. The self-reported function of the BC groups remains lower than that of our control population without shoulder impairment.

Nearly all ROM measures in participants with breast cancer were impaired by 4% to 12% compared with a healthy sample even 4 years after treatment. Only the HBB measure was not significantly diminished, yet in terms of raw numbers, the BC-DOM group demonstrated 3.5% less motion than the control group, whereas those with cancer on the nondominant side demonstrated 23% less motion. This greater loss on the nondominant side suggests greater impact of the cancer experience on this side. The mean shoulder flexion motion among participants with breast cancer in this study is 12 to 17 degrees less than that reported among women with breast cancer within the first 6 months after treatment,[16] suggesting that shoulder flexion ROM loss may continue past 1 year. Although none of the averages of motion are below what is generally accepted as a clinically significant level, a minimum range of 148 degrees of shoulder flexion is documented as necessary for reaching a high shelf.[37] A secondary analysis of participants with breast cancer with motion <148 degrees revealed that 30 of 51 (59%) of these participants did not have this level of motion available on the involved limb. The ER motion, although statistically significantly less in the BC-ND group, is not considered to be clinically deficient at 83 degrees, as most functional tasks can be completed with this available range. Although women with breast cancer 4 years following treatment generally demonstrate ROM at an adequate level to complete most daily activities, these women may have difficulty completing tasks requiring what is generally accepted as full ROM, such as reaching to higher heights or participating in overhead activities. Furthermore, the effect sizes of these results (>1) suggest that the differences seen are greater than 1 standard deviation from the mean. It is important to understand that even 4 years after treatment, these women demonstrate motion at levels less than their peers without breast cancer.

Strength differences compared to the CTRL group were found to affect primarily participants who had cancer on their nondominant side. This group demonstrated strength impairments in both IR and ER that show a 26% to 28% deficit compared with a population of women without a history of breast cancer. Additionally, the strength values of participants with breast cancer in this study are more than 30% less than published reference values for a healthy population of similarly aged women.[14,31] Although methodologies for measurement differed slightly (flexion resistance at the epicondyle instead of distally at the ulnar styloid process[14] and rotation positioning at 45 degrees[14,31] instead of 90 degrees of abduction used in this study), the deficits appear greater than can be explained by differing methodologies. It is possible that recovery of strength does not occur spontaneously but with use of the upper extremity, and the lack of apparent recovery seen in participants with breast cancer whose involved limb is nondominant may be due to lower levels of nondominant limb use in daily activities. In studies of arm activity using accelerometry individuals who are healthy, the nondominant limb typically has less activity than the dominant limb.[38] This loss of strength occurring in the involved nondominant limb was interesting because the strength deficits were not observed in the dominant limb, suggesting that women with breast cancer involving the nondominant limb may need to to have their rehabilitation for breast cancer managed differently than women with breast cancer in their dominant limb.

Research on muscular endurance among women with breast cancer is limited. Two published studies that have examined muscular endurance have used the Upper Body Strength and Endurance Test, for which psychometric data are unavailable.[39,40] Results from these studies show less endurance in the involved limb compared with the noninvolved limb. The current study is the first study to examine the use of the FIT-HaNSA in a population of women with breast cancer. Findings in this study indicate that upper extremity endurance is not impaired compared with a similar healthy population. The lack of differences found between groups may be due to the level of variance between the 2 groups. A large ceiling effect was observed in performing the FIT-HaNSA; 66% to 81% of the CTRL group completed the full test duration of 300 seconds, and 53% to 76% of participants with breast cancer completed the full test. Examining muscular endurance with a more responsive test without a ceiling effect might provide a clearer picture of the level of muscular endurance among women with breast cancer.

When examining the statistically significant deficits in light of clinical relevance in DASH scores, ROM, and involved nondominant limb strength, we determined that most daily activities can be completed at reported levels, but it is higher level functional activities that may be compromised among this group of women with breast cancer. The DASH outcome measure was designed to evaluate an overall level of disability, and questions are answered based on an individual's ability to perform a task regardless of limb used.[41] This may explain why scores among participants with breast cancer are similar to those in a healthy population, as not all tasks would be performed with the involved limb. Additionally, this outcome measure asks only 1 out of 30 questions related to reaching overhead and therefore may not be capturing disabilities related to reaching overhead to higher levels. The limitation to higher ROM seen in nearly 60% of participants suggests that although most daily tasks can be completed, tasks that require greater motion, such as reaching high shelves or participating in overhead activities, may be difficult to perform. Certainly, clear deficits in strength are noted among women who experienced breast cancer on their nondominant side, and this strength deficit can affect the ability to complete more demanding functional tasks that require higher levels of strength.

Several limitations in this study may have impacted the results. As the sample was limited to women with more involved cancer treatments, these results may not be generalizable to the subset of women who were treated with lumpectomy, sentinel node biopsy, or chest wall radiation alone or who underwent a contralateral prophylactic mastectomy. Incomplete data regarding rehabilitation intervention after surgical treatment for cancer and before data collection makes analysis of the impact of intervention difficult. It is possible that those who had interventions directed toward upper extremity functional return may have skewed the results. Incomplete data about how many women underwent reconstructive surgery is also a limitation; the impact of reconstructive surgery on arm function cannot fully be assessed. However, with two-thirds of those who had a mastectomy reporting on reconstruction status, it appears that about half of the sample who had mastectomies underwent reconstruction. In addition, the range of time after breast cancer treatment was long (12–336 months) and therefore may have allowed normal tissue healing to occur, thus mitigating long-term functional deficits. A longitudinal study would help differentiate at what point in time following treatment breast cancer symptoms improve, giving insight into the probable time line for return of function. The variance associated with the FIT-HaNSA was large (>60 seconds), suggesting that the measure was not sensitive enough to identify those individuals with decreased endurance. Furthermore, the significant ceiling effect does not allow for discrimination between groups.

[H1] Conclusion

Although long-term survivors of breast cancer often report upper extremity functional limitations, the results of this study indicate that, at an average of 4 years posttreatment, most women recover ROM and strength to levels comparable to women of similar ages without breast cancer. The important new finding focuses on which limb was involved with cancer treatment. Those women whose cancer impacted the nondominant limb appear to demonstrate long-term deficits that their counterparts with dominant involved limb do not. Although the clinical relevance of these statistically significant lower ROM and strength values in women with nondominant involvement may not seem important, these women continue to report functional deficits higher than their counterparts without shoulder dysfunction. The fact that most daily tasks could be completed with the available ROM and strength measured showed some recovery of function. These findings--a loss of shoulder flexion motion that can impact certain activities requiring a higher reach and the unexpected finding that strength deficits affect only those who have experienced cancer in the nondominant limb--have not been previously reported. As such, the findings in this study present a novel and important consideration in the treatment of women with breast cancer on the nondominant side. These findings were the most meaningful differences that require further investigation.

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Concept/idea/research design: M.I. Fisher, G. Capilouto, T. Malone, H. Bush, T.L. Uhl

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Project management: M.I. Fisher

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Ethics Approval

This study was approved by the institutional review boards of the University of Kentucky, Lexington, Kentucky, and the University of Dayton and Miami Valley Hospital, Dayton, Ohio.

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Disclosures and Presentations

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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This study is adapted in part from “A Comparison of Upper Extremity Function Between Female Breast Cancer Survivors and Health Controls: Typical Self-Report of Function, Motion, Strength and Muscular Endurance,” which was submitted by M.I. Fisher in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Rehabilitation Sciences at the College of Health Sciences, University of Kentucky, Lexington, Kentucky.

Figure Legend:

Fig 1a Flexion ROM

Arc of motion generated for illustrative purposes only by Kinovea.org

Fig 1b External Rotation ROM

Arc of motion generated for illustrative purposes only by Kinovea.org

Fig 1c Hand Behind Back Motion

Fig 2a Flexion Strength

Fig 2b Internal Rotation Strength

Fig 2c External Rotation Strength

Fig 3a FIT-HaNSA sub-test 2

Fig 3b FIT-HaNSA sub-test 3

Tables:

Table 1. Participant Demographics, Mean (SD)

	BCS Non-dominant (n=23)	BCS Dominant (n=28)	Control (n=59)
Age, years (range)	57 (41-67)	56 (41-69)	54 (40-68)
BMI	28.3 (6.4)	27.3 (5.9)	26.8 (5.4)
IPAQ, mets	2580 (2441)	3071 (4567)	3190 (2926)
Time since surgery, months (range)	51 (12-336)		
Surgery			
Mastectomy alone	8	15	
Mastectomy + ALND	3	2	
Mastectomy + ALND + Axillary Radiation	3	3	
ALND + Axillary Radiation	4	2	
Previous Rehabilitation (n=35)	5	11	

BCS = Survivor of breast cancer; BMI = Body Mass Index; IPAQ = International Physical Activity Questionnaire; ALND = Axillary Lymph Node Dissection

Table 2. Outcome Measures, Mean (SD)

	BCS Non-dominant (n=23)	Control Non-dominant (n=59)	*p* value	CI	Cohen's *d*	BCS Dominant (n=28)	Control Dominant (n=59)	*p* value	CI	Cohen's *d*
DASH	12.3 (13.1)	3.3 (4.6)	*0.008**	2.20, 16.21	1.13	12.0 (11.6)	3.3 (4.6)	*≤0.001**	3.33, 14.36	1.13
Range of Motion (in degrees except as noted)										
Flexion	140 (17)	154 (9.0)	*0.006**	-13.08, -0.11	1.19	146 (14)	152 (9.0)	*0.07*	-13.57, .46	0.55
External Rotation	83 (15)	94 (7.0)	*0.009**	-18.62, -1.98	1.11	90 (12)	95 (9.0)	*0.15*	-11.02, 1.17	0.50
HBB (cm)	16.6 (6.3)	13.5 (4.1)	*0.092*	-1.09, 4.13	0.64	17.6 (5.4)	17.0 (4.5)	*0.83*	-2.16, 3.50	0.12
Strength (% of body weight)										
Flexion	7.3 (3.1)	8.7 (3.1)	*0.24*	-0.03, 0.01	0.45	8.5 (3.0)	9.2 (3.0)	*0.06*	.73, .97	0.23
External Rotation	10.3 (4.7)*	14.3 (4.4)	*0.003**	0.09, 0.12	0.89	14.3 (5.4)	14.3 (4.2)	*0.27*	0.12, 0.16	0.0
Internal Rotation	10.5 (3.5)*	14.2 (4.2)	*0.001**	0.10, 0.13	0.92	12.7 (4.2)	14.3 (4.5)	*0.99*	0.11, 0.14	0.36
Muscular Endurance (in seconds)										
FIT-HaNSA 2	237.1 (86.7)	262.7 (67.7)	*0.42*	-63.74, 19.93	0.35	246.0 (77.8)	269.7 (56.8)	*0.35*	-64.04, 17.33	0.37
FIT-HaNSA 3	257.7 (69.4)	281.1 (45.1)	*0.31*	-61.90, 15.19	0.44	269.9 (67.2)	281.1 (45.1)	*0.71*	-45.89, 23.49	0.21

**Significant at alpha ≤0.05*

BCS = Survivor of breast cancer; CI = confidence interval; DASH = Disabilities of the Arm, Shoulder, Hand; FIT-HaNSA = Functional Impairment Test-Hand and Neck, Shoulder, Arm; HBB = hand behind back

Figure 1a

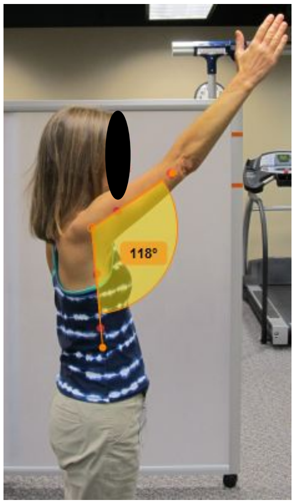

Figure 1b

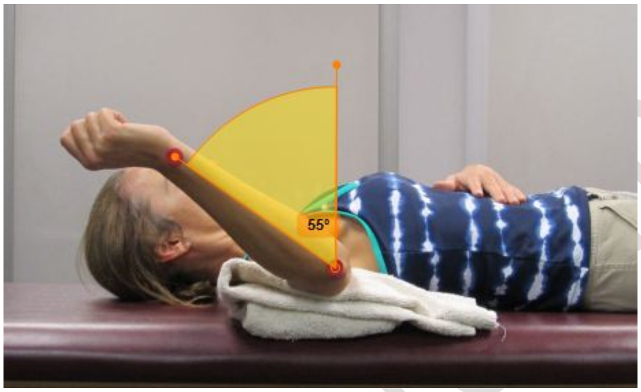

Figure 1c

Figure 2a

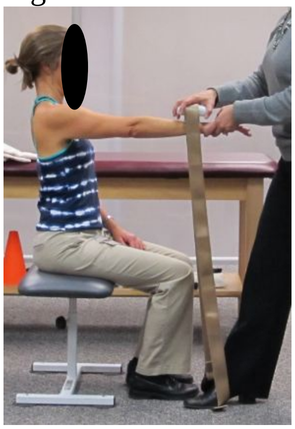

Figure 2b

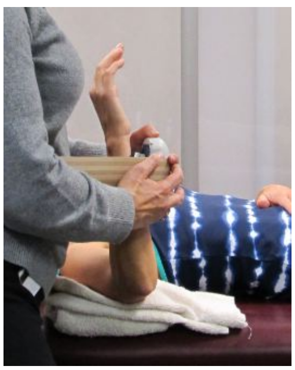

Figure 2c

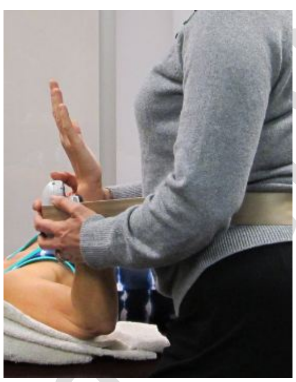

Figure 3a

Figure 3b