COMPARISON OF SHOULDER KINEMATICS, FLEXIBILITY, STRENGTH, AND FUNCTION BETWEEN BREAST CANCER SURVIVORS AND HEALTHY PARTICIPANTS

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ABSTRACT

SHANA HARRINGTON: Comparison of Shoulder Kinematics, Flexibility, Strength, and Function between Breast Cancer Survivors and Healthy Participants
(Under the direction of Dr. Darin A. Padua)

The present study compared shoulder kinematics, flexibility, strength, and function between breast cancer survivors and healthy, matched participants. Twenty four breast cancer survivors and twenty four matched controls completed the Disabilities of Arm, Shoulder, and Hand (DASH) and the Pennsylvania Shoulder Score (PSS) outcome measure questionnaires. Clinical measures of shoulder active (AROM) and passive (PROM) range of motion, cervical AROM, and shoulder strength were analyzed. Participants also had scapular kinematics assessed during the elevation phase of three tasks: flexion, scaption, and reaching. The results indicated statistically significant differences with the breast cancer survivors demonstrating decreased scores on the DASH and PSS, decreased AROM and PROM flexion and 90° ER, decreased AROM extension, and decreased strength for the measures of scapula abduction and upward rotation, scapula depression and adduction, shoulder flexion, shoulder adduction, shoulder internal and external rotation, and scaption. Kinematic analysis revealed a main effect for group during the scaption task for protraction/retraction with the breast cancer survivors demonstrating greater protraction throughout arm elevation. Correlation analyses revealed a relationship with the DASH to AROM flexion, PROM flexion and 90° ER, strength measures of scapula abduction and upward rotation, scapula depression and adduction, shoulder flexion, shoulder adduction, shoulder internal, and scaption, and cervical spine AROM left rotation. The PSS was found to correlate with AROM flexion, PROM flexion and 90° ER, strength measures of shoulder flexion, shoulder adduction, shoulder internal, and scaption, and cervical spine AROM left sidebending, left rotation, and right rotation. The results demonstrate the ROM measures of humeral flexion and humeral ER at 90º appear to be affected in the breast cancer survivor population. All seven of the strength measures assessed in this study were found to be decreased in the breast cancer survivor cohort. Finally, increased scapula protraction is another key finding. The results from this study provide preliminary evidence to suggest that clinicians focus on these particular ROM and strength measures when treating a breast cancer survivor who has recently completed their primary treatment. Results from this study also show women who have recently completed their primary breast cancer treatment appear to have function deficits as revealed in this study when using outcome measures such as the DASH and PSS.

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ABBREVIATIONS

Add	Adduction
A/P	Anterior/Posterior
BCS	Breast cancer survivor
CON	Control
DASH	Disabilities of the Arm, Shoulder, and Hand
Elev/Dep	Elevation/Depression
ER	External rotation
IR	Internal rotation
Int/Ext	Internal/External
Pro/Ret	Protraction/Retraction
PSS	University of Pennsylvania Shoulder Score
ROM	Range of motion
Rot	Rotation

LIST OF FUNCTIONAL QUESTIONNAIRES

CHAPTER I

INTRODUCTION

1.1 Breast Cancer

Breast cancer accounts for approximately 1/3 of all cancers diagnosed in American women.[1] In the United States, breast cancer is the most common non-skin cancer and the second leading cause of cancer related death in women.[2] The overall breast cancer death rate has dropped steadily since the early 1990's, although the breast cancer diagnosis rate has increased.[2] The National Cancer Institute estimates that more than $8 billion is spent each year in the United States on the treatment of breast cancer.[2] It has also been estimated that the number of cancer patients receiving treatment will increase threefold over the next 30 years, causing many to speculate that oncology may soon exceed cardiology as the most costly medical field in the United States.[3] Because of the increased number of women diagnosed with breast cancer, which can be most likely be attributed to improved technology and early detection, approximately 2.5 million women in the United States who have been diagnosed with and treated for breast cancer.[4] Approximately 89% of women diagnosed with breast cancer survive for 5 years or longer.[4] These statistics draw attention to the number of women experiencing, as well as surviving breast cancer. While survival rates continue to improve, the focus on survivorship issues and quality of life related to breast cancer treatment has now gained significantly more attention.[5] Therefore, it is imperative that these women be afforded the best possible care to manage the after effects of breast cancer treatment in order to restore function and live a healthy life.

1.2 Breast Cancer Treatment and Side Effects

Women diagnosed with breast cancer can be treated in a variety of ways depending upon several factors such as age, stage of cancer, location of tumor, size of the tumor, lymph node status, estrogen/progesterone receptors, and her-2-neu receptors. The most common types of breast cancer treatment include surgery, hormone therapy, chemotherapy, and/or radiation. Due to these treatments, many women experience secondary complications not only from the disease of breast cancer itself but because of its treatments. These secondary complications include decreased quality of life, weight gain, poor body image, fatigue,[6] increased risk for osteoporosis, cardiovascular disease, premature menopause, and lymphedema.[7] More specifically a loss of energy, pain, muscular weakness, a decrease in lean mass, and a reduction in total body flexibility and agility can contribute to the decrease in general activities of daily living, impacting an individual's overall quality of life.[3] Many of the side effects from cancer treatment are often debilitating and leave the individual with the inability to function at their pre-cancer level.[3]

Traditionally, management of breast cancer often primarily focuses on tumor response to treatment and survival rate.[9] However, there has been a recent interest in examining the physical morbidities associated with breast cancer survivorship.[8] In a study conducted by Isaksson and Feuk, 21% of the 45 breast cancer survivors in the study reported restricted arm/shoulder movements and 23% reported upper extremity pain six months after surgery, while 1 – 2 years after surgery, 13% reported weakness, 9%

complained of restricted arm/shoulder movements, and 9% described pain in their upper extremity.[9] Higher prevalence levels of reported weakness, restricted arm/shoulder movements, and pain in the upper extremity have been reported in other studies examining breast cancer survivors.[10] Among 233 women with newly diagnosed breast cancer, 82% stated having at least one arm problem, 55% reported pain, 40% complained of stiffness, 32% had limited arm movements, and 26% reported weakness 3 months after surgery, with little change 15 months later.[10] While some research has demonstrated that arm-related complaints usually decrease within three months of treatment[11], these complaints may become chronic to the extent that the arm dysfunction related to breast cancer is often underestimated.[12] Many of the studies examining upper extremity dysfunction in breast cancer survivors incorporate a broad selection of inclusion criteria making it impossible to determine what aspects of breast cancer treatment contribute to impairments. Therefore, the limited amount of research and conflicting results warrants that continued research should be undertaken to determine the factors contributing to these impairments in breast cancer survivors.

1.3 Limitations in Previous Breast Cancer Research

Given the significant impact that breast cancer has on individuals, it is evident that the breast cancer care continuum should include evidence based supportive therapeutic services to help the individual limit fatigue, deconditioning, and upper extremity dysfunction during and following treatment.[3] While arm disability appears to be a problem in breast cancer survivors, there is little known regarding shoulder function. Two aspects regarding breast cancer research have not been established as of this date. These include, 1) understanding what differences occur due to breast cancer and its treatment and 2) understanding the role of scapula and clavicle kinematics in these individuals. Specifically, it is important rehabilitation professionals have an appreciation of the following clinical variables: affected shoulder girdle strength, shoulder active ROM, shoulder passive ROM, and cervical ROM. These variables are imperative for rehabilitation professionals to recognize clinically in order to better understand what may be driving the upper extremity dysfunction that has been recognized recently in the breast cancer survivor population. Preliminary evidence suggests weakness in previous study designs involving breast cancer survivors. There have been no studies that have compared breast cancer survivors to healthy age, matched, and gender controls in order to establish baseline data of the exact deficits these women experience regarding range of motion, strength, and upper extremity function. Furthermore, no one has examined what differences may be occurring with regards to scapula and clavicle kinematics in breast cancer survivors. Research has demonstrated individuals with shoulder impairments such as subacromial impingement syndrome demonstrate altered scapula kinematics when compared to healthy controls.[13-20] Scapula motions are key components of shoulder function, and understanding what scapula and clavicle kinematic differences may exist in this population could provide clinicians with an enhanced understanding of the role the scapula and clavicle might have regarding pain and function, as well as prevention of dysfunction, in the breast cancer population. Results from this study hope to add to the body of knowledge for rehabilitation professionals who work with breast cancer survivors experiencing arm disability that affects function. Therefore, the primary purpose of this study was to examine differences that may exist between breast cancer survivors and healthy age, matched, and gender controls for upper extremity function, strength, shoulder active ROM, shoulder passive ROM, cervical active ROM, and scapula and clavicle kinematics during humeral elevation tasks of reaching, elevation in the sagittal plane, and elevation in the scapula plane (30° anterior to the frontal plane of the thorax) on the affected side. A secondary purpose of this study was to assess if relationships exist in the breast cancer survivor population between functional scores on the DASH and PSS with affected active shoulder ROM, affected passive shoulder ROM, cervical active ROM, and affected shoulder girdle strength.

1.4 Research Questions

RQ1. Are there significant differences between breast cancer survivors and matched controls on shoulder function (DASH and PSS)?

- a. Function
    - a. Disabilities of the Arm, Shoulder, and Hand (DASH) Scores
    - b. University of Pennsylvania Shoulder (PSS) Scores

RQ2. Are there significant differences between breast cancer survivors and matched controls on shoulder girdle strength, shoulder active ROM, shoulder passive ROM, cervical ROM, and 3D kinematics?

- a. Affected shoulder girdle strength
    - a. Scapula abduction and upward rotation
    - b. Scapula depression and adduction
    - c. Humeral flexion
    - d. Humeral IR
    - e. Humeral ER
    - f. Shoulder Scaption
    - g. Shoulder horizontal adduction
- b. Affected shoulder girdle active shoulder ROM
    - a. Supine flexion
    - b. Supine ER at 0°
    - c. Supine ER at 90°
    - d. Supine IR at 0°
    - e. Prone extension
- c. Affected extremity passive shoulder ROM
    - a. Supine flexion

        b. Supine ER at 0°
        c. Supine ER at 90°
        d. Supine IR at 0°
        e. Prone extension
    d. Cervical spine Active ROM
        a. Flexion
        b. Extension
        c. Left side bending
        d. Right side bending
        e. Left rotation
        f. Right rotation
    e. 3D kinematic variables
        a. Scapula anterior/posterior tipping
        b. Scapula upward/downward rotation
        c. Scapula internal/external rotation
        d. Clavicle elevation/depression
        e. Clavicle protraction/retraction

RQ3. Is shoulder active shoulder ROM, passive shoulder ROM, shoulder girdle strength, or active cervical ROM correlated to scores on the DASH in breast cancer survivors?

a. Active shoulder ROM
b. Passive shoulder ROM
c. Shoulder girdle strength
d. Active cervical ROM

RQ4. Is shoulder active shoulder ROM, passive shoulder ROM, shoulder girdle strength, or active cervical ROM correlated to scores on the PSS in breast cancer survivors?

a. Active shoulder ROM
b. Passive shoulder ROM
c. Shoulder girdle strength
d. Active cervical ROM

1.5 Research Hypotheses

RH1. There will be significant differences between breast cancer survivors and matched controls on shoulder function.

a. Breast cancer survivors will demonstrate the following differences when compared to matched controls:
    a. Function

i. Increased DASH Scores
ii. Decreased PSS Scores

RH2. There will be significant differences between breast cancer survivors and matched controls on shoulder girdle strength, shoulder active ROM, shoulder passive ROM, active cervical ROM, and 3D kinematics.

a. Breast cancer survivors will demonstrate the following differences when compared to matched controls:

   a. Shoulder girdle strength
      i. Decreased scapula abduction and upward rotation
      ii. Decreased scapula depression and abduction
      iii. Decreased humeral flexion
      iv. Decreased humeral internal rotation
      v. Decreased humeral external rotation
      vi. Decreased shoulder scaption
      vii. Decreased shoulder horizontal adduction
   b. Active shoulder ROM
      i. Decreased supine flexion
      ii. Decreased supine ER at 0°
      iii. Decreased supine ER at 90°
      iv. Decreased supine IR at 90°
      v. Decreased prone extension
   c. Passive shoulder ROM
      i. No differences in supine flexion
      ii. No differences in supine ER at 0°
      iii. No differences in supine ER at 90°
      iv. No differences in supine IR at 90°
      v. No differences in prone extension
   d. Active cervical ROM
      i. Decreased flexion
      ii. Decreased extension
      iii. Decreased left side bending
      iv. Decreased right side bending
      v. Decreased left rotation
      vi. Decreased right rotation
   e. Scapula kinematics
      i. Increased scapula anterior tipping
      ii. Increased scapula upward rotation
      iii. Increased scapula internal rotation
      iv. Increased clavicle elevation
      v. Decreased clavicle protraction

RH3. There will be a significant negative relationship between active shoulder ROM, shoulder passive ROM, shoulder girdle strength, and active cervical ROM to scores on the DASH in breast cancer survivors.

a. Variables of Interest

    a. DASH
    b. Active shoulder ROM
    c. Passive shoulder ROM
    d. Shoulder girdle strength
    e. Active cervical ROM

RH4. There will be a significant positive relationship between active shoulder ROM, shoulder passive ROM, shoulder girdle strength, and active cervical ROM to scores on the PSS in breast cancer survivors.

b. Variables of Interest

    a. PSS
    b. Active shoulder ROM
    c. Passive shoulder ROM
    d. Shoulder girdle strength
    e. Active cervical ROM

1.6 Operational Definitions

<u>Affected side:</u> The side, right or left, that the breast cancer was diagnosed and treated.

<u>Ascending phase:</u> Humeral motion from baseline (resting position) until the participant's maximum humeral elevation angle is achieved.

<u>Scapula plane</u>: Defined as 30° anterior to the frontal plane of the thorax

<u>Humeral elevation task of reaching:</u> The participants imagined that they were holding a soup can while placing their ulna styloid at a target that was positioned perpendicular to the affected AC joint on a shelf with the hand held in neutral rotation. The shelf was positioned so that the goal for the task was to move the arm from a height equal to the

participant's greater trochanter to a shelf at a height which allowed for extension of the elbow. A standard goniometer was used to ensure the humeral elevation relative to each participant's trunk was greater than 120° and that the elbow was comfortably extended.

<u>Humeral elevation in the frontal plane:</u> The participant was standing and a pole constructed of PVC pipe served as a guide in order for participants to maintain the proper plane of movement during the glenohumeral elevation task in the sagittal plane. This guide was placed in the sagittal plane in line with the affected side acromion and participants began with their arm at rest by their side and proceeded to full humeral elevation. The participants were asked to maintain a neutral hand position in which the palm of their hand lightly touched the PVC guide during the elevation task while their thumb was pointed towards the ceiling.

<u>Humeral elevation in the scapula plane</u> (30° anterior to the frontal plane of the thorax): The participant was standing and a pole constructed of PVC pipe served as a guide in order for participants to maintain the proper plane of movement during the glenohumeral elevation task in the scapula plane. This guide was placed 30° anterior to the frontal plane of the thorax, where a piece of tape was placed on the ground, and was confirmed using a standard goniometer. Participants began with their arm at rest by their side and proceeded to full humeral elevation. The participants were asked to maintain a neutral hand position in which the palm of their hand lightly touched the PVC guide during the elevation task while their thumb was pointed towards the ceiling.

<u>Baseline humeral elevation:</u> The angle of humeral elevation when the arm is at rest beside the participant.

Ascending phase of motion: Humeral motion from baseline humeral elevation until the participant's maximum humeral elevation angle

Beginning of phase: Defined as the point when the humeral elevation angle is greater than the baseline humeral elevation angle for 10 consecutive frames.

End of phase: Defined as the point when the humeral elevation angle is equal to the baseline humeral elevation angle for 10 consecutive frames.

Shoulder girdle strength: Represents the peak force during a 5 second muscle contraction, measured in pounds (lbs.)

Active range of motion: Defined as the amount of joint motion attained by a participant during unassisted voluntary joint motion, measured in degrees.

Passive range of motion: Defined as the amount of motion attained by the principal investigator without assistance from the participant.

Scapula anterior/posterior tipping: Scapula motion that occurs about an axis through the scapula spine. Posterior tipping rotates so that the anterior acromion moves upwards during humeral elevation and reverses this path during descending humeral elevation.

Scapula upward/downward rotation: Scapula motion that occurs about an axis approximately perpendicular to the scapula. Upward rotation moves toward a position so that the glenoid faces superiorly during humeral elevation and downward rotation moves toward a position where the glenoid faces inferiorly during the descending phase of humeral elevation.

Scapula internal/external rotation: Scapula motion that occurs about the long axis of the scapula. Internal motion is motion which moves toward a position where the glenoid faces anteriorly and external rotation moves toward a position where the glenoid faces posteriorly.

Clavicle elevation/depression: Clavicle motion that occurs along the joints anterior-posterior axis.

Clavicle protraction/retraction: Clavicle motion that occurs along the joints vertical axis.

1.7 Assumptions/Limitations

The following limitations and assumptions apply to this study:

1. Participants self-reported information was both honest and unbiased.
2. Kinematic data obtained from the skin mounted sensors on the scapula and humerus were representative of the true motion of these segments
3. Participants provided a true maximal voluntary isometric contraction during strength data collection
4. Participants performed to the best of their ability on all functional tasks and ROM measures
5. No subject randomization
6. No blinding of the researcher

1.8 Delimitations

The following delimitations apply to this study:

1. Forty-eight participants (24 breast cancer survivors and 24 healthy, matched, controls) were recruited from the University and the Chapel Hill surrounding community.
2. All control participants had no history of shoulder and neck injury in the past 6 months prior to data collection.

3. Kinematic data was collected from the thorax, scapula, and humerus using an electromagnetic tracking system.

1.9 Independent Variables

Four independent variables were used in this study:

1. Group
    a. breast cancer survivors
    b. healthy, matched controls

2. Phase of humeral elevation
    a. ascending

3. Humeral elevation angle
    a. 0° (start)
    b. 30°
    c. 60°
    d. 90°
    e. max (reaching task only)

4. Functional task
    a. Humeral elevation task of reaching
    b. Humeral elevation in the sagittal plane
    c. Humeral elevation in the scapula plane

1.10 Dependent Variables

Seven categories of dependent variables were used in this study:

1. Function
    a. DASH Scores
    b. PSS Scores

2. Affected shoulder girdle strength
    a. Shoulder abduction and upward rotation
    b. Scapula depression and adduction
    c. Humeral flexion
    d. Humeral IR
    e. Humeral ER
    f. Shoulder scaption
    g. Shoulder horizontal adduction

3. Affected active shoulder ROM
    a. Supine flexion
    b. Supine ER at 0°

c. Supine ER at 90°
d. Supine IR at 90°
e. Prone extension

4. Affected passive shoulder ROM
   a. Supine flexion
   b. Supine ER at 0°
   c. Supine ER at 90°
   d. Supine IR at 90°
   e. Prone extension

5. Cervical active ROM
   a. Cervical forward bending
   b. Cervical backward bending
   c. Cervical left side bending
   d. Cervical right side bending
   e. Cervical left rotation
   f. Cervical right rotation

6. Scapula Kinematics
   a. Scapula anterior/posterior tipping
   b. Scapula upward rotation/downward rotation
   c. Scapula internal/external rotation

7. Clavicle Kinematics
   a. Clavicle elevation/depression
   b. Clavicle protraction/retraction

1.11 Significance

The overall goal of this study was to compare function, affected shoulder girdle strength, affected active shoulder ROM, affected passive shoulder ROM, cervical active ROM, and 3D scapula and clavicle kinematics between breast cancer survivors and matched controls. The secondary goal of this study was to assess if any relationships exist in the breast cancer survivor population between functional scores on the DASH and PSS with affected shoulder girdle strength, affected active shoulder ROM, affected passive shoulder ROM, and cervical active ROM. These goals were accomplished by comparing 24 individuals who have a known diagnosis of breast cancer to 24 individuals who were considered healthy, matched controls. Selected scapula and clavicle kinematic variables were compared between the groups during three humeral elevation tasks. This is a unique study because there have been no prior comparisons of breast cancer survivors who have completed their treatment measuring upper extremity strength, shoulder AROM, shoulder PROM and cervical AROM to healthy, matched controls. Also, no studies have examined breast cancer survivors' scapula and clavicle kinematics during functional tasks. Understanding what differences exist with regards to function, affected shoulder girdle strength, affected active shoulder ROM, affected passive shoulder ROM, cervical active ROM, and scapula and clavicle kinematics between breast cancer survivors and matched controls will provide rehabilitation professionals with evidence based data that may assist clinicians in providing the best care possible when treating breast cancer survivors who present with shoulder dysfunction. This study has the ability to answer two significant missing pieces in the research literature regarding breast cancer survivors who have recently completed (within the past 6 months) their primary treatment of surgery, chemotherapy/and or radiation. The information from this study could help with future endeavors in reducing the impact of shoulder dysfunction for this group of women to provide them with the ability to return to a normal level of function.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

There are over 2.5 million women in the United States who are either living with or who have battled breast cancer.[21] Research has shown that these women may suffer from both psychological and physical long term consequences from not only the diagnosis of the breast cancer, but also the treatments these women receive. Because of this, there is a need to provide these women with the best possible care to allow them to return to their prior level of function before the initial diagnosis of breast cancer.

This literature review will provide a background on what is breast cancer, common treatments women who have been diagnosed with breast cancer receive, and how these treatments affect function, pain, shoulder girdle strength, shoulder range of motion (ROM), and quality of life. Since no studies to date have examined scapular kinematics in breast cancer survivors, the current understanding of scapular kinematics will be discussed in other populations who suffer from shoulder dysfunction. This review will also examine the current limitations in breast cancer research in order to provide supportive rationale for conducting this research study.

2.1 What is Cancer

Cancer is the universal name for a group of more than 100 diseases in which cells in a part of the body begin to grow out of control. All cancers start because atypical cells grow out of control. If left untreated, cancer can cause serious illness and even death. In a healthy individual, normal body cells grow, divide, and die in an orderly fashion. During the early years of a person's life, normal cells divide more quickly until the person becomes an adult. As a person ages, cells in most parts of the body divide only to replace depleted or dying cells and to repair injuries. Cancer cells often develop because of damage to deoxyribonucleic acid (DNA). DNA is in every cell and directs all of the cell's processes. In most cases, when DNA becomes damaged, either the cell dies or is able to repair the DNA, however, in cancer cells; the damaged DNA is not repaired.

2.2 What is Breast Cancer

It is believed that the Egyptians were the first to diagnosis breast cancer around 1600 B.C. [22] Today, breast cancer is defined as a malignant tumor that starts from cells of the breast. Breast cancers can begin in the cells that line the ducts, known as ductal cancer or in the lobules, known as lobular cancer and is classified as either non-invasive or invasive. Non-invasive (or “in situ”) breast cancer is limited to the ducts or lobules and do not spread to the surrounding tissues of the body. Whereas invasive breast cancer is when the cancer has started to spread through the normal breast tissue barriers and invades surrounding areas.

In some instances breast cancer may be found in other tissues of the breast.

2.2.1 Breast Cancer Cost and Incidence

In 2007, according to the National Institute of Health, cancer cost the United States an estimated $219 billion.[23] The Center for Disease Control estimates that each year, breast cancer treatment costs nearly $7 billion.[23] Other than skin cancer, breast cancer is the most common cancer in women in the United States.[24] After lung cancer, it is the second leading cause of cancer death in women. It is estimated that in the year 2008, 182,460 women will be diagnosed with some form of invasive breast cancer in the United States.[24] Of those, it is estimated that 40,480 will die of this disease.[24] The chance of a woman being diagnosed in her lifetime with invasive breast cancer is 1 in 8 and the chance of a woman dying from invasive breast cancer is 1 in 35.[24] Currently in the United States there are over 2.5 million breast cancer survivors.[24]

2.2.2 Breast Cancer Staging and Survival Rates

Understanding each stage of breast cancer is important in order to provide the best type of treatment to each individual survivor. Also, breast cancer staging is useful for the clinician because of its ability to estimate prognosis.[22] Breast cancer is most often classified using the tumor-node-metastasis (TNM) system that was developed by Pierre Denoix in 1942.[22] This system attempts to classify cancer based on the major morphological attributes of malignant tumors that were thought to influence disease prognosis: size of the primary tumor (T), presence and extent of regional lymph node involvement (N), and presence of distant metastases (M).[22] In 1977, the American Joint Committee on Cancer (AJCC) published a breast cancer staging system based on the TNM.[22] Since then, regular revisions have been made to reflect advances in diagnosis and treatment.[22]

Breast cancer is expressed as a Roman numeral beginning with stage 0 and further staged from I through IV. Some stages are sub-divided using the letters A, B, and C. In general, the lower the number, the less the cancer has spread and the higher the number, such as stage IV, means more advanced cancer. All non-invasive breast cancers such as DCIS and LCIS are described as Stage 0.[24] Women who have been diagnosed with Stage

0 breast cancer have a 5-year relative survival rate of 100%. [24] Breast cancers staged from I through IV.

Stage I breast cancer can be described as having a tumor that measures up to 2 centimeters and has no lymph node involvement.[24] The 5-year relative survival rate for this stage is also 100%.[24]

Stage II breast cancer is often subdivided into two categories known as IIA and IIB. Stage IIA breast cancer has no tumor that can be found in the breast, but cancer cells are found in the axillary lymph nodes, or the tumor measures 2 centimeters or less and has spread to the axillary lymph nodes, or the tumor is larger than 2 centimeters, but not larger than 5 centimeters and has not spread to the axillary lymph nodes.[24] Ninety-two percent of these women have a 5-year relative survival rate.[24] Stage IIB breast cancer is described as having a tumor larger than 2 but no larger than 5 centimeters and has spread to the axillary lymph nodes, or the tumor is larger than 5 centimeters but has not spread to the axillary lymph nodes.[24] The 5-year relative survival rate of women in this stage of breast cancer is 81%.[24]

Stage III breast cancer can be subdivided into three further categories known as IIIA, IIIB, and IIIC. Stage IIIA has no tumor found in the breast. The cancer in this stage is found in the axillary lymph nodes, or the tumor is 5 centimeters or smaller and has spread to the axillary lymph nodes, or the tumor is larger than 5 centimeters and has spread to the axillary lymph nodes.[24] The 5-year relative survival rate of these women is 67%.[24] Stage IIIB describes breast cancer in which the tumor may be any size and has spread to the chest wall and/or skin of the breast, and may have spread to axillary lymph nodes. Inflammatory breast cancer is considered at least to be a stage IIIB.[24] Approximately fifty-four percent of women diagnosed with stage IIIB with survive 5 years.[24] With breast cancer stage IIIC, there may be no sign of cancer in the breast or, if there is a tumor, it may be any size and may have spread to the chest wall and/or the skin of the breast and the cancer has spread to lymph nodes above or below the collarbone, and the cancer may have spread to the axillary lymph nodes or to lymph nodes near the breast bone.[24] Survival rates for stage IIIC have not been established because this is a relatively new defined stage.[24]

Stage IV breast cancer has spread to other organs of the body, most often the lungs, liver, bone or brain.[24] The term "metastatic" is used meaning that the breast cancer has spread beyond the breast and nearby lymph nodes, despite this being the first diagnosis of breast cancer.[24] This is because the primary breast cancer was not found when it was only inside the breast. All stage IV breast cancers are metastatic and have a 5-year relative survival rate of 20%.[24]

2.3 Breast Cancer Treatment

Breast cancer is treated by a variety of combinations of treatment. These include surgery, radiation therapy, chemotherapy, hormone therapy, and targeted therapy. Treatment selection depends on a variety of factors that include age, menopausal status of the patient, stage of breast cancer, histologic and nuclear grade of the primary tumor, estrogen-receptor (ER) and progesterone-receptor (PR) status, measures of proliferative capacity, and HER2/neugene amplification.[25] The majority of women who have been diagnosed with breast cancer will undergo intensive treatment, often involving multiple modalities that are described below.[25] What continues to remain unknown are the effects these modalities have on breast cancer survivors. This is because it is almost impossible to tease out the effect of one modality from another.

2.3.1 Biopsies

Women who are diagnosed with breast cancer will often undergo one of two types of procedures both of which can be performed to identify cancer specifically in the lymph nodes. These two procedures are the Axillary Lymph Node Dissection (ALND) and the Sentinal Lymph Node Biopsy (SLNB).

The status of axillary lymph nodes is an important prognostic factor in breast cancer staging and often guides further treatment.[26] During an ALND, anywhere from ten to forty lymph nodes are removed and then examined under a microscope for cancer.[26] Removal or resection of the pectoral muscles may occur depending on the level of ALND which also could involve the surrounding pectoral nerves.[26] This procedure is often performed in conjunction with a radical or modified radical mastectomy, or lumpectomy.[26] The presence of cancer cells in the axilla indicates that the cancer has spread beyond the breast, thereby worsening the prognosis.[27] Despite the advantages of ALND negative long-term effects have been found to include pain[10, 28-33], numbness[10, 28-30, 32, 33], swelling[10, 29, 30, 32-35], weakness[10, 29, 30, 32, 33, 36], and decreased sweat production.[37] Furthermore, research has shown that patients who undergo an ALND are 10 times more likely to report upper arm complaints.[26]

Due to the considerable arm morbidity often associated with ALND, physicians have developed the SLNB within the last decade.[26] The SLNB procedure removes fewer nodes then the ALND.[26] A sentinel node is the first lymph node into which a tumor drains.[26] These nodes are the ones most likely to contain cancer cells if the cancer has started to spread.[26] During a SLNB a small incision is made in the axillary region that is approximately ½ inches.[38] Following a SLNB, some women may experience pain, nerve damage, and/or lympedema.[38] If cancer has been found during the SLNB, the next step is usually to perform an ALND. Purushotham et al. conducted as study assessing quality of life (QOL) immediately after surgery in 298 women who were diagnosed with early breast cancer (tumors 3 cm or less on ultrasound examination).[39] Results revealed that those who had an ALND had significantly decreased QOL scores when compared to those who had a SLNB immediately after surgery.[39]

2.3.2 Local Treatment - Radiation

Localized treatment involves treating a tumor at the site of the cancer without affecting the rest of the body. Examples of localized treatment include surgery and radiation. Radiation therapy is a type of breast cancer treatment using high-energy rays or particles that destroy cancer cells.[40] Radiation can be administered in two ways: through an external beam radiation and brachytherapy.[40] The most common type of radiation for women with breast cancer is external beam radiation.[40] The extent of radiation depends on the type of surgical procedure performed and whether lymph nodes are involved.[40] Brachytherapy is known as "internal radiation". This procedure involves radioactive seeds or pellets being placed directly into the breast tissue next to the cancer.

A meta-analysis of 78 randomized controlled trials including approximately 42,000 women with breast cancer was conducted to determine the effects of radiotherapy.[41] Results show that radiation after either breast conserving surgery (BCS) or mastectomy in women with early breast cancer decreases both 5-year recurrence and 15-year mortality rates.[41] Radiotherapy after mastectomy can reduce the risk of a local recurrence by approximately 2/3 and remains an important component of management for breast cancer.[40]

Although the beneficial effect of postoperative radiotherapy for breast cancer is well documented, there are a number of complications associated with this treatment that might affect patients' QOL and possibly survival. Long-term radiation complications may include cardiac and lung damage, impaired shoulder mobility, and chronic pain.[42] Many studies have found axillary radiation to be a predictive factor for the development of shoulder morbidity.[43, 44] This is due to the fact that radiation may cause injury to normal tissues resulting in changes of the vascular network causing ischemia, ultimately affecting the efficacy of muscle contraction.[37, 45, 46] The muscles that are most commonly affected by radiation are the pectoralis major,[47, 48] serratus anterior, and lattisimus dorsi.[36] Radiation has been shown to cause subcutaneous fibrosis of the pectoralis muscles which in turn could be a factor causing shoulder pain and restriction.[49, 50] Chest wall adhesion may also be a side effect and can lead to increased risk of pain and reduction in ROM of the shoulder on the involved side as well as postural dysfunction.[51] Furthermore, soft tissue changes have been reported from the beginning of radiotherapy to as late as 3 years after the start.[47, 48]

2.3.3 Surgical Procedures

Most women who have been diagnosed with breast cancer will undergo some type of surgical procedure. The two categories of surgical procedures include breast conserving surgery (BCS) and mastectomy. Breast conserving surgery can be subdivided into lumpectomy, quadrantectomy, and partial mastectomy procedures. A lumpectomy removes only the breast lump that contains the cancer cells and a surrounding margin of normal tissue.[52] After a lumpectomy is performed, a seroma, or clear fluid trapped in the wound, often fills the surgical cavity.[38] Several months following a lumpectomy, the seroma is replaced by scar tissue.[38] The final result may vary from person to person depending on such factors as the location of the mass, its initial size, and the type of incision used.[38] A quadrantectomy is the removal of one quarter, or a quandrant of the breast.[2] A partial or segmental mastectomy is removal of the cancer, as well as some of the breast tissue around the tumor and the lining over the chest muscles below the tumor.[2]

A mastectomy involves removal of all of the breast tissue. Mastectomy procedures can be further subdivided into simple or total mastectomy, modified radical mastectomy, and radical mastectomy. A simple or total mastectomy is when the entire breast is removed, including the nipple.[52] However, the axillary lymph nodes and muscle tissue from beneath the breast is not removed.[52] In contrast, a modified radical mastectomy does involve removing some of the axillary lymph nodes along with removal of the entire breast.[52] Two common types of modified radical mastectomy procedures are the Patey and Madden. In the Patey procedure, the pectoralis minor muscle is often removed, but the pectoralis major is spared.[53] In contrast, the Madden procedure preserves both the pectoralis minor and major.[54] A radical mastectomy is a very extensive operation that removes the entire breast, axillary lymph nodes and the pectoral muscles.[52] This surgical procedure used to be very common; however it is rarely performed today because research has demonstrated that performing a modified radical mastectomy is just as effective.[52]

Even today, many physicians do not refer patients who have undergone[43, 55] mastectomies to physical therapy. This is most likely due to a lack of scientific evidence detailing the benefits of physical therapy in breast cancer survivors. Physicians also fear side-effects, such as lymphedema, may occur from rehabilitation programs that could hinder healing from breast cancer surgery and treatment. Fortunately, there is a recent increased interest in the rehabilitation of breast cancer survivors. In a recent study conducted by Cinar et al., fifty-seven women were randomly assigned to either a treatment group or a home exercise group.[55] The purpose of this study was to evaluate the effectiveness of an early rehabilitation program in women who had undergone a modified radical mastectomy.[55] After removal of each subject's drain, the treatment group participants attended fifteen sessions of individualized rehabilitation.[55] Range of motion (ROM) of the shoulder, upper extremity circumferential difference, and functional status, which was devised by Wingate (1985), were assessed preoperatively and then postoperatively at the fifth day, first, third, and sixth months.[55] Results demonstrated statistically significant improvements in ROM of shoulder flexion, abduction, and adduction, as well as improvements in the functional questionnaire scores for the treatment group.[55] Also, there was no statistical difference in the development of lymphedema or reported postoperative complications in either group.[55] Continued research, such as the study conducted by Cinar et al., needs to be performed in order to dispel any fear from the medical community about potential negative side-effects that could arise from participating in a rehabilitation program for breast cancer survivors who have undergone mastectomies.

2.3.4 Systemic Treatment

Systemic treatment refers to drugs that can be administered orally or directly into the blood stream to target cancer cells anywhere in the body. Examples of systemic treatment include chemotherapy, hormonal therapy, and targeted therapy.

2.3.4a Chemotherapy

Chemotherapy is a type of cancer treatment in which drugs are administered intravenously or by mouth. Chemotherapy is given in cycles in which the treatment is followed by a period of rest.[52] Chemotherapy cycles generally last anywhere from 3 – 6 months.[52] Breast cancer chemotherapy is considered to be either adjuvant or neoadjuvant.[52]

Adjuvant chemotherapy is given to cancer patients after surgery in which there is no evidence that the cancer has spread.[52] Adjuvant chemotherapy is often administered after BCS or mastectomy to reduce the recurrence of breast cancer.[52] Neoadjuvant chemotherapy is chemotherapy that is administered before surgery.[52] Two benefits of having chemotherapy before surgery include the ability to shrink large cancers so they are small enough to be removed by a lumpectomy instead of mastectomy and physicians are able to see how the tumor responds to chemotherapy.[52] Currently there is no evidence as to whether providing neoadjuvant chemotherapy improves survival rates in women with breast cancer.[52]

Patients with cancer who are receiving chemotherapy may experience a variety of side effects including hair loss, nausea, pain, weight changes, vomiting, anxiety, and fatigue.[56] One of the most common reported breast cancer-related side-effect is fatigue. Fatigue has been shown to increase significantly after the start of chemotherapy.[56]

Fatigue is a multidimensional and complex concept involving subjective feelings of tiredness, weakness, and/or a lack of energy.[57-59] Research has shown that fatigue can often be debilitating affecting daily activities for a long period of time after a cancer diagnosis.[60]

Sitzia and Huggins conducted a study on fifty-two breast cancer patients who were receiving 6 cycles of chemotherapy.[61] Questionnaires revealed that the incidence of fatigue was approximately 90% with the severity of fatigue remaining stable throughout the chemotherapy treatment cycles.[61] A longitudinal study conducted by Bower et al. surveyed 763 breast cancer survivors 1 – 5 and 5 – 10 years after diagnosis.[60] Approximately 34% of the breast cancer survivors in this study reported significant fatigue at 5 – 10 years after diagnosis.[60] What is not known is whether factors such as pain and impaired function causes fatigue or vice versa in breast cancer survivors. Therefore, it is important for clinicians to evaluate the effects of chemotherapy, specifically fatigue, on function in breast cancer survivors.

2.3.4b Hormone Therapy

Hormone therapy is another type of systemic treatment often administered to breast cancer survivors. For more than 100 years, hormone therapy has been known to be effective in treating breast cancer.[62] This type of treatment is most often used as an adjuvant to decrease cancer recurrence after surgery.[62] The hormone estrogen plays an important role in this type of adjuvant treatment. Estrogen functions as the primary female sex hormone and is produced by a woman's ovaries up until menopause.[62] It has been discovered that the estrogen hormone promotes the growth of 2 out of 3 breast cancers – the estrogen receptor positive (ER+) and progesterone receptor positive (PR+)

breast cancers.[62] Because of these two hormones, several pharmacological agents that block and/or decrease estrogen levels are used to treat ER+ and PR+ breast cancers.

Commonly used drugs to treat ER+ and PR+ breast cancers are Tamoxifen, Femara, Arimidex, and Aromasin. Tamoxifen is the most often used anti-estrogen drug that is taken daily in pill form for 5 years after breast cancer diagnosis. In 1998 a study was conducted by Fisher et al. on 13,388 women who had taken Tamoxifen.[63] Results showed that there was a 49% reduced risk of developing invasive and noninvasive breast cancer 69 months after taking Tamoxifen[63]. Taking Tamoxifen may produce side effects such as a higher risk of endometrial cancer, venous thrombotic events, cataracts, fatigue, hot flashes, and decreased quality of life.[52, 64]

Femara, Arimidex, and Aromasin are classified as Aromatase Inhibitors (AIs).[52] These types of drugs stop estrogen production in postmenopausal women[52]. Aromatase inhibitors work by blocking the enzyme aromatase which is responsible for making small amounts of estrogen in postmenopausal women.[52] It is important to understand that this classification of drug cannot stop the ovaries in premenopausal women from making estrogen.[52] Common side effects that may occur when taking AIs include nausea, vomiting, diarrhea, rashes, and arthralgia.[65] Currently, there is no study that has reported a difference in overall survival rates between breast cancer survivors who take an AIs or Tamoxifen.[66]

Due to the many side-effects that breast cancer survivors may have a result of hormonal therapy, it is important that clinicians who are treating women who are taking this type of medication recognize the potential side-effects. More specifically, how these side-effects influence function and activities of daily living, especially on the affected upper extremity.

2.3.4c Targeted Therapy

Targeted therapies are newer drugs that specifically target genes in cells and are often used along with chemotherapy. One of these genes is the human epidermal growth factor receptor-2 (HER2). This gene has been found to be an important prognostic and predictive marker for women with breast cancer.[67] The HER2 gene is present in small amounts on the surface of breast cancer cells.[67] If there is too much of this protein, breast cancer tends to grow and spread more aggressively.[52] Approximately 20% to 25% of women diagnosed with breast cancer have the HER2 gene amplified and the HER2 protein overexpressed resulting in a poor prognosis and shortened survival.[68] Therefore, women who have breast cancer as well as the HER2 gene amplification will most often have a more aggressive clinical course.[67]

One drug that is commonly used in combination with chemotherapy is Trastuzumab® (Herceptin). Herceptin was approved in 1998 by the U.S. Food and Drug Administration (FDA) for treatment of women who had been diagnosed with metastatic breast cancer.[67] This drug works to slow the growth of breast cancer cells along with stimulating the immune system to more effectively attach the cancer.[52] Herceptin is given as an injection intravenously 1 time a week for approximately 3 weeks.[52] Research is ongoing to determine the optimal length of time to administer this type of treatment.[52] Side effects from this treatment include fever, chills, weakness, nausea, vomiting, cough, diarrhea, and headache.[52] More serious side effects of taking Herceptin include the development of clinically manageable left ventricular systolic dysfunction and occasionally advanced congestive heart failure (CHF).[67] Risks for cardiac complications can be as high as 27% depending upon the combination of treatment used with Herceptin.[69]

When women who have been diagnosed with HER2+ breast cancer become no longer helped by chemotherapy and Herceptin, Lapatinib® (Tykerb) is another drug that targets the HER2 protein. Side effects experienced when taking Tykerb include nausea, diarrhea, vomiting, rash, hand foot syndrome, and in rare instances a decrease in heart function.[52] Symptoms of hand foot syndrome include tingling, redness, swelling, and discomfort of the hands and feet.[52] In a study conducted by Burris et al., sixty-seven patients with metastatic tumors were treated with Tykerb.[70] The two most common side effects were diarrhea (42%) and skin rash (31%).[70]

New biologic therapies have been developed that specifically target growth factor receptor signaling pathways. The vascular endothelial growth factor (VEGF) signal transduction pathway is one such pathway that plays a key role in new blood vessel formation.[71] One of the monoclodal antibodies that targets VEGF, which is one of the central growth factors responsible for tumor angiogenesis is Bevacizumab® (Avastin).[71] Avastin can be used when treating metastatic breast cancer in combination with chemotherapy.[52] Common side effects reported when taking Avastin include hypertension, headaches, loss of appetite, dyspnea, asthenia, and myalgia.[52, 71]

Targeted therapies are new treatments for those diagnosed with breast cancer. Because of this, not much is known regarding the side-effects resulting from these treatments. Despite this, it is important that clinicians understand what types of targeted therapies are often provided to these women and monitor the effects of these treatments on function and quality of life.

Breast cancer can be a confusing topic to not only those diagnosed, but for rehabilitation clinicians as well. For clinicians who treat women with breast cancer, it is our responsibility to understand what is breast cancer, staging of breast cancer, and the many types of treatments that may be prescribed for these women. It is also important that clinicians have an understanding of the common side effects that may arise from these treatments in order to provide the best care as well as modify treatment programs when needed to improve each breast cancer survivor's quality of life and function. The most common side-effects of these treatments include pain, fatigue, and weakness. It is essential for clinicians who work with breast cancer survivors to understand what treatments these women receive, as well as their common side effect to provide the best possible care to return these women to their level of function prior to the diagnosis of breast cancer. Furthermore, it is imperative to understand that because of the myriad of treatments described above that breast cancer survivors may receive, these women are more likely to protect their affected side and use their arm less to avoid pain due to the many side effects of these treatments.[72] Protection of the affected side may lead to potential disuse problems that include limits in ROM and surrounding muscle weakness.

2.4 Function in Breast Cancer Survivors

It is estimated that approximately 89% of women diagnosed with breast cancer survive for 5 years or longer.[73] These statistics draw attention to the number of women experiencing, as well as surviving breast cancer. Traditionally, management of breast cancer often primarily focuses on tumor response to treatment and survival rate.[74]

However, with improved survivorship there is also a recent increased awareness of complications that may arise from breast cancer treatment. Challenges associated with breast cancer survivorship are now widely recognized to have a long-term impact on a significant proportion of those affected by breast cancer.[75] These include decreased shoulder range of motion (ROM), decreased shoulder strength, pain, decreased quality of life (QOL) and function, and lymphedema. In one study, breast cancer participants reported their most distressing problem in association with their breast disease was “arm symptoms” (29%); even more stressful than the “fear for cancer recurrence” (22%).[76] Many researchers have studied these impairments relative to the type of treatment[77, 78] and type of surgery, ALND[27, 79-81], or a combination of these.[9, 82-85] However, many studies incorporate a broad selection of inclusion criteria making it impossible to determine what aspects of breast cancer treatment contribute to impairments. Therefore, the limited amount of research and conflicting results warrants that continued research should be undertaken to determine the factors contributing to these impairments in breast cancer survivors.[86]

2.4.1 Upper Extremity Range of Motion

The shoulder is a complex joint that has an incredible amount of ROM and mobility with many degrees of freedom.[87] This mobility is needed to complete several different tasks in daily life.[87] For example, a study conducted by Magermans et al. investigated how 24 healthy female subjects performed ADL’s and the glenohumeral and scapular joint angles needed to perform these tasks.[87] When these women combed their hair an average of 90° of glenohumeral frontal plane elevation, 59° of glenohumeral flexion in the scapular plane, and 34° of scapular external rotation was used.[87] Eating with a spoon required an average of 121° of glenohumeral frontal plane elevation, 60° of glenohumeral flexion in the scapular plane, and 26° of scapular external rotation.[87] Washing the axilla required and average of 53° of glenohumeral frontal plane elevation, 100° of glenohumeral flexion in the scapular plane, and 29° of scapular external rotation.[87] When these subjects lifted a 4kg bag from the ground to the front of their body, subjects' average motion utilized was 64° of glenohumeral frontal plane elevation, 79° of glenohumeral flexion in the scapular plane, and 23° of scapular external rotation.[87] Understanding what is considered to be "normal" glenohumeral and scapular ROM in healthy individuals is imperative in being able to define ROM deficits in those with dysfunction.

Decreased ROM has been recognized as a potential impairment after breast cancer treatment.[88-90] Research has shown that having less than 100-120° of ROM for shoulder abduction or flexion is often associated with reduced functional use of an upper extremity.[91] Incidence of impaired shoulder movements in breast cancer survivors reveals a lot of variability, ranging from 1.5% to as high as 50% [9, 76, 81, 92-94]

In a retrospective study, 396 breast cancer survivors were examined using a self-report questionnaire and a clinical ROM examination of shoulder flexion and abduction performed by a physical therapist.[76] Results showed that 55.4% had limited shoulder abduction (>10° difference) and 30% had limited forward flexion.[76]. Those subjects who did have limitations in ROM revealed a mean restriction of 21° for abduction and 12° for forward flexion when compared to the contralateral arm.[76]

Thomas – Maclean et al. conducted a research study on 347 women to examine shoulder abduction and external rotation active ROM in women with breast cancer 6 – 12 months after surgery.[75] Fifty – nine percent of the women in this study had limited abduction (defined as < 170°) and 46% had limited external rotation (< 80°).[75] When defining disability as a difference of >10° between the affected and non-affected side, 41% showed differences with abduction and 28% had external rotation differences.[75] Surprisingly, 66% of the women in this study who experienced decreased ROM on their affected side had not discussed treatment options for this problem with a healthcare professional.[75] Researchers asked open-ended questions to try and determine why these women did not seek treatment for these ROM restrictions. Reasons given were many women expressed that their symptoms were "not that bad", a lack of awareness of treatment options, and the perception that the symptoms would diminish over time[75].

It is apparent that decreased shoulder ROM can be a deficit during and following breast cancer treatment as evidenced by the above research studies. It is important that clinicians who work with breast cancer survivors provide appropriate assessments of shoulder ROM to identify deficits that may be present. If ROM deficits occur as a result of breast cancer treatment and are not addressed, future problems might arise when performing functional activities and could possibly lead to shoulder dysfunctions such as adhesive capsulitis.

2.4.2 Shoulder Girdle Strength

Cancer and cancer treatments can potentially cause a loss of lean tissue and abnormalities in the metabolic system, as well as cardiac and skeletal muscle, resulting in a loss of muscle strength in cancer survivors.[95] The loss of lean muscle mass occurs due to a decline in protein synthesis in combination with enhanced protein catabolism.[96] The major adaptations that occur as a result of a decline in protein synthesis and protein degradation include: 1) a decrease in muscle and muscle fiber cross-sectional area as a result of a loss of myofibrils and myofilaments, 2) a loss of muscle extensibility, and 3) a decrease in proteins necessary for metabolism, especially the oxidative enzymes in the Krebs cycle and electron transport chain, leading to a decrease in the muscles' oxidative potential.[97] In a healthy population, researchers[98-100] have found decreases in muscular endurance after only 2 weeks of physical inactivity and reductions (~60%) in oxidative enzymatic activity within 3 months of physical inactivity.

There is a need to examine upper extremity strength to determine the differences that may occur during and after breast cancer treatment. In a study conducted by Isaksson and Feuk, approximately 13% of breast cancer survivors experienced weakness even 2 years after their surgery.[9] In other studies, muscle weakness in the upper extremity has been found among 18 - 23% of breast cancer survivors.[76, 81, 84]

In 2007, Merchant et al. conducted a study on 40 women to determine whether muscle strength, power, and endurance at the affected shoulder were reduced in breast cancer survivors.[101] Dynamic concentric strength was measured at one repetition maximum (1RM), endurance at 90% 1RM, and power through a range of 40 – 100% 1RM for the shoulder protractors, retractors and, extensors.[101] Additionally, strength and endurance were measured for shoulder flexors. Results showed that the affected side was significantly weaker than the unaffected side for shoulder protractors, retractors, and extensors.[101] Also, power was significantly less in the affected arm than the unaffected arm although endurance of the affected arm was not consistently poorer than the unaffected arm.[101] The results from this study also revealed that self-reported weakness correlated poorly with the clinical measures of muscle strength.[101] Therefore, women who did not report weakness demonstrated a decrease in muscle strength when assessed.

It may be difficult to draw conclusions about upper strength in breast cancer survivors because subjective measures may differ than the objective measures. Therefore, when assessing strength in breast cancer survivors, it is of value to ask the person if they feel strength deficits and also objectively measure strength as well.

2.4.3 Pain

Pain is a subjective term that is both difficult to describe and define. This is due to a wide variation from individual to individual about the perception and tolerance to pain.[102] Essentially, pain is the way the brain interprets information about a particular sensation a person's body is experiencing.[102] Since everyone feels pain differently, it is often difficult to define objectively.

Persons diagnosed with cancer may have pain for many different reasons.[103] Pain may be caused by the cancer itself, especially when it has spread into soft tissues such as muscle or connective tissue.[103] Treatment related pain may also be present and possibly caused by radiation therapy, chemotherapy, surgery, and/or other types of treatment such as hormone therapy.[103] Pain can be one of the most distressing symptoms of cancer[104] and has been recognized as impacting all facets with regard to quality of life.[105-107]

The prevalence of pain in breast cancer survivors continues to remain unclear.[108] Some recent studies have reported approximately 50% of breast cancer survivors complain of chronic pain years after treatment.[32, 109-112] According to the particular study analyzed, along with how pain is measured, pain prevalence in breast cancer survivors varies greatly from about 20%[113, 114] to more than 70% in selected groups.[115, 116] The variability in reported pain by breast cancer survivors may reflect differences in the selection of breast cancer survivors and the wide variety of treatments these women receive.[108]

In 2008, a study was conducted by Peuckmann et al. investigating self-reported chronic pain in 1316 women who had survived for at least 5 years after their primary breast cancer surgery without recurrence.[108] Results from this study revealed the total prevalence of chronic pain in these women to be 42%.[108] Women who received radiotherapy had a greater prevalence of pain 36%, versus those who did not 26%.[108] Interestingly, women who received a lumpectomy reported a higher prevalence of pain 34%, when compared to those who received a mastectomy 27%.[108] The highest prevalence of reported pain were the areas of the axilla (20%), arm (20%), shoulder/neck (12%), and chest (9%).[108]

In another study, a telephone survey was administered to 148 breast cancer survivors to examine self-reported pain.[8] The mean age was 57.2 years and more than two-thirds of the participants had a lumpectomy (69%), while 25% had a total mastectomy, and the remainder underwent a modified radical mastectomy procedure.[8] Approximately 14% reported moderate to severe pain in the affected arm, chest wall/breast tissue area, and axillary area.[8] In 2005, a prospective study was conducted on ninety-six breast cancer survivors.[117] The purpose of the study was to describe the impairments of upper body and limb functions, the impact of these impairments on activity limitations, and participation restrictions experienced at work, in the home, and in leisure 6 and 12 months after breast cancer surgery.[117] Data were collected using a questionnaire that included both closed and open-ended questions. At both 6 and 12 months after surgery one of the most limiting impairment reported was neck and shoulder pain 6 months (38.5%) and 12 months (40.6%) after surgery.[117]

While the definition of pain varies from person to person, untreated, pain has the potential to have a strong impact on factors such as quality of life and function.[75] More studies need to be conducted on women who experience pain during and after their breast cancer treatment in order to help these survivors, along with their clinicians, provide improved treatment options.

2.4.4 Quality of Life and Function

Quality of life (QOL) is a subjective, multidimensional term, which consists of different domains such as physical functioning, social functioning, and psychological well-being .[118] The World Health Organization[74, 119] defines QOL as a person's perception about his or her life position in cultural context in relation to his or her aims, expectations, and concerns. Furthermore, QOL is a complicated model that incorporates a person's physical health, psychological status, level of independence, beliefs, and social and personal relationships.[74, 119] As there has been an increase in breast cancer survivors due to earlier detection and advances in medical care, it has become increasingly vital to assess these survivors perspective of their symptoms and their impact on the daily life. (Kuroi et al 2007) Evaluating QOL can provide clinicians a tool for determining treatment and a means to assess the outcome of a chosen treatment.[120] Only a few studies have been published over the past 20 years investigating prevalence of the upper extremity disability in relation to daily activities and QOL in breast cancer survivors.[43]

Rietman et al. conducted a retrospective study on 55 breast cancer survivors who underwent a modified radical mastectomy or a segmental mastectomy with ALND.[121]

The aim of this study was to assess impairments, disabilities, and health related QOL after treatment of breast cancer and to analyze the relationship between treatment modalities, impairments, disabilities, and health related QOL.[121] The impairments assessed were shoulder ROM, grip strength, arm volume, pain using a visual analog scale (VAS), disability assessed by the Shoulder Disability Questionnaire (SDQ), and health related QOL measured by means of the RAND 36-item Health Survey (RAND-36).[121] Results of this study showed that pain, explained 61% of the variance, followed by ROM (12%), were the most important factors when impairments are used to predict health related QOL.[121]

The European Organization for Research and Treatment of Cancer Breast Cancer (EORTC BR 23) questionnaire was utilized in a study by Albert et al. to assess QOL in 389 women 1 year after they were diagnosed with primary breast cancer. The EORTC BR 23 is a questionnaire that contains three items related to arm morbidity (pain, swollen arm, difficulty to raise). In this particular study, manually scoring these three items were aggregated into a single score.[122] Results from this study showed that approximately 20% of the breast cancer survivors experienced considerable impairment in arm functioning even one year after their initial diagnosis.[122] A significant limitation of this study is the use of the EORTC BR 23, specifically the fact that this QOL questionnaire has only 3 items that address upper extremity/arm function.

The Disabilities of Arm, Shoulder, and Hand Questionnaire (DASH) has been utilized in a few studies to specifically address shoulder/arm disability and how it is related to activities of daily living and function in breast cancer survivors. The DASH is a 5-level Likert scale with 21 items addressing the ability of a person to perform daily activities relating to functional use of the involved shoulder, arm, and hand within the past week. Five questions assess activity related pain, weakness, and stiffness. Four questions examine the effects of social activities, work, sleep, and psychological impact. Scores on the DASH range from 0 – 100, with 0 reflecting no disability (good function) and 100 representing extensive disability (poor function).

One study utilizing the DASH, examined 347 breast cancer survivors 6 – 12 months after surgery.[75] Pain ($r = 0.468$) and active ROM restrictions, specifically abduction ($r = -.493$), were found to be associated with disability.[75] The strongest correlations ($r > 0.30$) were performing heavy household chores, gardening and doing yard work, making a bed, carrying a shopping bag or briefcase, carry and object heavier than 10 lbs, and putting on a pullover sweater.[75] A second study administered the DASH to assess changes in upper-body disability over time, from pre to post-intervention, and 6 to 12 months post-diagnosis, in women receiving two community interventions as well as a non-intervention group.[5] Sixty-seven breast cancer survivors participated in the two community interventions with a common goal of restoration of upper-body strength and flexibility, and general support after breast surgery. One program was termed DAART which was administered by physiotherapists in a patient's home. The program consisted of education and a tailored exercise program for self-management lasting 1 hour for 6 weeks.[5] The second community intervention, named STRETCH, was administered by exercise physiologists delivered in group sessions providing education and discussion of psychosocial issues lasting 1-2 hours for 8 weeks. Results of this study revealed that 6 months post diagnosis the mean DASH scores were: DAART 13.4, STRETCH 12.4, and non-intervention 7.3. Although the authors concluded "overall, mean DASH scores suggest women have relatively little disability”.[5] Several limitations regarding this study exist. First, there is no mention of what stage of breast cancer these participants were diagnosed and secondly, whether the breast cancer survivors affected arm was their dominant arm.[5] Hayes et al. utilized the DASH to survey 258 unilateral breast cancer survivors.[86] DASH scores ranged from 0 – 71.7 on the affected side with approximately 50% of the respondents reporting scores > 12.[86] These results reflect a wide range of DASH scores, however, once again, a significant limitation in this study was that there was no mention of how many of these 258 breast cancer survivors were affected on their dominant arm. A significant limitation when administering the DASH is that it is not specific to a patient’s affected limb.[123] Therefore, when research studies are conducted on those with upper extremity disability such as breast cancer survivors and limb dominance is not discussed; results and interpretations of the DASH may not be a true representation of the disability and therefore be skewed.

While there have been a few research studies utilizing the DASH to examine function and quality of life in breast cancer survivors, no study to date has used to PSS in this manner. The PSS provides additional information that cannot be found in the DASH. The PSS contains three portions, the first contains 20 questions regarding function, the second portion has three questions regarding pain, and the final portion asks one question about a person’s satisfaction with their current level of shoulder function. Because the PSS has different domains than the DASH, valuable added information can be obtained when using this outcome questionnaire to assess function and quality of life in a pathologic population.

Examining QOL as an outcome is as challenging as it is dynamic, and may even change as a breast cancer survivor adapts to living with cancer.[124] There appears to be no standard or consensus in the research and rehabilitation communities as to what is the best way to assess arm morbidity with relation to function and QOL in breast cancer survivors. Furthermore, little is known about what specific assessments for breast cancer survivors are commonly used in rehabilitation settings and what predictive factors they may have in order to improve function and QOL. Additional research needs to be conducted in order to determine the most appropriate assessment instrument to explain how upper extremity morbidity affects function and QOL in this group of individuals.

2.5 Lymphedema

Lymphedema is the most recognized form of arm morbidity in breast cancer survivors.[75] Although lymphedema is not a primary outcome measure in this study, it warrants discussion because of its potential effects on arm function. Lymphedema in the upper limb results from an excessive accumulation of interstitial fluid due to an obstruction or interruption of the lymph system.[125, 126] Lymphedema may range from mild to severe, be chronically swollen, unappealing, and cause functional impairment of the arm.[127] Lymphedema may occur immediately after breast cancer treatment or up to 20 years after initial treatment.[127, 128] Among women treated for early stage breast cancer, lymphedema prevalence rates are estimated to range from 2.7% [129] to 37%.[130] Lymphedema can progress to cause pain, psychological distress, body image alterations, impairments in mobility, strength, and function if left untreated.[34, 131]

There appears to be no standardized definition of breast cancer-related lymphedema and therefore it may go underreported.[132] The most widely used strategy to diagnose upper extremity lymphedema is circumferential upper extremity measurements using specific anatomical landmarks.[133] Petryk and colleagues have tried to create a measurable, clinical definition of lymphedema by stating it to be a "2-cm difference between the surgical-side upper extremity and the contralateral upper extremity".[134]

Women who have been treated for breast cancer have traditionally been advised to avoid strenuous or repetitive activities that require effort with the affected arm because these activities were thought to initiate or exacerbate lymphedema.[135] Risk factors for lymphedema in breast cancer survivors have been poorly characterized.[128] There are clinicians who believe factors such as arm infection, injury, tumor stage, nodal status, radiotherapy to the breast and/or axilla, and elevated body mass may cause lymphedema.[29, 136-139] Even though leisure and occupational activities are thought to be risk factors for lymphedema, it is believed that no form of physical activity has been associated with lymphedema in prospective research.[137]

Several studies have been conducted showing that using the affected upper extremity in a repetitive manner, mostly with exercise activities, does not cause a significant increase in lymphedema in breast cancer survivors. A study was conducted by Ahmed et al. examining the effects of a supervised upper and lower-body weight training on the incidence and symptoms of lymphedema in 45 breast cancer survivors.[128] Twenty-three of these women participated in the treatment group while 22 served as controls. The intervention was conducted twice a week over a 6 month period.[128] Lymphedema was monitored by measuring the circumference of each arm and by self-report of symptoms and clinical diagnosis.[128] None of the intervention-group participants experienced a change in arm circumference ≥ 2.0 cm after performing the 6 months of prescribed exercise.[128] Therefore, this study concluded that during the 6 month exercise trial, there was no incidence or onset of lymphedema symptoms in either the intervention or control group participants.[128] A study was conducted by Turner et al. utilizing 10 breast cancer survivors who had completed their surgical treatment and adjuvant chemotherapy.[6] This pilot study was conducted to determine the impact of a mixed-type, moderate-intensity exercise program on the presence of physical measures such as lymphedema, fatigue, fitness and body composition, and quality of life.[6] The exercise program was conducted once per week over 8 consecutive weeks.[6] The initial weeks consisted of aerobic-based exercise, such as low-impact aerobics and ergometery.[6] During weeks 4 and 5, the women performed water-based exercise and during the final weeks, moderate resistance exercise using free and machine weights were incorporated into the program.[6] Lymphedema was assessed using total sum of arm circumference, as well as bio-electrical impedance. Measures were taken at intake, at the completion of the 8 week program, as well as at a 6 week and 3 month follow-up.[6] No statistically significant changes were observed for the presence of lymphedema.[6] This is another study that shows promise explaining the minimal effects upper extremity exercise has on lymphedema in breast cancer survivors, although the limitations of this study need to be considered. These include a small sample size (n=10), no control group, and an exercise program that was only performed 1 time a week.

There have been several studies examining the effects of exercise on lymphedema, however, in all of these studies, none of the breast cancer subjects had measurable lymphadema at baseline. There has been one study conducted that examined the effects on lymphedema on women who had measurable lymphedema from breast cancer. The goal of this study was to determine whether these women would experience any changes in arm volume if they performed a regular exercise routine.[140] Fourteen breast cancer survivors with unilateral lymphedema were randomly assigned into either an exercise (n=7) or a control group (n=7).[140] The exercise group followed a progressive, 8-week upper-body exercise program consisting of resistance training plus aerobic exercise using an arm ergometer while wearing a professionally fitted compression sleeve[140] The control group was given no specific exercise instruction. Lymphedema was measured in two manners; using arm circumference and measurement of arm volume by water displacement.[140] Upper extremity volume and circumference were measured on all subjects at baseline and every 2 weeks after for the 8 week duration.[140] Results showed that there were no changes in arm circumference or arm volume as a result of participating in the exercise program.[140] As well as no significant change in either the control or exercise groups over time.[140] Although this study does have a small sample size (n=14), important conclusions can be drawn regarding whether women who have measurable lymphedema following breast cancer treatment should participate in an exercise program. As these results show, performing a progressive, controlled upper-body exercise program did not significantly affect the volume of the upper extremities in women with lymphedema after breast cancer treatment.

Factors such as shoulder ROM, strength, and even function may not be addressed after breast cancer treatment out of concern that these measures may cause lymphedema.[133, 141] However, this may be changing due to several recent studies that have been conducted measuring the effects of exercise and lymphedema in women with breast cancer. These studies have provided scientific evidence to suggest that exercise for breast cancer survivors is safe, although continued monitoring of lymphedema should be conducted in any exercise program on breast cancer survivors.[1]

2.6 Other Factors

There appears to be other factors that necessitate consideration when treating a breast cancer survivor from those mentioned above. A study was conducted by Hayes et al. describing associations between upper body function and certain personal and treatment characteristics six months following treatment for unilateral breast cancer.[86] Objective measures were defined as upper body strength and endurance, upper body flexibility, and hand grip strength.[86] Subjective measures were scores on the Disability of Arm, Shoulder, and Hand (DASH) and Functional Assessment of Cancer Therapy, Breast (FACT-B+4).[86] Two important conceptual findings emerged from the study relating to the limited correlation between various objective and subjective measures on upper body function and the relevance of dominance of the treated side when considering upper body function.[86] Specifically, treatment on the dominant side was associated with better upper body function compared to those treated on the non-dominant side.[86] However, subjective upper body function was reduced when treatment occurred on the dominant side.[86] The results show that those women who were treated on their dominant side may demonstrate higher upper body strength and endurance; however, being treated on the dominant side may potentially cause more disruption in their lives that may be perceived as more burdensome and thus hinder function and quality of life.[86]

Optimal upper body function is essential for maintaining independent living, performing daily routine activities, returning to work, performing tasks requiring physical strength, and for general quality of life.[142] The above research demonstrates that in order to achieve optimal upper body function in breast cancer survivors, many aspects of care need to be considered and well understood in these women. These aspects of care include understanding the types of biopsies, effects of radiation, types of surgical procedures, effects of chemotherapy, hormonal treatment, and targeted therapy, upper extremity ROM and strength limitations, quantifying pain, evaluating QOL, and assessing function.

2.7 Shoulder Anatomy

Kinematics can be defined as the "description of time-dependent aspects of motion in terms of displacement, velocity, and acceleration without dealing with the forces causing the motion".[143] Shoulder joint kinematics consists of coordinated movements of the clavicle, scapula, and humerus. To better appreciate shoulder and scapular kinematics, it is essential to understand the basic anatomy of the shoulder region.

The clavicle, scapula, and humerus form the bony structures of the shoulder region.[144] The clavicle extends laterally and horizontally across the root of the neck.[145] The clavicle has three functions; to act as a strut for holding the upper limb free from the trunk so it may have maximum freedom of action, to provide attachments for muscles, and to transmit forces from the upper limb to the axial skeleton.[145] The scapula is a triangular flat bone that lies on the posterolateral aspect of the thorax, overlying the 2nd through 7th ribs.[145] In what is thought of as a normal erect standing and relaxed position, with the arm dependent, the superior angle of the scapula lies at the level of the second thoracic vertebra. The root of the scapular spine is at the level of the third thoracic spinous process and the inferior angle is at the level of the spinous process of the seventh or eighth thoracic vertebra.[146] The plane of the scapula is approximately at right angles to the plane of the glenoid[147] and lies obliquely between the frontal and sagittal planes, 30 - 45° anterior to the coronal plane.[148-150] Motions of the scapula include: elevation/depression, abduction/adduction, and depression and downward rotation/abduction and upward rotation.[151] The humerus is the largest bone in the upper extremity.[145] The proximal portion is smooth, ball-shaped, and articulates with the glenoid cavity of the scapula.[145] The distal portion consists of the medial and lateral epicondyles.

The joints of the shoulder region include the sternoclavicular (SC), acromioclavicular (AC), and glenohumeral (GH). Together, these articulations provide the shoulder with a range of motion (ROM) that exceeds any other joint in the body. In order to achieve full mobility of the shoulder, coordinated and synchronous motion in all of these joints is required.[144]

The SC joint is a plane synovial joint which is dependent on the disc, strong capsule, and three ligaments for stability.[144] The SC joint functions as a ball-and-socket joint, although the articular surfaces are saddle-shaped.[152, 153] This joint has three degrees of freedom, the first elevation and depression of the clavicle, occurs between the medial end of the clavicle and disc.[154] The second, protraction and retraction occur between the disc and the sternum. [148, 154, 155] The third degree of freedom, rotation, occurs about the clavicles longitudinal axis.[148, 153, 155, 156]

The AC joint is also a plane synovial joint.[157] The stability of this joint is dependent on the superior and inferior acromioclavicular ligaments that reinforce a weak joint capsule.[153] The AC joint permits movement of the scapula on the clavicle in three planes.[144] The movement of rotation occurs about the coronal, sagittal, and vertical axes.[144]

The GH joint is a synovial ball-and-socket joint that lies between the glenoid fossa of the scapula and humeral head.[144] This particular joint is inherently unstable due to the shallowness of the glenoid fossa and the disproportionate size and lack of congruency of the articular surfaces.[144] Stability of the GH joint is primarily dependent upon the osseous morphology, glenoid labrum, capsuloligamentous mechanism, intra-articular pressure, and musculotendinous cuff.[144] The biomechanics of the GH joint rely on the interaction of both static and dynamic stabilizing structures.[158] The static stabilizing structures include the bony anatomy, negative intra-articular pressure, the glenoid labrum, and the GH ligaments along with the joint capsule.[158] The dynamic-stabilizing structures include the rotator cuff and scapulothoracic muscles.[158]

2.7.1 Shoulder Stability

The upper limb is not often involved in weight bearing, therefore its stability has been sacrificed to gain mobility.[145] The glenohumeral joint is distinct because it maintains stability despite having few restraints.[158] These restraints consist of the static and dynamic components. Bony, cartilaginous, capsular, and ligamentous structures all function to provide static stability of the glenohumeral joint.[159] The musculature surrounding the shoulder composes what is known as the dynamic stabilizers.[158]

Although the static stabilizers of the upper limb have an important role, it is imperative to understand the influence of the dynamic stability provided to the shoulder in order to fully appreciate mobility and function of this region. The dynamic stability is primarily the result of neuromuscular control between the scapulothoracic musculature and the rotator cuff (RC) muscles.[158] This dynamic stability can be described further as scapulohumeral balance. Scapulohumeral balance refers to the theory that the humeral head is balanced in the glenoid if the net joint reaction force passes through the fossa.[160] Therefore, the glenohumeral joint will remain stable, as long as the scapula is positioned so that the glenoid fossa encloses the net forces acting on the humeral head.[160] It is essential that the RC and scapulothoracic musculature work in a synchronous manner so the resultant compressive force across the joint falls within a stable arc provided by the glenoid concavity.[160] If these muscles do not work together efficiently, deficits may arise which could lead to shoulder dysfunction such as impingement syndrome.

When assessing the upper extremity, it is essential to understand the function of the surrounding musculature. The rotator cuff's primary function is to guide and stabilize the GH joint.[161, 162] The RC muscles help to strengthen the GH joint in every direction except inferiorly and are well positioned to resist GH shear stresses in order to prevent pathologic translation.[145, 158, 161] The RC consists of the supraspinatus, infraspinatus, teres minor, and subscapularis. Each of the individual muscles of the rotator cuff along with the biceps brachii originate on the scapular body and insert onto the humeral head, thus pulling the humerus closer to the glenoid cavity upon activation. Simultaneous contraction of these 5 muscles creates a compression effect of the humeral head into the glenoid cavity. As the rotator cuff and biceps brachii musculature contract to pull the humeral head downward and inward, this humeral head compression is coupled by the upward and outward pull of the anterior, middle, and posterior deltoid musculature. This mechanism is commonly referred to as the glenohumeral force couple, and, when in balance, functions to center the humeral head in the glenoid cavity.

The interaction of the RC muscles works in combination with other muscles in the shoulder girdle to provide stability. Another classification of dynamic stabilizing structures in the upper extremity is known as the scapulothoracic muscles. Several research studies have established the importance of a coordinated, synchronous action of the glenohumeral and scapular muscles.[17, 163-165] The muscles included in the scapulothoracic region that provide this dynamic stability are the: latissimus dorsi, serratus anterior, pectoralis major, rhomboid major and minor, and the upper, middle, and lower trapezius. These muscles are capable of producing large torques about the shoulder joint because of their cross-sectional anatomy and distance from the joint center of rotation.[158]

When discussing the dynamic stability of the shoulder joint provided by the scapulothoracic region, it is important to discuss the scapula force couple. The scapula force couple refers specifically to the stability and balance provided to the scapulothoracic region by the upper trapezius, lower trapezius, rhomboid major, rhomboid minor, levator scapulae, and serratus anterior.[166] It is important to understand how contraction of each of these muscles effect movement of the scapula. Contraction of the upper trapezius creates scapular upward rotation, elevation, and retraction.[145] When the lower trapezius is contracted, it causes scapular upward rotation, depression, and retraction.[145] When the rhomboid major and minor are fired, both muscles produce scapular retraction, downward rotation, and depression.[145] Activation of the serratus anterior creates scapular protraction and upward rotation.[145]

There is a need to understand the intricate relationships between the static and dynamic stabilizing structures at the shoulder when evaluating and treating this region.

Research has shown that even the smallest alteration in performance and coordination of the muscles surrounding the shoulder has the potential to lead to dysfunctions and compensations that could compromise normal joint function and lead to disabilities,[17] resulting in inactivity,[167]and lower quality of life.[168] As mentioned previously in the literature review, muscle weakness in the upper extremity has been found among 18-23% of breast cancer survivors and this weakness may be present even up to 2 years after their surgery.[76, 81, 84] Breast cancer treatments appear to effect a percentage of these survivors upper extremity strength, specifically around the scapulothoracic region. Therefore, weakness of the upper extremity must be evaluated when a breast cancer survivor has complaints of either pain and/or loss of function when using their upper extremity. It is important that clinicians understand the function of the scapulothoracic muscles, effects breast cancer treatments may have on this region, and are able to assess weakness appropriately. In summary, when clinicians develop rehabilitation programs for breast cancer survivors to correct dysfunction at the shoulder, it is necessary to break down this complex region into its various components in order to discover the fundamental principles that may be the underlying cause of the problem.

2.7.2 Shoulder and Cervical Mobility

Understanding what is considered to be "normal" active ROM of the shoulder in the healthy population is essential when assessing those who present with upper extremity dysfunction. The mobility of the glenohumeral joint can be described as having three degrees of freedom: flexion/extension, abduction/adduction, and internal/external rotation.[144] Full ROM of the shoulder involves humeral, scapular, and clavicle motion at the GH, SC, AC, and scapulothoracic joints.[147] The American

Academy of Orthopaedic Surgeons (AAOS) and the American Medical Association (AMA) values for mean ROM at the glenohumeral joint are as follows: flexion 150°-180°, extension 50°-60°, abduction 180°, internal rotation 70°-90°, and external rotation 90°.[169, 170] What is unknown about the above recommendations from the AAOS and AMA are the age, gender, and number of subjects that were measured to obtain these values.[147] Another study was conducted on 109 males to assess AROM using a clinical goniometer.[171] Males ranging from 20 – 54 years of age demonstrated mean values of shoulder AROM: flexion 166.7°±4.7°, extension 62.3°±9.5°, abduction 184°±7.0°, internal rotation 68.8°±4.6°, and external rotation 103.7°±8.5°.[171] Limitations of the above study include only utilizing males as subjects and the fact that no one was studied over the age of fifty-four.

As mentioned previously, decreased ROM has been recognized as a potential impairment after breast cancer treatment.[88-90] The incidence of impaired shoulder motion in breast cancer survivors is quite variable, ranging from 1.5% to as high as 50%.[76, 81, 89, 92-94] Two research studies has found the greatest deficits in ROM of breast cancer survivors appears to be during the motions of forward flexion, shoulder abduction, and shoulder external rotation.[75, 76] The results of these studies appear to correlate with other pathologic populations, such as adhesive capsulitis and shoulder impingement syndrome, in regards to limitations in active shoulder ROM. A study was conducted by Ardic, et al. on 59 patients with diagnosed impingement syndrome.[172] Although the exact methodology of how shoulder active ROM was not discussed, results revealed an average of 139.2°±24.5 of flexion, 53.0°±21.6° of external rotation, and 50.7°±° of internal rotation.[172] A similar study was conducted on 65 patients with idiopathic adhesive capsulitis.[172] Measures of active shoulder forward elevation and external rotation were measured in a seated position using a goniometer.[172] Results showed that the average active ROM for flexion was 102° and 17° for external rotation.[172] Both of these pathologic populations demonstrate reductions in active ROM, when compared to normative values. Continued studies need to be conducted to gain a better understanding of the effects of breast cancer treatment on shoulder active ROM and function.

There has been some initial evidence to suggest that impairments of the cervical spine may contribute to shoulder pain and disability.[173] Neck pain appears to have a variable definition as apparent in several research studies.[174, 175] The term "neck pain" has been used to describe pain in the area between the occiput and the upper back.[175] Because of the ambiguity of the term "neck pain" it can be difficult to obtain an exact diagnosis and is it possible that shoulder and neck pain may coexist and overlap.[175] In one research study, neck pain was described as a referred pain syndrome originating in the shoulder.[175] In this study, a retrospective review was conducted on 34 patients with neck pain.[175] Eighty-eight percent of these 34 patients had a positive referred shoulder impingement test, with relief of their neck pain five minutes after injection in the shoulder.[175] The authors go on to conclude that "shoulder impingement is a previously undescribed cause of chronic neck pain along the medial border of the scapula".[175] The results of this study demonstrate that a thorough examination should be performed on both the shoulder and cervical spine by clinicians who are evaluating persons who present with decreased upper extremity function and disability.

As of this date, there have been no studies to examine cervical spine active ROM in the breast cancer population. Despite this, it is important to understand what has been described as “normal ROM of the cervical spine” for gender and age, in order to examine if cervical ROM deficits exist in populations such as breast cancer survivors. In 1992, Youdas et al. examined cervical active ROM measurements on 337 subjects whose ages ranged from 11 to 97 years.[176] A CROM was used to measure the 6 cervical active ROM measures and of these 337 subjects, 171 were females.[176] The results revealed that for females who range in age of 40-69 years (n=62) demonstrate an average extension ROM from 65.2° to 77.5°, left side bending 34.4° to 40.8°, right side bending 32.7° to 42.5°, left rotation 59.7° to 64.0°, and right rotation 65.2° to 70.2°.[176] This study also revealed that the active ROM measures of extension, left and right side bending, and left and right rotation were significantly correlated to age.[176] Furthermore, the number of degrees of motion lost per year did not differ between genders, but female subjects started with a higher degree of active ROM, which appears to be maintained with increasing age.[176] Since neck flexion did not differ between male and female subjects, the range of 41.0° to 49.5° was found in both males and females who range in age of 40-69 years (n=122).[176]

2.8 Normal Scapular Kinematics

In order for normal shoulder motion to occur, coordinated movements of the clavicle, scapula, and humerus must occur. In particular, scapular motion is a key component of shoulder function, and a comprehensive understanding of scapular biomechanics may provide clinicians with better knowledge that can be applied when assessing and treating shoulder dysfunctions. The capability of the scapula to move about the trunk while maintaining glenohumeral alignment and proper angulation of the humerus with the trunk, enables the scapula to provide a stable base of support between the humerus and trunk.[177] This allows for the high degree of movement observed in the shoulder that is needed for upper extremity function.[177]

Cathcart was the first to describe the scapulothoracic contribution for normal shoulder kinematics.[178] He described the scapula moving on the thorax throughout humeral elevation.[178] Recent three-dimensional (3-D) studies have expanded Cathcart, as well as Inman and colleagues' original description of "scapulohumeral rhythm" to include three rotations and two translations.[179, 180] Scapulohumeral rhythm is often defined as the ratio of scapular upward rotation relative to humeral elevation. (Codman 1934) Scapulohumeral rhythm is further described as a 2:1 ratio of humeral to scapular movement.[181] Stookey was the first to specifically investigate scapulohumeral rhythm, defining three distinct phases of humeral elevation: 0-60°, 60-115°, and 115° to maximal shoulder elevation.[182] During the initial phase of elevation from 0-60°, large variations in the amount of scapular upward rotation were observed.[182] But the middle phase, 60-115°, had less variation in the amount of movement and is what is often used to describe the typical 2:1 ratio of scapulohumeral rhythm. Therefore, as humeral elevation increases, the scapula rotates in an upward manner one degree for every two degrees of humeral abduction.[183] There has been variability in defining scapulohumeral rhythm, ranging from 1.25:1 to 3:2 depending on the plane of humeral elevation (frontal, scapular, or sagittal), and the arc of elevation evaluated.[184] Furthermore, the differences in methodology of these studies make it difficult to compare results and to understand why such discrepancies in the scapulohumeral rhythm exist. Despite these difference, there does appear to be a consensus in the literature to support a non-linear pattern of scapular upward rotation relative to glenohumeral elevation progressing from 2:1 in the early phases (30-100°) and 3:2 (100° to max) in successive phases.[185]

The three rotations of the scapula include upward/downward rotation, internal/external rotation, and anterior/posterior tipping. More specifically, rotation about an axis perpendicular to the plane of the scapula is defined as upward/downward rotation, whereas scapular rotation around an axis roughly parallel to the scapular spine has been termed anterior/posterior tipping.[147] Scapular motion around a vertical axis has been defined as internal/external rotation.[179] The two translations occurring with scapular motion are protraction/retraction and elevation/depression.

Scapular motion has been studied for over 60 years, beginning with two-dimensional (2D) methods such as radiography,[180] goniometry,[180, 186] and Moire' topography..[187] These techniques have been used to describe humeral elevation in the scapular and frontal planes. Recent advances in technology have afforded the ability to examine scapular motion from a three-dimensional (3D) non-invasive perspective. With the development of electromagnetic tracking devices in the late 1980's[188] and their validation for application to the shoulder region[189, 190] a substantial improvement has occurred regarding the accessibility of scapula kinematic research.[191] An electromagnetic tracking system consists of a transmitter and receivers. Within the past 10 years, the development of the extended range transmitters has enabled a larger operating space allowing for advances in the study of shoulder kinematics.

Before understanding the effects of motion on the scapula, one must understand the normative data regarding the resting position of the scapula. Recognizing what is considered to be a normal resting position of the scapula can aid a clinician in identifying scapular abnormalities which may lead to identifying the underlying causes of dysfunction in the shoulder region. In 1998, Meskers et al. examined static scapula positions in steps of 10° using a six-degree-of-freedom electromagnetic tracking device in 3 elevation planes: forward flexion (90° angle with the frontal plane), elevation in the scapular plane (30°), and elevation in the frontal plane (0°).[192] The resulting resting position of the scapula was upward rotation 3°, internal rotation 30°, and posterior tipping -12°.[192] Similar results regarding the resting position of a healthy scapula have been found by several other authors with the resting scapula being positioned from -1.7° - 3° of upward rotation, 30.2° - 37.4° of internal rotation, and -8° - -20.6° of posterior tipping.[144, 179, 193]

Three-dimensional kinematics has been described for shoulder motion during elevation in the frontal, scapular, and sagittal planes.[14, 179, 194] Several studies have found that as the humeral angle is increased, the scapula demonstrates a pattern of progressive upward rotation and movement from an anterior to a posterior tipped position.[17, 179, 190, 192, 193, 195] The most variable scapular motion appears to be internal/external rotation, either decreasing, increasing, or staying relatively unchanged.[17, 18, 192, 196] These discrepancies regarding scapular internal/external rotation appear to be due to the definition of the local axis systems, choice of Euler angle rotations, arc of elevation, and plane of humeral elevation evaluated.[195]

Several previous studies have shown that healthy subjects use a reproducible and complex pattern of scapular kinematics with a large ROM during arm elevation..[194, 197] Most studies examining scapular kinematics in healthy individuals appear to analyze subjects moving in what is known as the “scapular plane”.[17, 19, 179, 196, 197] Researchers believe that arm elevation during functional activities occurs in this scapular plane that can have variations in its definition, but is most often described as 30° anterior to the frontal (sagittal) plane of the thorax.[141, 179, 193] In 1996, Ludewig et al. examined 3D scapular orientation in 25 asymptomatic subjects (19-37 years old) during humeral elevation in the scapular plane.[179] The results of this study showed that at 90° of humeral elevation, the scapula demonstrated averages of 21°of upward rotation, 28° of internal rotation, and 2° of anterior tipping.[179] At the higher elevation angle of 140°, the scapula demonstrated averages of 36° of upward rotation, 20° of internal rotation, and 7° of posterior tipping.[179] A similar study examining elevation in the scapular plane was conducted on 26 healthy construction workers.[17] At 60° of humeral elevation, the scapula averaged values of 22° of upward rotation and 8° of posterior tipping.[17] Similar scapular angles were found in another study conducted by Borstad and Ludewig during humeral elevation in the scapular plane.[196] The scapula progressively moved into greater upward rotation during humeral elevation from 22.5° at 60°, 29.1° at 80°, 35.3° at 100°, and 40.7° at 120°.[196] The scapula also moved into a slightly more anterior position by 3° during humeral elevation from 11° at 60°, 12° at 80°, 13° at 100°, and 14° at 120°.[196] Finally, the scapula moved progressively into a more internally rotated position during the humeral elevation task from 40.5° at 60°, 42° at 80°, 44° at 100°, and 44° at 120°.[196] More recently in 2007, 17 healthy subjects performed 5 repetitions of scapular plane elevation reporting averages of the 5 trials of scapular motion at 60°, 90°, and 120°.[198] As humeral elevation increased, so did scapular upward rotation from 26° at 60°, 36° at 90°, and 49° at 120°.[198] The scapula moved into a greater anterior position during the humeral elevation task from 10° at 60°, 14° at 90°, and 18° at 120°.[198] Finally, the scapula demonstrated small changes of moving into greater internal rotation from 45° at 60°, 46° at 90°, and 49° at 120°.[198] Although slight differences in methodology were used for the above studies, the results appear to be similar demonstrating that during a humeral elevation task in the scapular plane in healthy individuals, the scapula moves progressively into greater upward rotation, posterior tipping, and internal rotation.

Two studies have examined humeral elevation in the sagittal plane. A study conducted by Fayad and colleagues examined 30 healthy subjects performing two repetitions of arm elevation in the sagittal plane.[197] Results revealed small changes with the scapula moving into a slightly more anterior position by 3° when moving from 60°, 90°, and 120° (-8°, -9°, and -5°).[197] The scapula also moved into greater upward rotation during sagittal plane flexion when moving from 60°, 90°, and 120° (22°, 38°, and 49°).[197] McClure and colleagues examined 3D scapular kinematics in 45 healthy subjects during 3 cycles of active elevation in both the sagittal and scapular planes.[19] Result of this study show that during the sagittal plane motion, the scapula moved into progressive upward rotation from 28°, 38°, and 53° when moving from 60°, 90°, and 120°.[19] Small changes were seen in this plane, showing the scapula moving into a more posterior position from 2°, 3°, and 4° when moving from 60°, 90°, and 120°.[19] Two degree changes were observed moving from 60°, 90°, and 120° (41°, 43°, and 43°) regarding scapular internal rotation. During the task of humeral elevation in the scapular plane in this study, similar results were seen as presented above.[17, 179, 196, 198] Result of this study show that during the scapular plane motion, the scapula moved into progressive upward rotation from 26°, 36°, and 50° when moving from 60°, 90°, and 120°.[19] Small changes were seen in this plane, showing the scapula moving into a more posterior position from 3°, 3.5°, and 4°

when moving from 60°, 90°, and 120°.[19] Two degree changes were observed when moving from 60°, 90°, and 120° (37°, 37.5°, 35°) demonstrating the scapula moving into more internal rotation.[19]

In order to understand if there are differences in scapular kinematics in the breast cancer survivor population, an understanding of what is considered to be "normal" kinematics in healthy populations needs to be understood. Although all of the above studies utilized different methodology and subject characteristics, during either a humeral task of elevation in the sagittal or scapular plane, the scapula demonstrates a pattern of progressive upward rotation. [17, 18, 179, 190, 192, 193, 195, 196] Movement of the scapula was slightly variable regarding tipping, although the variability was small ranging from 1° - 3°.[17, 18, 179, 190, 192, 193, 195, 196] Internal and external rotation of the scapula continues to be variable in these studies. [172, 191,195]

2.8.1 Alterations in Scapular Kinematics

The scapular component of shoulder movement patterns is thought to play a key role in the understanding of shoulder dysfunction.[17, 18, 136, 185, 187, 197, 199] Alterations in scapular kinematics in one or all planes are believed to contribute to shoulder pain and pathology.[179, 200-202] Changes in scapular resting position and motion have been seen in subjects with impingement syndrome,[13-20] rotator cuff tears,[185, 203, 204] frozen shoulder,[198, 205-207] and glenohumeral instability.[185, 187, 208-211] It is believed that factors such as muscle weakness or shortening, trauma, repetitive overhead work conditions, or pain may potentially disrupt muscular control and lead to scapular motion abnormalities.

It is important to understand scapular kinematics in other populations who suffer from shoulder dysfunction to formulate a basis for examining scapular kinematics in breast cancer survivors. Alterations in scapular motion may cause increase stress on the muscular, ligamentous, and capsular structures, placing the shoulder at risk for dysfunction.[20] The historical emphasis on clinical evaluation of scapular motion patterns during an assessment of the shoulder should be used to guide treatment in those with shoulder dysfunction.[181, 202] Understanding abnormalities that exist in populations such as persons diagnosed with impingement syndrome and frozen shoulder could help provide a foundation for pursuing such research on breast cancer survivors.

Shoulder impingement appears to be the most common studied pathology with regards to scapular kinematics. This is most likely due to the high prevalence (16-40%) of shoulder complaints consistent with impingement in occupations and those who perform repetitive work that is above 60° of elevation in any plane.[212-216] Several studies have examined 3D scapular kinematics in those with shoulder impingement syndrome. The general consensus from research on persons with impingement syndrome demonstrates that this population presents with decreased posterior tipping, decreased upward rotation, and increased internal rotation when compared to healthy subjects.[14, 17, 18, 217] One study conducted by Ludewig and Cook analyzed glenohumeral and scapulothoracic kinematics in a group of male construction workers with symptoms of shoulder impingement (n = 26) relative to a group of subjects without symptoms of shoulder impingement (n = 26) during humeral elevation in the scapular plane.[17] The results revealed that those subjects with symptoms of shoulder impingement demonstrated decreased upward rotation during the first 60° of humeral elevation and a more anteriorly tipped position as elevation progressed when compared to the subjects without symptoms of shoulder impingement.[17] Some researchers believe that a decrease in the amount of scapular posterior tilt may decrease the size of the subacromial space, potentially causing greater compressive forces to the RC tendons.[18]

Another study conducted by McClure et al. compared 3D scapular kinematics in male and female subjects with (n = 45) and without (n = 45) primary shoulder impingement syndrome during active elevation in both the sagittal and scapular planes, as well as during external rotation with the arm at 90° of elevation in the frontal plane.[19] Results revealed that upward rotation was greater during the flexion task in those subjects with shoulder impingement when compared to those who did not have impingement.[19] These results contrast those found by Ludewig and Cook, regarding the upward rotation component, but may be explained in part by differences in the subject population and measurement methods. Another study found similar results regarding upward rotation as McClure et al. Karduna and colleagues studied the effects of scapular orientation on contact forces in the subacromial space using cadavers.[136] The researchers found that posterior tilt and external rotation did not affect subacromial space, but that upward rotation did.[136] Specifically, an increase in scapular upward rotation was found to decrease subacromial clearance. Results of this particular study should be read cautiously and seem to differ regarding upward rotation which could be due to the very low number of subjects, 8, the use of cadavers, and the muscle forces were simulated by a man made “mechanical testing machine”.

It is important to understand the clinical significance of scapular kinematic alterations in those with shoulder dysfunction such as impingement. Result of many of the above studies show that a decrease in the amount of scapular posterior tilt may decrease the size of the subacromial space, potentially causing greater compressive forces to the RC tendons.[18] The results of the above studies disagree as to what role upward rotation contributes to shoulder impingement, but what the results show that there are differences between healthy individuals and those with shoulder impingement regarding upward rotation. The kinematic differences found between pathologic populations and healthy controls may represent scapulothoracic compensatory strategies for glenohumeral weakness loss of motion. As clinicians it is our responsibility to evaluate these differences in the shoulder region to provide the best possible care for individuals who present with such dysfunction.

The second most common shoulder dysfunction analyzed with 3D scapular kinematics is frozen shoulder, also known as adhesive capsulitis or idiopathic loss of shoulder ROM. This shoulder dysfunction is often characterized by a pattern of limited external rotation, abduction, forward flexion, and internal rotation.[207] With frozen shoulder, abnormal motion of the scapula is thought to exist, although it has been difficult to describe and measure clinically.

Vermeulen and colleagues examined 10 patients with unilateral frozen shoulder.[207] Scapular kinematics on both the affected and unaffected upper extremities in 3 planes: humeral elevation in the sagittal plane, elevation in the scapular plane and abduction in the frontal plane, were recorded.[207] The researchers analyzed the 3D kinematic data using curves showing scapular movement in relation to glenohumeral movement, as opposed to the most common practice of reporting the three scapular rotations at angles. However, the results from this study showed that the affected upper extremity showed earlier and more scapular movement in relation to the curves on the unaffected side.[207] Clinically, the authors believe this early and excessive scapular motion is to compensate for the lack of glenohumeral joint mobility.[207] Rundquist examined 3D scapular kinematics in seventeen subjects with frozen shoulder (impaired) and 17 subjects with normal shoulder ROM (unimpaired). Subjects performed 5 repetitions of bilateral humeral elevation in the scapular plane (40° anterior to the coronal plane).[198] Results showed that the impaired subjects' involved side demonstrated a significant greater upward rotation (7.7°) at peak scapular plane elevation than their non-involved side.[198] Although 7.7° may not seem like a large difference, it did represent 23% of the total scapular motion during upward rotation excursion.[198] The authors suggest that the upward rotation differences may be attributed to scapulothoracic compensation in order to overcome a loss of glenohumeral motion.[198] Clinically, this may allow subjects with frozen shoulder complete activities of daily living despite glenohumeral ROM restrictions.

A more recent study was conducted to examine 3D scapular kinematics in 32 patients with a "stiff shoulder", 16 with GH joint osteoarthritis and 16 with frozen shoulder.[197] These subjects performed 2 repetitions of maximal arm elevation in the sagittal and frontal planes on both the affected and unaffected side.[197] Results of this study showed that patients with either GH osteoarthritis or frozen shoulder had increased scapular external rotation during both planes of movement.[197] Similar to Rundquist and colleagues, the authors of this study suggest that the increase in scapular external rotation may be an adaptation that enables patients to perform activities of daily living requiring humeral elevation.[197]

The results of these studies illustrate that alterations exist for scapular kinematics in several shoulder dysfunction classifications when those individuals are compared to matched controls or their unaffected side. What remains unclear is whether scapular dysfunction is a contributing factor or a compensatory mechanism for shoulder pathology. Despite this, understanding what scapular kinematic differences exist in pathologic populations such as shoulder impingement and frozen shoulder, along with breast cancer survivors, could provide clinicians with an enhanced understanding of the role the scapula might have regarding pain and function. Although the long term consequences of altered scapular kinematics are uncertain, having an understanding of what alterations exist in pathologic populations such as breast cancer survivors, could provide clinicians with evidenced based rehabilitation techniques to improve function and disability.

CHAPTER III

METHODS

3.1 Research Design

A case-control design was used to compare breast cancer survivors and a control group of healthy, matched participants. The following dependent variables were measured on the affected arm and compared between the two groups: 1) shoulder active and passive range of motion (ROM); 2) cervical active ROM; 3) shoulder girdle strength; and 4) three-dimensional scapula kinematics during humeral elevation tasks (sagittal plane flexion, scapula plane elevation, and reaching). Functional outcome measures were also recorded using the Disabilities of the Arm, Shoulder, and Hand (DASH), and The University of Pennsylvania Shoulder Score (PSS).

3.2 Procedures

3.2.1 Recruitment and Population

The breast cancer survivor (BCS) group consisted of women who had been diagnosed with breast cancer in the Raleigh-Durham-Chapel Hill region and had completed all of their systemic and/or surgical treatment no greater than six months prior to testing date. The BCS group was recruited through the *Get Real and Heel Program* at UNC-CH and by word of mouth. The eligibility criteria were: 1) a diagnosis of stage I-III breast cancer, 2) female age between 25 and 75 years, 3) no history of shoulder or neck surgery, and 4) no known neuromuscular dysfunctions or taking medications that may influence neuromuscular performance. The control (CON) group served as the comparison group and was matched by gender, age, and body mass index to those participants in the BCS group. Participants will be matched by gender, (all were female), ages within ±5 years, and a BMI within ±3 kg/m^2. Eligibility criteria for the comparison group were: 1) female age between 25 and 75 years, 2) no history of upper extremity or neck pain within the last 6 months, 3) no previous history of shoulder or neck injury, 4) no known neuromuscular dysfunctions or taking medications influencing neuromuscular performance, and 5) no previous diagnosis of breast cancer.

3.3 Instrumentation

3.3.1 Shoulder Function

Shoulder function was measured using the Disabilities of the Arm, Shoulder and Hand (DASH) and the University of Pennsylvania Shoulder Score (PSS) functional outcome instruments. (Appendix C) Both of these outcome measures are self-report questionnaires that assess upper extremity function.

3.3.2 Scapular kinematics

Kinematics was assessed using the miniBIRD® (model 800, Ascension Technologies, Inc., Burlington, VT) 3D electromagnetic motion analysis system controlled by the MotionMonitor™ software (Innovative Sports Training, Inc. Chicago, IL) software, Version 6). The electromagnetic motion analysis system consists of a transmitter and six miniature receivers, which are all hardwired to the system's main computer unit. The transmitter emits a low-frequency electromagnetic field, which was detected by the receivers. Each receiver was able to calculate linear motion within 3 planes, rotational motion around 3 axes, and translational motion around 2 axes, thus allowing six degrees of freedom to be measured. The receivers entered and were moved throughout the electromagnetic field and relayed the relative orientation and position of the receiver within the field to the computer. Once the information was received by the main computer, the data was processed and displayed using the MotionMonitor™ motion-capture software.

The miniBIRD® system has been shown to be accurate demonstrating a Root Mean Squared (RMS) of 1.8mm for position and .5° for orientation.[218] Three-dimensional angular data was recorded in degrees for the three scapula rotations of anterior/posterior tipping in the sagittal plane, upward/downward rotation in the scapula plane, and internal/external rotation in the transverse plane. Three-dimensional data was recorded in degrees for the two scapula translations of elevation/depression in the sagittal plane and protraction/retraction in the transverse plane.

3.3.3 Shoulder Active and Passive Range of Motion

Active and passive ROM was measured in degrees on the affected extremity using a digital inclinometer (The Saunders Group, Inc., Chaska, MN). Measures included shoulder flexion, extension, external rotation at 0° and 90° of shoulder abduction, and internal rotation at 90° of shoulder abduction.

3.3.4 Shoulder Girdle Strength

Strength was measured by means of a maximal voluntary isometric contraction (MVIC) using the Lafayette manual muscle tester (Lafayette Instrument®, Lafayette, IN). Bilateral peak muscle force in pounds was assessed for scapula abduction and upward rotation, scapula depression and adduction, shoulder flexion, shoulder internal rotation, shoulder external rotation, shoulder scaption, and shoulder horizontal adduction.

3.3.5 Cervical Active Range of Motion

Cervical active ROM was measured using the CROM (Cervical Range of Motion Instrument) (Performance Attainment Associates, Lindstrom, MN). ROM was measured for cervical flexion, extension, left side bending, right side bending, left rotation, and right rotation.

3.4 Testing Procedures

The method for data collection was the same for both groups (BCS and CON). Participants reported for a single testing session lasting approximately 90 minutes. Participants wore athletic attire including a tank top or camisole and a shirt that was removed so that the shoulders and neck were appropriately exposed for the measurements to be taken. Prior to data collection all participants read and signed an informed consent form approved by the University of North Carolina at Chapel Hill Biomedical Institutional Review Board. Participants then completed two self-report questionnaires, the DASH and PSS. Next, participants underwent a series of physical tests. The first consisted of three trials of shoulder active range of motion (ROM) followed by three trials of shoulder passive range of motion (ROM) on the affected side for flexion, external rotation at 0° of abduction, internal rotation at 90° of abduction, external rotation at 90° of abduction, and extension. To assess scapula kinematics, participants were asked to perform ten repetitions of each of the 3 tasks: 1) reaching, 2) humeral elevation in the frontal plane, and 3) humeral elevation in the scapula plane without a limb load. The order of tasks was randomized by having each participant choose three pieces of paper out of a cup. After 3D kinematics were collected, three trials of strength measures on the affected side for scapula abduction and upward rotation, shoulder flexors, adductors, shoulder internal and external rotators, and scaption positions were measured with the order of these strength testing positions randomized. The final assessment included three trials of cervical AROM for flexion and extension, left and right side bending, and left and right rotation.

3.4.1 Functional Questionnaires

3.4.1a Disabilities of Arm, Shoulder, and Hand

The Disabilities of the Arm, Shoulder, and Hand (DASH) is a 30-item self-report questionnaire appropriate for those with upper extremity musculoskeletal conditions.[219, 220] The American Academy of Orthopaedic Surgeons and the Institute for Work & Health developed this tool to assess "upper extremity-related symptoms and measure functional status at the level of disability".[221] All questions asked in the DASH require the use of the upper extremity. The DASH questionnaire is the most validated measure of upper extremity function in upper extremity disorders.[219] The average time it takes to complete the DASH is 6 minutes and it can be scored in less than 5 minutes.[220]

The DASH consists of two components, the disability/symptom section containing 30 items and the high performance sport/music or work section containing 4 items, both sections are scored from 1-5.[222] For purposes of this study, only the disability/symptom section was administered. Each item in this section was scored on a 5 point scale ranging from 1 "no difficulty" to 5 "unable". The DASH has a maximum score of 100, where a higher score is a sign of greater disability.[219] For a score to be calculated, at least 27 of the 30 items must be answered. To make the score on the DASH easier to compare to other measures, the score is then transformed to a score out of 100 by subtracting 1 and multiplying by 25.[222] The equation to calculate a score on the DASH is as follows, where n is the number of completed responses:

$$\underline{[(\text{sum of n responses}) - 1] * 25} \div n$$

The DASH has been shown to be a valid and reliable measure for reporting outcome of patients with a variety of shoulder disorders.[223] The DASH psychometric properties have been evaluated and have revealed relative reliability to be excellent with ICC's varying from 0.82 – 0.98.[224-236]

3.4.1b University of Pennsylvania Shoulder Score

The University of Pennsylvania Shoulder Score (PSS) is a 100-point shoulder-specific self-report questionnaire that first became available in 1999. [223] The PSS consists of 3 subscales: pain, satisfaction, and function.[223] Higher scores on each subscale indicate increased function.

The pain subscale comprises of 3 pain related questions that address pain at rest, with normal activities, and with strenuous activities. The pain related questions are based on a 10-point numeric rating scale with 0 = "no pain" and 10 = "worst pain". For calculating points in this portion, each item circled is subtracted from 10. Therefore, 30 points represents a complete absence of pain, whereas 0 points means the arm is not able to be used.

The function subscale of the PSS is based on a sum of 20 items, each with a 4-point Likert scale. The response options are: can't do at all (0), much difficulty (1), with some difficulty (2), and no difficulty (3). If all activities can be performed with no difficulty a total of 60 points is calculated. There is an option to respond "did not do before injury" for those questions who are not applicable. When this option is answered, for scoring purposes, the total possible points for the function subscale is reduced by 3. Scoring of the function subscale is based on a percentage of the total possible points. For example, when a total score of 24 points of this subscale is calculated and he or she responded "did not do before injury" for 1 question, the total possible points would be 57 (60 – 3). The final function score would be calculated 24 ÷ 57 = 0.42, then 0.42 x 60 = the function subscale score of 30 points, equaling a 25.2/30. All three of the subscales, pain, satisfaction, and function were examined in this study.

The PSS has been found to be a valid and reliable measure for reporting outcome of patients with a variety of shoulder disorders.[223] The PSS psychometric properties have been evaluated and has revealed a test-retest $ICC_{2,1}$ of 0.94 (95% CI, 0.89 – 0.97).[223] Internal consistency has been found to be a Cronbach's alpha of 0.93 with a standard error of measurement of ± 8.5 scale points (based on a 90% CI).[223]

3.4.2 Measurement of Scapular kinematics

Three electromagnetic tracking sensors were attached using double sided carpet tape (Scotch®, 3M, St. Paul, MN) and were affixed using Transpore™ (3M Health Care, St. Paul, MN) surgical tape to: 1) the thorax over the spinous process of C7, 2) the affected (or matched) shoulder over the broad flat surface of the scapula acromion, and pre-wrap (Cramer® Products, Inc. Gardner, KS) was additionally used over 3) the posterior one third of the affected upper arm with the sensor over the area of least muscle mass to minimize potential sensor movement. A fourth receiver was secured to a stylus for digitization of landmarks.[177, 237] Figure 1 represents the electromagnetic tracking sensor placement.

To assess scapula kinematics, reconstruction of the bony segments were performed by following the International Society of Biomechanics-Shoulder Group Recommendations that have been used in previous studies.[136] The bony landmarks were: T_{12}, medial and lateral epicondyle of the humerus, T_8, xyphoid process, C_7, sternal notch, spine of the scapula at the medial border, posterior-acromion of the scapula, inferior angle of the scapula, and the glenohumeral joint rotation center. The glenohumeral joint center was defined as the point that moves least with respect to the scapula when the humerus is passively moved through short arcs of mid-range glenohumeral motion (≤ 45°) for a total of 20 positions during glenohumeral circumduction in approximately 20 seconds.[238] The glenohumeral joint was moved by the researcher in three different directions: abduction-adduction, flexion-extension, and internal-external rotation while trying not to apply a dislocating force to the joint, or to press the humerus against the glenoid. As a result of this passive motion, regression equations as published by Meskers and colleagues were used to determine the ultimate position of the glenohumeral rotation center.[192] The mean error when using this system will vary from 8mm to 16.5mm.[238]

The electromagnetic transmitter was positioned on a custom stand allowing for the establishment of a global reference system. The global reference system axes were defined such that the Y-axis was designated as positive in the superior direction, the positive X-axis was designated as anterior, and the Z-axis was designated as positive to the right, all relative to the participant. The local axes systems were aligned with the reference axes of the electromagnetic system to simplify data reduction.

Once the participants were set up on the miniBIRD® system, they completed three different tasks of glenohumeral elevation in a randomized order: reaching, glenohumeral elevation in the sagittal plane, and glenohumeral elevation in the scapula plane (30° anterior to the frontal plane of the thorax). Randomization was accomplished by having each participant choose 3 pieces of numbered papers, one at a time, out of a cup.

Before the beginning of each task, participants stood upright with both arms hanging beside their body in a resting position (palms facing body) with their feet at a comfortable width apart and their eyes fixed forward. Participants elevated the affected (or matched) upper extremity to the terminal end point of their available ROM while maintaining a neutral hand position throughout the entire ROM. Movement velocity was maintained by asking participants to sustain a speed that was set to the beat of a metronome at 60 beats per minute, approximately 1 beat every second. This allowed the participants to move at a two count during the elevation phase and a two count during lowering phase. Before recording each task, the participants completed three practice trials to become familiar with the movement and velocity. Participants were then asked to complete 10 continuous repetitions of each elevation task. After completing 10 repetitions of each task, the participants were allowed a two-minute rest interval before testing of the next task.

Description of Each Elevation Task

All of the elevation tasks were performed with each participant's affected (or matched) side while the arm was unloaded (or without holding a weight). During all of the tasks, the participants were asked to maintain a neutral hand position in which the palm of their hand can lightly touch the PVC guide during the elevation task while their thumb is pointed towards the ceiling.

The reaching task required the participants to imagine that they were holding a soup can while placing their ulna styloid at a target that was positioned perpendicular to the affected AC joint on a shelf with the hand held in neutral rotation,. A standard goniometer was used to ensure the humeral elevation relative to each participant's trunk was greater than 120° and that the elbow was comfortably extended. This task has been used in previous studies examining scapula kinematics.[237] Figures 2 and 3 refers to examples of how the reaching task was performed.

For the glenohumeral elevation task in the sagittal plane, a pole constructed of PVC pipe was used to serve as a guide in order for participants to maintain the proper plane of movement. This guide was placed in the sagittal plane in line with the affected side acromion. The sagittal plane was defined as the plane perpendicular to a line through each participant's fifth metatarsal head. Participants elevated their arm greater than 120° and elevation was visually confirmed with a goniometer. Figures 4 and 5 demonstrate the humeral elevation task in the sagittal plane.

During the elevation task in the scapula plane (scaption), a PVC pipe was also used as a guide. This guide was placed 30° anterior to the frontal plane of the thorax, where a piece of tape was placed on the ground, and was confirmed using a standard goniometer. Once again, participants elevated their arm greater than 120° and elevation was visually confirmed with a goniometer as depicted in Figure 6.

3.4.3 Shoulder active ROM and passive ROM

Participant's upper extremity active ROM was assessed in the following order: supine flexion, supine ER at 0° of abduction, supine ER at 90° of abduction, supine IR at 90° of abduction, and prone extension. Three trials of active ROM were performed followed by three trials for passive ROM on the affected extremity. Participants practiced each active ROM one time before measures were recorded. Each measurement was taken three times and the average was used for data analysis. All active and passive ROM measures were performed according to Norkin and White.[147] Intratester reliability has been established during pilot data for active ROM ($ICC_{2,1}$ .84 – 1.0) and passive ROM ($ICC_{2,1}$ .97 – 1.0) and is shown in Table 1.

Supine flexion

The participant was supine with the knees flexed. The shoulder was positioned at 0° of abduction, adduction and rotation. The forearm was positioned in 0° of supination and pronation so that the palm of the hand faced the body. Stabilization was provided at the scapula to prevent elevation, posterior tipping, and upward rotation. The participant was asked to "move your shoulder, keeping your elbow straight from the table to your ear until you can go no further without substituting". The participant held this position while the digital inclinometer was placed parallel to the long axis of the posterior humerus displaying the flexion angle and is depicted in Figure 7.

Supine ER at 0°

The participant was supine with the knees flexed and the arm being tested at 0° of shoulder abduction. The forearm was perpendicular to the supporting surface and was in 0° of supination and pronation so that the palm of the hand was facing their other arm. The full length of the humerus rested on the supporting surface while the elbow was not supported. Stabilization was provided at the distal end of the humerus to keep the shoulder in 0° of abduction. Stabilization was provided at the scapula to prevent posterior tipping. The participant was asked to "rotate the arm as if you are bringing the back of your hand to the floor, while keeping your elbow by your side, until you can go no further without substituting". Figure 8 demonstrates how the participant held this position while the digital inclinometer was placed parallel to the long axis of the forearm displaying the flexion angle.

Supine ER at 90°

The participant was supine with the knees flexed and the arm being tested in 90° of shoulder abduction. The forearm was perpendicular to the supporting surface and was in 0° of supination and pronation so that the palm of the hand faced the feet. The full length of the humerus rested on a supporting surface while the elbow was not supported. Stabilization was provided at the distal end of the humerus to keep the shoulder in 90° of abduction. Stabilization was also provided to the scapula to prevent posterior tipping. The participant was asked to "rotate the arm as if you are bringing the back of your hand to the floor until you can go no further without substituting". The participant held this position while the digital inclinometer was placed parallel to the long axis of the forearm displaying the flexion angle as portrayed in Figure 9.

Supine IR at 90°

The participant was supine with the knees flexed and the arm being tested in 90° of shoulder abduction. The forearm was perpendicular to the supporting surface and was in 0° of supination and pronation so that the palm of the hand faced the feet. The full length of the humerus rested on a supporting surface while the elbow was not supported. Stabilization was provided at the distal end of the humerus to keep the shoulder in 90° of abduction. Stabilization was also provided to the scapula to prevent elevation and anterior tipping. The participant was asked to "rotate the arm as if you are bringing the palm of your hand to the floor until you can go no further without substituting". Figure 10 reveals how the participant held this position while the digital inclinometer was placed parallel to the long axis of the forearm displaying the flexion angle.

Prone extension

The participant was prone, with the head facing away form the shoulder being tested without a pillow. The shoulder was positioned in 0° of abduction and rotation. The elbow was positioned in slight flexion so the tension in the long head of the biceps brachii muscle did not restrict the motion.[147] The forearm was positioned in 0° of supination and pronation so that the palm of the hand faced the body. Stabilization was applied to the scapula to prevent elevation and anterior tipping. The participant was asked to "lift your arm up to the ceiling until you cannot go any further without substituting". The participant held this position while the digital inclinometer was placed parallel to the long axis of the posterior humerus displaying the extension angle as shown in Figure 11.

3.4.4 Shoulder Girdle Strength

Participant's shoulder girdle strength was assessed for scapula abduction and upward rotation, scapula depression and adduction, shoulder flexion, shoulder adduction, shoulder internal and external rotation, and scaption, with the order of these strength testing positions randomized. Randomization occurred by having each participant choose 7 pieces of numbered papers, one at a time, out of a cup. Participants practiced each testing position sub maximally one time before measures were recorded. Each measurement was taken three times and the average was used for data analysis. The participant were asked to "push as hard as you can against my force without moving your arm" for a five second count that both began and ended with a beep. During the 5 second push, participants received verbal cues of "push, push, push", and then "relax" after the stopping beep. Thirty seconds rest occurred between each trial. A 1 minute rest period occurred between each extremity and testing position. Scapula abduction and upward rotation and scapula depression and adduction were performed according to Kendall et al.[239] and the test positions of humeral flexion, scaption, and adduction were performed according to Hislop and Montgomery.[151] Intratester reliability has been established during pilot data for shoulder girdle strength ($ICC_{2,1}$ .72 – .99) and is displayed in Table 2.

Scapula abduction and upward rotation

The participant was seated without their back supported with their feet flat on the ground. The participant's arm was placed in 120° to 130° of flexion with the elbow straight and the upper extremity fully internally rotated so the thumb is pointing towards the ground. Flexion of 120° to 130° was verified using a standard goniometer. Pressure was applied against the dorsal surface of the arm between the shoulder and elbow in the direction of extension as demonstrated in Figure 12. The primary muscle tested in this position is the serratus anterior.

Scapula depression and adduction

The participant was positioned in prone with their head turned toward the test side and the shoulder that is being tested at the edge of the table. The arm was positioned at 90° of horizontal abduction and 135° of coronal abduction, with arm fully externally rotated so that their thumb faces the ceiling. Coronal abduction of 135° was verified using a standard goniometer. Figure 13 shows how the pressure was applied against the proximal portion of the humerus in a downward direction toward the table. The primary muscle tested in this position is the lower trapezius.

Shoulder flexion

The participant was seated without their back supported with their feet flat on the ground. The arm was positioned at 90° of coronal abduction and at 0° of horizontal abduction with the elbow extended and the forearm pronated so that the palm was facing the floor. Pressure was over the distal humerus just above the elbow in the downward direction of extension toward the floor as shown in Figure 14. The primary muscles tested in this position are the anterior deltoid and coracobrachialis.

Shoulder external rotation

The participant was seated without their back supported with their feet flat on the ground. The elbow was flexed to 90° with the arm in 0° of horizontal abduction and the forearm in a neutral position so that the thumb was pointing up towards the ceiling. Figure 15 depicts how the pressure was applied to the ventral surface of the distal forearm in the direction of internal rotation. The primary muscles tested in this position are the infraspinatus and teres minor

Shoulder internal rotation

The participant was seated without their back supported with their feet flat on the ground. The elbow was flexed to 90° with the arm in 0° of horizontal abduction and the forearm in a neutral position so that the thumb was pointing up towards the ceiling. Pressure was applied to the dorsum of the distal forearm in the direction of external rotation as shown in Figure 16. The primary muscle tested in this position is the subscapulais.

Shoulder scaption

The participant was seated without their back supported with their feet flat on the ground. The arm was positioned halfway between flexion and abduction (30° anterior to the frontal plane of the thorax) with the forearm in a neutral position so that the thumb was pointing toward the ceiling. Figure 17 demonstrates how the pressure was applied just above the elbow in a downward direction of extension toward the floor. The primary muscles tested in this position are the anterior deltoid, middle deltoid, and supraspinatus.

Shoulder horizontal adduction

The participant was seated without their back supported with their feet flat on the ground. The arm was positioned at 90° of coronal abduction and at 10° of horizontal adduction with the arm fully internally rotated. Pressure was applied on the medial surface of the proximal humerus into the direction of horizontal abduction as displayed in Figure 18. The primary muscle tested in this position is the pectoralis major.

3.4.5 Cervical active ROM

Participants cervical AROM was measured using the CROM. Measures of cervical flexion, extension, left side bending, right side bending, left rotation, and right rotation were measured in this order while the participant was standing in an erect posture with their hand relaxed at their sides. Each measurement was taken three times and the average was used for data analysis. Intratester reliability has been established during pilot data for cervical active ROM ($ICC_{2,1}$ .87 – .99) and is shown in Table 3.

Flexion

Participants were instructed to “bring your chin down to your chest, as if you are nodding, as far as you can while keeping your back straight” as depicted in Figure 19.

Extension

Participants were instructed “to look up to the ceiling, as far as you can without bending your back” as demonstrated in Figure 20.

Left side bending

Participants were instructed to “keep your nose facing me while you bring your left ear down to your left shoulder, do not move your body, just your neck” as shown in Figure 21.

Right side bending

Participants were asked to “keep your nose facing me and bring your right ear down to your right shoulder, moving your neck and not your body” as seen in Figure 22.

Left rotation

Participants were instructed to “keep your body facing forward while you look over your left shoulder as far as you can without turning your body” as depicted in Figure 23.

Right rotation

Participants were asked to “keep your body facing forward while you look over your right shoulder as far as you can without turning your body” as demonstrated in Figure 24.

The intratester reliability of the CROM has been assessed on 25 adult subjects without neck pain and 22 adults with pain (Fletcher and Bandy, 2008). The intraclass coefficients ($ICC_{3,1}$) for subjects without neck pain was 0.87 for forward bending, 0.90 for backward bending, 0.92 for left and right side bending, 0.94 for left rotation, and 0.90 for right rotation. In those subjects who had had neck pain, the $ICC_{3,1}$ were as follows: forward bending 0.88, backward bending 0.92, left side bending 0.89, right side bending 0.93, left rotation 0.96, and right rotation 0.92. Table 3 shows the within day, intratester reliability that was established for the active and passive ROM positions described above

3.5 Data Reduction and Processing

3.5.1 Kinematic Data

Euler-angle decompositions were used to describe humeral and scapula orientation with respect to the thorax. Scapula orientation was defined using three axes as seen in Figure 24: the x-axis describes the vector from thoracic spine to acromial angle, the y-axis describes the vector perpendicular to the plane of the thoracic spine, acromial angle and inferior angle of scapula and the z-axis is defined as the vector perpendicular to the x and y axes. Humeral orientation was determined as rotation about the y-axis of the humerus (plane of elevation), rotation about the z-axis of the humerus (elevation), and rotation about the y-axis of the humerus (axial rotation). When a participant stood in the anatomical position, the coordinate system for each segment was vertical (y-axis, describing the motion of internal/external rotation), horizontal to the right (x-axis, anterior/posterior tipping), and posterior (z-axis, describing upward/downward rotation). The clavicle attaches the scapula to the thorax and is considered a rigid body with a fixed length. Because of this, scapula position can be described as the orientation of the vector extending from the sternoclavicular joint to the acromial angle in regard to the thorax. This vector extending from the sternoclavicular joint to the acromial angle is thought to closely represent the orientation of the clavicle. Therefore, the scapula elevation/depression angle was calculated as the angle formed between this vector and the transverse plane of the thorax. Whereas, the scapula protraction/retraction angle was estimated as the angle formed between this vector extending from the sternoclavicular joint to the acromial angle and the frontal plane of the thorax. These coordinates system have been used previously and has been chosen based on the recommendations of the International Shoulder Group.[136] The Euler-angle sequences were used to most closely represent clinical definitions of movements and to decrease mathematical inconsistencies.[136]

3.6 Data Processing

3.6.1 Reduction for Scapula Kinematics

The average of trials 3 – 7 of each humeral elevation task was used for the assessment of mean scapula angles. The three rotations of scapula upward/downward rotation, internal/external rotation, anterior/posterior tipping, along with the two scapula translations of elevation/depression, and protraction/retraction were selected using a custom MATLAB (Mathworks™, Natick, MA) code to identify angles at 0 º, 30 º, 60°, and 90° of humeral elevation during the ascending phase of humeral elevation in the frontal plane, and elevation in the scapula plane (30° anterior to the frontal plane of the thorax) tasks. Scapula angles were identified for 0 º, 30 º, 60°, and max of the reaching task. Kinematic data were smoothed through a Butterworth low pass digital-filter (4th order, recursive, zero phase lag) at an estimated optimum cutoff frequency of 3.5 Hz.

Several breast cancer survivors had difficulty performing the humeral elevation tasks in the frontal and scapula plane above 100° consistently for all of the 10 trials. Therefore, 90° was the final angle assessed in this study during the two humeral elevation tasks in the frontal and scapula planes. A similar problem was discovered with the reaching task and the final angle assessed in this study during that task was the maximum available humeral elevation angle for the breast cancer survivors. This maximal humeral elevation angle was then matched for the healthy, controls.

3.6.2 Missing Data

3.6.2a. Function Data

One breast cancer survivor did not complete the DASH or PSS. A second breast cancer survivor's PSS was unable to be scored due to missing data. Because of this, corresponding matched controls were dropped from analysis of function on the DASH and PSS. Therefore analysis of the PSS included a total of 22 breast cancer survivors and 22 matched controls. Analysis of the DASH included a total of 23 breast cancer survivors and 23 matched controls.

3.6.2b. ROM and Strength Data

One breast cancer survivor was unable to lie prone to complete passive and active extension ROM measures as well as the prone strength measure of scapula depression and adduction. Because of this, the matched control was also dropped from the data analysis. Therefore, a total of 23 breast cancer survivors and 23 matched controls were used in the analysis for the ROM and strength data. There was no loss of cervical spine data for either group.

3.6.2c. Kinematic Data

Two participants kinematic data was not able to be analyzed during all 3 elevation tasks due to data collection errors for the rotational motions of anterior/posterior tipping, upward/downward rotation, and internal/external rotation, as well as the translational motions of elevation/depression and protraction retraction. Because of these errors the matched controls were dropped from the analysis. Therefore, for the scapula motions of anterior/posterior tipping, upward/downward rotation, and internal/external rotation a total of 22 breast cancer survivors and 22 matched controls were analyzed during all three of the elevation tasks.

For the analysis of the translation motions of elevation/depression and protraction/retraction during the flexion, 9 breast cancer survivors who had cancer on the left side were lost due to errors with the preference file setup. As a result, for analysis of the scapula translations of elevation/depression and protraction/retraction a total of 15 breast cancer survivors and 15 matched controls were analyzed during the flexion task.

During the scaption and reaching tasks, two additional participants had errors during data collection and the translation motions of elevation/depression and protraction/retraction were dropped from the analysis. Therefore, for the scapula translation of elevation/depression and protraction/retraction a total of 13 breast cancer survivors and 13 matched controls were analyzed during the scaption and reaching tasks.

3.7 Statistical Analysis

3.7.1 Study Power

A-priori power calculations were based on previous literature comparing group (impaired versus unimpaired) or side (affected versus unaffected) differences, as well as pilot data for the dependent variables. Effect sizes, references, and sample size required to obtain a power of .80 in this study are provided in Tables 4 - 7. Based on these estimates, it is proposed that this study contain 20 – 25 participants in each group (BCS and CON). Although not every dependent variable meets this sample size, it is believed that the majority of the dependent variables of interest are included.

3.7.2 Analysis Plan

Means and standard deviations were calculated for the demographic data of the two groups, including age, height, weight, and BMI. The analysis plan for each research question was as follows:

RQ1. Are there significant differences between breast cancer survivors and matched controls on shoulder function (DASH and PSS)?

> *Analysis*: A one-way analysis of variance (ANOVA) was conducted to evaluate the functional outcome measure scores on the DASH and PSS between the breast cancer survivors and healthy, matched controls. The independent variable was group, while the dependent variables were the scores on the DASH and PSS. Means, standard deviations (SD), 95% confidence intervals (CI), p-values, and effect sizes are reported.

RQ2. Are there significant differences between breast cancer survivors and matched controls for shoulder active ROM, shoulder passive ROM, shoulder girdle strength, cervical active ROM, and scapula and clavicle kinematics?

> *Analysis*: A one-way multivariate analysis of variance (MANOVA) was conducted to determine if differences existed between the two groups, breast cancer survivors and controls, on the dependent variables of affected shoulder

girdle active shoulder ROM, affected shoulder girdle passive shoulder ROM, affected shoulder girdle strength, and cervical spine active ROM. Analyses of variance (ANOVA) on each of the dependent variables were conducted as follow-up tests to the MANOVA. Means, standard deviations (SD), 95% confidence intervals (CI), p-values, and effect sizes are reported.

Five mixed model 2x4 ANOVAs (group x angle) were performed to examine changes in scapula (3 variables) and clavicle (2 variables) position for each of the three elevation tasks (flexion, scaption, and reaching). Post-hoc testing using Bonferroni post-hoc adjusted t-tests (adjusted α=0.0125) were performed for significant findings from the ANOVAs. F-values, p-values, partial eta^2, and power are reported.

RQ3. Is shoulder active shoulder ROM, passive shoulder ROM, shoulder girdle strength, or active cervical ROM correlated to scores on the DASH in breast cancer survivors?

Pearson Product Moment correlation coefficients were computed to assess the relationship between each dependent variable with scores on the DASH. P-values and r-values are reported.

RQ4. Is shoulder active shoulder ROM, passive shoulder ROM, shoulder girdle strength, or active cervical ROM correlated to scores on the PSS in breast cancer survivors?

Pearson Product Moment correlation coefficients were computed to assess the relationship between each dependent variable with scores on the PSS. P-values and r-values are reported.

SPSS® statistical software (version 16.0, SPSS Inc., Chicago, IL) was used to analyze all data. Statistical significance levels for all comparisons was set at an a priori of alpha = 0.05.

CHAPTER IV

RESULTS

Introduction

The results from this study are summarized below and organized by each research question. To explain differences between the two groups, F-values, p-values, 95% confidence intervals, and effect sizes are presented. Additionally, with kinematic variables, eta^2, and power are presented. To demonstrate relationships that existed between variables, Pearson Product Moment Correlation Coefficients are described and p-values and r-values are presented.

4.1. Participants

Volunteers were recruited from the university population and the surrounding Chapel Hill community through word of mouth. A total of 24 female breast cancer survivors aged 50.8 ± 9.51 years and 24 healthy female matched controls aged 50.4 ± 9.97 years participated in this study. Eight of the breast cancer survivors underwent a lumpectomy while the other 16 received a mastectomy. The breast cancer survivor group was matched to the healthy controls by gender and BMI. Table 8 shows the means for the subject descriptive data.

4.2 Research Questions

4.2.1 Research Question 1

Are there significant differences between breast cancer survivors and matched controls on shoulder function (DASH and PSS)?

The results of the ANOVA revealed a statistical significant difference between groups for the DASH ($F_{1,45} = 27.90$, $p < .001$) and PSS ($F_{1,44} = 30.54$, $p < .001$) as shown in Table 9 with the breast cancer survivor group displaying significantly greater shoulder disability compared to the control group on both outcome measures. Twenty three breast cancer survivors and twenty three matched controls completed the DASH.

A higher score on the DASH reflects greater disability. The average score for the breast cancer survivors was 19.35, whereas the control group averaged 1.16. With the PSS, a lower score reveals greater disability. Breast cancer survivors averaged a 77.12 while the control group averaged 97.46 on the PSS. The PSS subscale means can be visualized in Table 10. There was a statistically significant difference found between all 3 subscales (pain, satisfaction, and function) between the two groups. These results demonstrate the importance of utilizing an outcome measure like the DASH and PSS during rehabilitation that can offer an objective measure to provide a baseline for function in a patient, as well as monitor progress.

4.2.2 Research Question 2

Are there significant differences between breast cancer survivors and matched controls on shoulder active ROM, shoulder passive ROM, shoulder girdle strength, cervical active ROM, 3D kinematics?

A one-way multivariate analysis of variance (MANOVA) was conducted to determine if differences existed between the two groups, breast cancer survivors and controls, on the dependent variables of affected shoulder girdle active and passive shoulder ROM. ROM was assessed on twenty three breast cancer survivors and twenty three matched controls. Significant differences were found between the groups on the dependent measures, Wilks's $\Lambda = .57$ ($F_{10,35} = 2.67$, $p = .015$). A one-way analysis of variance (ANOVA) on each of the dependent variables for active and passive shoulder ROM was conducted as follow-up tests to the MANOVA and results can be seen in Tables 11 and 12. Both active ($F_{1,46} = 20.95$, $p < .001$), and passive ($F_{1,46} = 18.06$, $p < .001$) shoulder flexion were significantly decreased in the BCS group. It was also found that both active ($F_{1,46} = 5.79$, $p = .020$) and passive ($F_{1,46} = 6.84$, $p = .012$) 90° ER were significantly decreased in the BCS group. The last ROM measure found to be significantly decreased in the BCS group when compared to the healthy control group was active extension ($F_{1,46} = 9.90$, $p = .004$).

A one-way MANOVA was conducted to determine if differences existed between the two groups, breast cancer survivors and controls, on the dependent variables of cervical spine active ROM and results can be viewed in Table 13. Cervical spine active ROM was analyzed on twenty four breast cancer survivors and twenty four matched controls. No significant differences were found on the dependent variables, Wilks's $\Lambda = .91$ ($F_{6,41} = .67$, $p = .67$) between the two groups.

A one-way MANOVA was conducted to determine if differences existed between the two groups, breast cancer survivors and controls, on the dependent variables of affected shoulder girdle strength with the results displayed in Table 14. Shoulder girdle strength was measured on twenty three breast cancer survivors and twenty three matched controls. Significant differences were found between the groups on the dependent measures, Wilks's Λ = .60 ($F_{7,40}$ = 3.81, p = .003) revealing decreased upper extremity strength in the breast cancer survivor group when compared to the control group. Analyses of variance on each of the dependent variables for affected shoulder girdle strength were conducted as follow-up tests to the MANOVA. All seven of the shoulder girdle strength measures were significant, abduction and upward rotation ($F_{1,46}$ = 8.45, p = .006), depression and adduction ($F_{1,46}$ = 9.20, p = .001), flexion ($F_{1,46}$ = 19.37, p < .001), external rotation (F1,46 = 12.05, p = .004), internal rotation ($F_{1,46}$ = 9.91, p = .001), scaption ($F_{1,46}$ = 15.07, p < .001), and adduction ($F_{1,46}$ = 20.55, p < .001). These results illustrate the importance of assessing shoulder girdle strength for abduction and upward rotation, depression and adduction, flexion, ER, internal rotation, scaption, and adduction in breast cancer survivors.

A summary of the repeated measures ANOVA (angle x group) for the scapula kinematic variables during the flexion task is shown in Table 15. Twenty two breast cancer survivors and twenty two matched controls were assessed for the kinematic variables of anterior/posterior tipping, up/down rotation, and internal/external rotation during the flexion task. During the flexion task, there was no group x angle interaction ($F_{3,126}$ = .04, p = .990) and no main effect for group ($F_{1,42}$ = 2.15, p = .150) for the scapula motion of anterior/posterior tipping. Analysis of scapula internal/external rotation demonstrated no group x angle interaction ($F_{3,126}$ = 1.16, p = .326) and no main effect for group ($F_{1,42}$ = 1.13, p = .294). There was also no group x angle interaction ($F_{3,126}$ = .132, p = .941) and no main effect for group ($F_{1,42}$ = 2.18, p = .147) during upward/downward rotation. A one-way ANOVA revealed no significant differences between the groups for humeral elevation maximum angle as shown in Table 21 ($F_{1,42}$ = 4.02, p = .051). Means, standard deviations, 95% confidence intervals, and effect sizes for the scapula rotations and translations are reported in Table 16 for the flexion task. Figures 26 - 30 shows the mean scapula rotations and translations during the flexion task.

The scapula kinematic results from the repeated measures ANOVA (angle x group) performed on the scaption task is shown in Table 16. Twenty two breast cancer survivors and twenty two matched controls were assessed for the kinematic variables of anterior/posterior tipping, up/down rotation, and internal/external rotation during the scaption task. Analysis of scapula anterior/posterior tipping demonstrated no group x angle interaction ($F_{3,126} = .25$, $p = .861$) and no main effect for group ($F_{1,42} = 3.57$, $p = .066$). There was no group x angle interaction ($F_{3,126} = .13$, $p = .942$) and no main effect for group ($F_{1,42} = 1.45$, $p = .235$) for the scapula motion of upward/downward rotation. For the scapula variable of internal/external rotation, there was no group x angle interaction ($F_{3,126} = .03$, $p = .994$) and no main effect for group ($F_{1,42} = .29$, $p = .597$). There was no significant difference found between the two groups for maximal humeral flexion angle ($F_{1,42} = 1.27$, $p = .266$). Means, standard deviations, 95% confidence intervals, and effect sizes for the scapula rotations and translations are reported in Table 17 for the scaption task. Figures 31 - 35 shows the mean scapula rotations and translations during the scaption task.

Analysis of scapula motion during the reaching task also was performed using repeated measures ANOVA (angle x group) with the results shown in Table 18. Twenty two breast cancer survivors and twenty two matched controls were assessed for the kinematic variables of anterior/posterior tipping, up/down rotation, and internal/external rotation during the reaching task. For anterior/posterior tipping no group x angle interaction ($F_{3,126}$ = .52, p = .678) and no main effect for group ($F_{1,42}$ = 3.07, p = .087) was found. There was also no group x angle interaction ($F_{3,126}$ = .090, p = .966) and no main effect for group ($F_{1,42}$ = .89, p = .352) during upward/downward rotation. A group x angle interaction was found for internal/external rotation ($F_{3,126}$ = 2.95, p = .035) although there was no main effect for group ($F_{1,42}$ = .483, p = .491). Bonferonni post-hoc testing (adjusted α=0.0125) found no significant differences for angle within the two groups (breast cancer survivor and control) for scapula internal/external rotation. Means, standard deviations, 95% confidence intervals, and effect sizes for the scapula rotations and translations are reported in Table 19 for the reaching task. Figures 36 - 40 shows the mean scapula rotations and translations during the reaching task.

A repeated measures ANOVA (angle x group) was also performed on the scapula translations of elevation/depression and protraction/retraction for all three tasks of flexion, scaption, and reaching as depicted in Table 15. Fifteen breast cancer survivors and fifteen matched controls were assessed for the kinematic variables of elevation/depression and protraction/retraction during the flexion task. For the flexion task there was no group x angle interaction ($F_{3,84}$ = 5.41, p = .842) and no main effect for group ($F_{1,28}$ = 1.36, p = .254) for the scapula translation of elevation/depression. There was also no group x angle interaction ($F_{3,84}$ = 5.39, p = .918) and no main effect for group ($F_{1,28}$ = .340, p = .564) during protraction/retraction. Thirteen breast cancer survivors and thirteen matched controls were assessed for the kinematic variables of elevation/depression and protraction/retraction for the scpation task. During the scaption task, a repeated measures ANOVA (Table 16) revealed no group x angle interaction ($F_{3,84}$ = .040, p = .989) and no main effect for group ($F_{1,24}$ = .309, p = .583) for the scapula translation of elevation/depression as shown in Table 17. During protraction/retraction, there was no main effect for angle ($F_{3,84}$ = .171, p = .915), however there was a main effect for group ($F_{1,24}$ = 5.183, p = .032). Thirteen breast cancer survivors and thirteen matched controls were assessed for the kinematic variables of elevation/depression and protraction/retraction for the reaching task. During the reaching task, analysis of elevation/depression found no group x angle interaction ($F_{3,72}$ = .264, p = .851) or main effect for group ($F_{1,24}$ = .358, p = .555) as seen in Table 19. Also, no group x angle interaction ($F_{3,72}$ = .2.40, p = .075) or main effect for group ($F_{3,72}$ = .212, p = .649) was found during the reaching task for protraction/retraction.

4.2.3 Research Question 3

Is shoulder active shoulder ROM, passive shoulder ROM, shoulder girdle strength, or active cervical ROM correlated to scores on the DASH in breast cancer survivors?

Twenty three breast cancer survivors completed the DASH and were analyzed for this correlation. Five active shoulder ROM measures were analyzed and from these measures correlation coefficients were calculated. The results of the correlational analyses presented in Table 22 show that 2 of the 5 correlations were statistically significant and were greater than or equal to -.615. The results of this correlation suggest there is a relationship with active shoulder ROM measures of flexion as seen in Figures 41 and 42 with the DASH. Revealing that limitations in these motions may result in a higher score on the DASH reflecting greater disability.

Five different positions of passive shoulder ROM were analyzed and relationships were calculated using correlation coefficients. The results of the correlational analyses presented in Table 23 show that 2 of the 5 correlations were statistically significant and were greater than or equal to -.544. In general, the results illustrate a relationship with the DASH and shoulder ROM measures of flexion and 90°ER as shown in Figures 43 and 44. More specifically, where limited passive shoulder ROM may result in a higher score on the DASH reflecting greater disability.

Correlation coefficients were computed among the seven shoulder girdle strength measures. The results of the correlational analyses presented in Table 24 show that 6 of the 7 correlations were statistically significant and were greater than or equal to -.477. The results of this correlation suggest that decreased shoulder girdle strength of abduction and upward rotation (Figure 45), depression and adduction (Figure 46), flexion (Figure 47), internal rotation (Figure 48), scaption (Figure 49), and adduction (Figure 50) demonstrate a relationship with the DASH. Decreased shoulder girdle strength may result in a higher score on the DASH reflecting greater disability.

. Six different measures of cervical spine active ROM was assessed and the resultant correlation coefficients were evaluated. The results of the correlation analyses presented in Table 25 show that only 1 of the 6 correlations were statistically significant demonstrating a moderate relationship r = -.476. The results of this correlation suggest a relationship between the DASH and cervical spine active ROM measure of left rotation (Figure 51). Limitations in this motion may result in a higher score on the DASH reflecting greater disability.

The variables that were not significantly correlated to the DASH were: active 0°ER, active 90°IR, active extension, passive 0°ER, passive 90°IR, passive extension, external rotation strength, cervical flexion, cervical extension, cervical left sidebending, cervical right sidebending, and cervical right rotation.

4.2.4 Research Question 4

Is shoulder active shoulder ROM, passive shoulder ROM, shoulder girdle strength, or active cervical ROM correlated to scores on the PSS in breast cancer survivors?

Twenty two breast cancer survivors completed the PSS and were analyzed for this correlation. Correlation coefficients were computed among the five active shoulder ROM measures. The results of the correlational analyses presented in Table 26 shows that only 1 of the 5 correlations were statistically significant demonstrating a moderate relationship r - .588. The results of this correlation suggest that decreased active shoulder ROM measure of flexion, as seen in Figure 52, will result in a lower score on the PSS reflecting greater disability.

Five passive shoulder ROM measures were assessed and the resultant correlation coefficients were calculated. The results of the correlational analyses presented in Table 27 shows that 2 of the 5 correlations were statistically significant and were greater than or equal to .424. In general, the results suggest that there is a relationship between decreased passive shoulder ROM measures of flexion (Figure 53) and 90°ER (Figure 54) and the PSS which may result in a lower score on the PSS reflecting greater disability.

Shoulder girdle strength was measured in seven different positions and the correlation coefficients were computed. The results of the correlational analyses presented in Table 28 show that 4 of the 7 correlations were statistically significant and were greater than or equal to .436. The results of this correlation suggest that decreased shoulder girdle strength of flexion (Figure 55), internal rotation (Figure 66), scaption (Figure 57), and adduction (Figure 58) have a relationship with scores on the PSS and may result in a lower score on the PSS reflecting greater disability.

.	Correlation coefficients were calculated for the six cervical spine active ROM measures. The results of the correlational analyses presented in Table 29 shows that 3 of the 6 correlations were statistically significant and were greater than or equal to .449. The results of this correlation demonstrate a relationship with cervical spine measures of left sidebending, left rotation, and right rotation, and limitations in these ROM measures may result in a lower score on the PSS reflecting greater disability as seen in Figures 59 - 61.

The variables that were not significantly correlated to the PSS were: active 0°ER, active 90°ER, active 90°IR, active extension, passive 0°ER, passive 90°IR, passive extension, abduction and upward rotation strength, depression and adduction strength, external rotation strength, cervical flexion, cervical extension, and cervical right side bending.

CHAPTER V

DISCUSSION

Purpose

The purpose of this study was to compare affected active and passive shoulder ROM, affected shoulder girdle strength, cervical active ROM, upper extremity function, and 3D scapula kinematics between breast cancer survivors and healthy, matched controls. The secondary goal of this study was to assess if relationships exist in the breast cancer survivor population between functional scores on the DASH and PSS with affected active shoulder ROM, affected passive shoulder ROM, cervical active ROM, and affected shoulder girdle strength. This is the first study known to the authors to compare breast cancer survivors affected side to a healthy age, matched population for these variables, as well as assess relationships between function and a number of clinical variables. Several significant differences were found between the two groups in this study, as well as relationships between function and clinical measures. This discussion will be divided into three main sections: 1) outcome measures of shoulder function from the DASH and PSS, 2) clinical measures of active and passive shoulder ROM, affected shoulder girdle strength, and cervical ROM, including what is driving differences in function, and 3) scapula kinematics.

5.1 Outcome measures

Significant differences were found between the two groups with regards to upper extremity outcome measures for both the DASH and PSS, supporting our hypotheses. The results from this study showed that the average score on the DASH for the breast cancer survivor group was 19.35, while the healthy matched controls averaged 1.56. The DASH is a validated measure and has been utilized in one previous study to objectively assess upper extremity function in breast cancer survivors. Hayes et al. conducted a study on 258 women six months after treatment for unilateral breast cancer.[86] Results from this study revealed an average DASH score of 10.8, with a wide range from 0.00 to 17.7.[86] The average of 10.8 is much less than the 19.35 average found on the DASH found in our study. Although the Hayes et al. study and our study have similar means for age and time since receiving breast cancer treatment, comparisons of the DASH score between these two studies may be difficult to make due differences in surgery type. Only 28% of the breast cancer survivors in the Hayes et al. study received a mastectomy, whereas 67% received a mastectomy in our study.[86] Further analysis of the 8 breast cancer survivors in this present study who received a lumpectomy scored an average of 9.88 on the DASH compared to the average of 24.40 for those who received a mastectomy. It is believed that the type of breast cancer surgery may affect upper extremity function. Future research should be conducted to assess whether those who receive a mastectomy demonstrate a greater loss of upper extremity function, such as scores on the DASH, when compared with those who received a lumpectomy.

Another study utilizing the DASH to assess upper extremity function in sixty-six breast cancer survivors was conducted by Gordon and colleagues. This study revealed the breast cancer survivors scored an average of 15.2 on the DASH, which falls in between what was found in the Hayes et al. study of 10.8 and our study's findings of 19.35. It is difficult to make comparisons with the results from our study to the results from our study because there was no explanation as to how long ago the women in the Gordon et al. study completed their breast cancer treatment.

There are relatively few studies that utilize the DASH to assess upper extremity function in breast cancer survivors making comparisons with the results from this study difficult. To gain a better understanding of the meaningfulness of the average score of 19.35 found on the DASH in this study, comparisons with other shoulder pathologies are needed. The DASH has been used to assess upper extremity function in several other shoulder pathologies including rotator cuff tears, impingement, and adhesive capsulitis. A recent study conducted by Colegate-Stone et al., assessed 123 persons who were to undergo a rotator cuff repair.[240] Individuals who had a rotator cuff tear <30 mm scored an average of 52 on the DASH, whereas those who had a tear >30mm scored an average of 68 prior to their surgery.[240] These average scores of 52 and 68 are significantly higher than the average score on the DASH found in the breast cancer survivors in this study. It is important to note that all of these individuals were surgical candidates, and pain descriptors were not utilized, which may explain the high DASH score. Also, the authors did not indicate how long these individuals have been affected by the rotator cuff pathology making comparisons difficult since the breast cancer survivors in our study had very recently completed their treatment. Fifty-eight individuals who were waiting to begin physical therapy for suspected shoulder impingement syndrome completed the DASH in a study conducted by Ardic et al.[172] The average score on the DASH was 58.3

for these individuals.[172] These individuals also complained of 7.5/10 shoulder pain, whereas the average shoulder pain found in the breast cancer survivor group was 2.2/10.[172] These individuals with impingement stated their shoulder pain had been bothering them for ~12 months.[172] This duration and intensity of pain also makes comparing their DASH scores to the breast cancer survivors difficult. A study was conducted on 63 individuals to test the efficacy of low-power laser therapy in persons with adhesive capsulitis.[241] These individuals completed the DASH prior to treatment and revealed an average score of 46.[241] The subjects with adhesive capsulitis demonstrated a higher score on the DASH when compared to the breast cancer survivors in this study.[241] However, once again, comparisons of the DASH scores between those who have been diagnosed with adhesive capsulitis and the breast cancer survivors in our study are difficult to make because the study conducted by Stergioulas did not report patient demographics such as average age and time of onset of pain, although the individuals did rate their pain an average of 7/10.[241] The results of the above studies reveal that it is very difficult to compare breast cancer survivors' function on an assessment like the DASH with other shoulder pathologies such as rotator cuff tears, impingement, and adhesive capsulitis. This appears to be due to a large amount of variability in the patient demographics and the different nature of these shoulder pathologies when comparing the effects of shoulder function in breast cancer survivors. One similar finding in all three of the shoulder pathologies discussed above is the higher subjective rating of pain when compared to the breast cancer survivors in our study which may also explain the difficulty in comparing DASH scores.

While the level of dysfunction as represented on the DASH in the breast cancer survivors for this study is not as great as that associated with shoulder impingement of rotator cuff tears, there is still an important difference in function between BCS and control subjects as evidenced by the large effect size of 1.08. The comparison to the other shoulder pathologies gives a sense of the relative level of dysfunction in comparison to several shoulder pathologies. The significant differences on scores of the DASH found between the breast cancer survivors and healthy, matched controls, along with the large effect sizes found illustrate that this is still an important decrease in function that is statistically and clinically important. As such, clinicians need to better understand this dysfunction in order to identify those breast cancer survivors who have a loss of shoulder function to develop the appropriate rehabilitation programs for these individuals

Assessing the clinical significance on scores of the DASH can be difficult. There is no set standard or cutoff on the DASH to represent a score for disability, although it has been suggested that scoring a 20 or higher may represent a significant loss of function.[242] The average score on the DASH for the breast cancer survivors in this study of 19.35 is just slightly below this average. However, further analysis reveals 11 of the 23 breast cancer survivors scored greater than a 20 with an average score of 32.6. Thus, while the average DASH score in breast cancer survivors is slightly below the cut score of 20 for displaying a significant loss of function our findings indicate that many individuals score well above this cut score and do display significant function loss. Because of this further analysis, it is recommended further research be conducted regarding outcome measures assessing function in breast cancer survivors to evaluate if there is a subgroup of women who are affected adversely by their breast cancer treatment. A second way to assess whether the 19.35 average score found in our study is clinically meaningful is to examine the minimal clinically important difference (MCID). Schmitt and DiFabio have suggested the MCID for the DASH to be 10.2.[243] When comparing the averages between the two groups in this study, breast cancer survivors (19.35) and healthy matched controls (1.56), the average difference is 17.79, therefore reflecting a clinically important difference between groups.

One limitation found on the DASH in this study is the wide range of scores from 0.86 to 71.3. Several factors may have contributed to the wide range in scores found in this study such as: stage of breast cancer, type of surgery (mastectomy or lumpectomy), reconstruction, and systemic treatment such as chemotherapy and/or radiation. Although these variables were recorded but not separately analyzed in this study due to a small sample size, it is recommended that these factors are examined in future research involving breast cancer survivors.

Although the DASH provides clinicians with an overall score reflecting function, it may be important to analyze each question individually when working with a breast cancer survivor to identify specific deficits for that individual. This is because; the DASH is not a specific outcome measure of function for breast cancer itself, and as discussed above, it can be used for a variety of upper extremity pathologies. Further analysis of each individual item on the DASH found that almost half of the breast cancer survivors in this study agreed or strongly agreed with feeling less capable, less confident or less useful because of their arm, shoulder or hand problem (question #30). Approximately half of the breast cancer respondents in this study reported moderate to severe difficulty, or the inability to perform recreational activities (golf, hammering, tennis, etc) which take some force or impact through the arm, shoulder, or hand (question #18). The breast cancer survivors in this study also reported difficulty with performing question 19, recreational activities in which the arm is moved freely (Frisbee, badminton, etc). While the average disability found on the DASH in this study for the breast cancer survivors was 19.35, assessing the response of each item on the DASH could help better guide an individual rehabilitation program for the specific function of each breast cancer survivor.

This is the first study known to the authors that utilized the PSS to analyze upper extremity function in a group of breast cancer survivors. With the PSS, a lower score reveals greater disability. In this study, breast cancer survivors averaged a 77.12 (out of 100) while the control group averaged 97.46 on the PSS. A wide range of variability can be seen in this study with the PSS scores for the breast cancer survivors ranging from 35 – 100. However, little variability existed with regards to PSS scores for the healthy, matched controls ranging from 88 – 100 with 11 of the 24 women scoring a 100. As described previously with the DASH, the large range in scores for the breast cancer survivors may be due to a variety of factors such as: stage of breast cancer, type of surgery (mastectomy or lumpectomy), reconstruction, and systemic treatment such as chemotherapy and/or radiation. These variables were recorded but not separately analyzed in this study due to a small sample size. It is recommended that variables such as these are examined in future studies investigating upper extremity function in breast cancer survivors.

Understanding what is clinically important can be difficult when analyzing the PSS. Unlike the DASH, there has been no recommended cutoff to delineate disability when analyzing the PSS. Furthermore, there has been no minimally important clinical difference established for the PSS. Therefore, comparisons must be made between breast cancer survivors' upper extremity function with other shoulder pathologies such as rotator cuff tears and impingement. Sauerbrey and colleagues conducted a retrospective comparative study on 54 individuals who were to undergo a rotator cuff repair.[244] The overall PSS score for these individuals prior to surgery was roughly 47 (out of 100) considerably lower than the average of 77 found for the breast cancer survivors in our study.[244] Another study utilized the PSS to assess shoulder function in 39 individuals who were diagnosed with shoulder impingement.[194] The average total score on the PSS for these individuals was 63.3, once again lower than the average score of 77 for the breast cancer survivors in this study.[194]

The PSS can be subdivided into three subscales: function, pain, and satisfaction. The average found for the function subscale in this study was 46.6 (out of 60, a higher number reflects greater function) for the breast cancer survivors and 58.6 for the healthy, matched controls. Similar to the findings above regarding the overall score on the PSS, differences are seen when trying to compare the breast cancer survivors in our study to individuals with other shoulder pathologies such as rotator cuff tears and impingement. These same studies discussed previously revealed the function subscale score to average 30.0 (out of 60, a higher number reflects greater function) and 42.7 for those with rotator cuff tears and shoulder impingement, respectively.[194, 244] Differences in group comparisons for pain were also observed. In the study conducted by Sauerbrev on individuals with rotator cuff tears, the average pain score was 15 (out of 30, a higher number reflects less pain) whereas the average pain score was 16.9 for those with shoulder impingement in the study conducted by McClure et al.[194, 244] These pain subscales averages are significantly lower, compared to the 25 average found in our study for the breast cancer survivors.

A unique feature of the PSS is the satisfaction subscale, which asks "how satisfied are you with the current level of function of your shoulder". To our knowledge, no other upper extremity outcome assessment tool asks individuals about their satisfaction regarding current shoulder function. The satisfaction subscale on the PSS is based on a score of 10, where a higher number reflects greater satisfaction. The average satisfaction score for the breast cancer survivors in this study was a 5.7. Shoulder pathologies such as individuals with rotator cuff tears and impingement have reported scores of 2.5 and 3.7 respectively. These satisfaction scores appear to reflect not as large of a magnitude of difference between the breast cancer survivors and other shoulder pathologies. There appears to be a trend when comparing the breast cancer survivors in our study with other shoulder pathologies. It appears that overall, the breast cancer survivors in our study tended to have better overall function, decreased pain, and are more satisfied than others with such shoulder pathologies as rotator cuff tears and shoulder impingement.

As with the DASH, it appears comparing the total outcome score as well as each subscale on the PSS for breast cancer survivors in our study with those individuals who suffer from other shoulder pathologies such as rotator cuff tears and impingement may not be an appropriate comparison. Onset of injury may be one area that could explain the differences in scores observed between the breast cancers survivors and those with other shoulder pathologies. The breast cancer survivors were no more than 6 months out from their last systemic and/or surgical treatment. In contrast, 50% of those individuals who were diagnosed with shoulder impingement had an average duration of injury of 6 months or greater. Unfortunately, the study conducted by Sauerbrey et al. does not mention the duration of injury before these individuals proceeded with their rotator cuff repair. One limitation of our study is the relatively small sample size of breast cancer survivors (n = 22) when compared to other research studies utilizing the PSS with other shoulder pathologies[194, 244] A second limitation with our study is the variability in treatment received in our breast cancer survivor cohort including type of surgery (mastectomy or lumpectomy) as well as type and duration of systemic treatment (chemotherapy and/or radiation). These factors were not analyzed separately due to the small sample size, but should be considered in the research design and subject recruitment during future research involving breast cancer survivors and shoulder function. Despite these limitations, while the level of dysfunction is not as large as that associated with other shoulder pathologies, there is still an important difference in function between the breast cancer survivors and control subjects as evidenced by the large effect size of 1.15 found in this study for the PSS. Similar to the DASH, the significant difference between the breast cancer survivors and the healthy, matched controls along with the large effect sizes reveal that the scores on the PSS demonstrates an important decrease in function that is both statistically and clinically important

Pain appears to be a significant factor affecting function when analyzing the PSS. Significant differences are evident when examining the pain subscale in those with rotator cuff tears and shoulder impingement compared to the breast cancer survivors' scores. Pain is a subjective measure and is interpreted and described differently person to person. Two significant factors may be causing “better” scores for pain on the PSS in the breast cancer survivor group. First, as mentioned above, they have only recently completed their primary treatment and many have stated they have not been able to return to their previous activity lifestyle due to a variety of factors including fatigue and uncertainty of what they can do regarding movement with their surgical side. Secondly, breast cancer survivors may report pain in a different manner when compared to other individuals who have not gone through such a life threatening diagnosis as cancer. Future research should be conducted within the breast cancer population to further assess their perception of pain in order to make comparisons to other pathologic populations.

The results from this study utilizing the DASH and PSS demonstrate breast cancer survivors who have recently completed their primary breast cancer treatment display a decrease in upper extremity function when compared to matched, healthy controls. The level of average functional loss in breast cancer survivors does not appear to be as great as other shoulder pathologies, such as rotator cuff tears and shoulder impingement; however, breast cancer survivors do suffer from significant loss of function as well as a low level of satisfaction with the use of the shoulder as indicated by the DASH and PSS scores. It is important to note a wide range of scores was observed in this study for both the DASH and PSS and should be further examined. Future research investigating upper extremity function in breast cancer survivors should utilize a larger sample size, take into account other factors such as surgical and systemic treatment, and consider examining women who have finished their primary treatment greater than six months ago. As Isaksson and Feuk found, breast cancer survivors continue to have pain, weakness, and restricted movements two years postoperatively.[9] This study does begin to provide insight regarding upper extremity function and breast cancer survivors and shows function can be significantly affected in this cohort. Utilizing quality, outcome tools such as the DASH and PSS could provide clinicians with important information regarding upper extremity function in order to help each breast cancer survivor resume a high quality of function in their lives. These findings also indicate that shoulder function is diminished in breast cancer survivors. To improve function in these individuals it is important to understand whether physical characteristics, such as strength and ROM are also affected in these women. This information may provide insight into factors which may need to be addressed during rehabilitation of breast cancer survivors

5.2 Clinical measures

Several clinical measures were examined in this study to quantify differences that may exist between breast cancer survivors and healthy, matched controls. These clinical measures included: active and passive shoulder ROM, shoulder girdle strength, and cervical spine active ROM. This is the first known study to compare breast cancer survivors' active and passive shoulder ROM to healthy, matched controls. Five active and passive shoulder ROM movements were assessed in this study. Of those, active and passive flexion and 90° ER, and active extension demonstrated significant differences between the two groups, partially supporting our hypotheses.

Research has shown that normative values for active shoulder flexion in females average approximately 176°.[245] The average active and passive shoulder flexion ROM found in this study for the breast cancer survivors was 156.5º and 160.5º compared to the 164.8º and 171.9º averages for the healthy, matched controls. This difference was statistically significant and represents an average difference of 8.29 º and 11.34º between the two groups for active and passive shoulder flexion respectively.

Shoulder flexion appears to be the most commonly studied motion in the breast cancer survivor population and has been recently examined by several different researchers. Hayes et al. found limitations in active shoulder flexion in 214 breast cancer survivors with a mean of 143°.[86] Other studies have revealed average active shoulder flexion in breast cancer survivors to be 155°,[246] 163°,[55] 163°,[247] and 168°.[55] Caution needs to be utilized when comparing the results of these studies amongst each other, as well as against the results of flexion ROM found in this study. This is because several different testing methodologies were incorporated in these studies. These include differing length of time since diagnosis of breast cancer, a wide range of ages, various treatments (systemic and surgical) for the breast cancer, and differing testing positions utilized (standing, seated, and supine) during the measurements of shoulder flexion.

To further understand the clinical significance regarding the limitations in flexion ROM found in the breast cancer survivor population, comparisons can be examined between the breast cancer population and other shoulder pathologies such as rotator cuff disease, shoulder impingement, and adhesive capsulitis. A recent study examined 85 Canadian postal workers who had symptoms lasting >6 weeks for rotator cuff tendinitis.[248] Results showed these individuals demonstrated 122° of active and 124° of passive shoulder flexion.[248] One limitation making comparisons difficult with this study to ours is that there is no description of how the subjects were positioned (seated, standing, or supine) during the testing measures of flexion ROM. Vermuelen et al, analyzed ten individuals who were diagnosed with adhesive capsulitis.[207] Results from this study demonstrated active and passive shoulder flexion to average 156° and 167°, which are very similar to the flexion ROM limitations found in the breast cancer population examined in our study.[207] In another study, 58 individuals who were diagnosed with shoulder impingement and waiting to begin physical therapy had a variety of clinical measures recorded.[172] Results revealed active shoulder flexion to average 139.2°.[172] A study performed by Lombardi et al. analyzed flexion active ROM in 60 patients who had impingement.[249] Interestingly, the results demonstrated greater deficits in active flexion ROM , 119.5°. The authors do state the measurement in standing was "performed against the pull of gravity".[249] This positioning of the patient may explain the differences in flexion ROM found when comparing the results from our study, and those like Ardic's with the study by Lombardi. Despite these factors limiting comparisons between other shoulder pathologies with our results, the results illustrate deficits do exist with regards to shoulder flexion ROM on the affected extremity in the breast cancer survivor population. Similar deficits in shoulder flexion ROM are observed between breast cancer survivors and other shoulder pathologies and breast cancer survivors. Thus, these appear to be clinically important differences in shoulder flexion ROM.

The average active flexion ROM found in this study was 156.5º for the breast cancer survivors and was significantly different when compared to the healthy, matched controls. What proves difficult is interpreting the clinical relevance of observed changes between these two groups. Some researchers recommend a clinical significant ROM difference be compared between the involved and uninvolved extremity.[75] It is believed when these measures differ by >10° between extremities, a clinical significance exists.[75]

Because comparison measures between extremities were not recorded in this study, analysis between the breast cancer survivors and control group flexion ROM reveals a difference of 8.3º for active ROM and 10.5º for passive ROM. To further explain the clinical significance of these findings, effect sizes can be examined to further emphasize the clinical importance of the flexion active and passive ROM differences found between the breast cancer survivors and healthy, matched controls. In this study, the effect sizes for active and passive flexion ROM were 1.14 and 1.05 respectively. These large effect sizes, the 8.3º and 10.5º differences between groups for this measure of flexion ROM, along with the statistical significance found in this study helps to demonstrate a meaningful clinical difference seems to exist for active and passive shoulder flexion ROM between breast cancer survivors and healthy, matched controls.

Although shoulder active and passive flexion ROM appears to be the most often studied shoulder motion in the breast cancer survivor population, results from this study demonstrate a necessity for clinicians to also examine active and passive ROM for 90° ER. Significant differences were found for both the active and passive ROM measures at 90° ER in this study. Outcomes for this measure demonstrated breast cancer survivors averaged 87.64° and 91.64°, whereas the healthy, matched controls averaged 98.36° and 102.17° respectively for the active and passive ROM measures.

Several other studies complement the results from this study reporting limitations of active ROM for 90° ER in breast cancer survivors to range from 80°,[250] 82°,[247] and 86°.[55] To further demonstrate the significance of deficits for this motion in breast cancer survivors, examining other shoulder pathologies may provide further insight into the clinical meaningfulness of the statistical differences found in this study. Lombardi and colleagues examined shoulder active ROM for 90° ER in 60 patients diagnosed with shoulder impingement syndrome.[249] These individuals with shoulder impingement demonstrated an average of 71.6° for active 90° ER.[249] There was one significant difference regarding methodology making comparisons between this measure of ROM with our measures is that the individuals with impingement were standing when active ROM was recorded. One hundred and seventy individuals who were about to undergo rotator cuff surgery had baseline measures of active and passive ROM for 90° ER assessed.[251] Averages for 90° ER active ROM was 50°, whereas passive ROM averaged 64°.[251] Although these averages are several degrees less than what was found for the breast cancer survivors in this study, it is important to note that these individuals reported an average duration of symptoms for 45 months, significantly longer than the time since the breast cancer survivors in this study were diagnosed. This large difference in duration since onset and assessment of these ROM measures should cause some concern when making comparisons.

Comparing breast cancer shoulder ROM measures to other pathologies such as impingement and rotator cuff dysfunction may provide limited understanding of clinical significance due to differences in methodology and length of time since injury. Reviewing normative data for active shoulder ROM at 90° ER reveals an average of 101° for healthy females.[245] This is approximately 13° greater than the averages found in this study for the breast cancer survivor population. When utilizing the minimal clinically important difference of >10º to demonstrate clinical significance, as suggested by MacLean and colleagues, differences between the two groups in this study reveal a 10.7° difference for active ROM and 10.5° difference for passive ROM measures.[75]

Furthermore, examining the effect sizes of 0.56 for active and 0.62 passive ROM demonstrates a possible clinical meaningful difference for the measure of 90° ER in the breast cancer survivor population. Although this effect size is moderate, clinicians who rehabilitate women who have recently undergone treatment for breast cancer should monitor this particular ROM especially if deficits exist when compared to the unaffected extremity and/or normative data.

The final ROM that was found to significantly differ between the breast cancer survivors and the healthy, matched controls was active extension. This motion averaged 25.78° for the breast cancer survivors compared to the average of 31.53° measured in the healthy, matched controls. Therefore, there was an average difference of 5.75° between the breast cancer survivors and healthy, matched controls when assessing active extension. The difference of 5.75° may not seem large; however, when this difference is converted into a percentage, a difference of 18% is evident between the two groups. To try and further explain the significance of this measure between the two groups in this study a large effect size of 0.82 was calculated.

Only a few studies have examined active extension in the breast cancer survivor population. Cho et al. examined fifty-five women who had completed their breast cancer treatment approximately 1 year from the time of the study and found active extension to average 41°.[250] One of the difficulties in making comparisons to this study and a significant limitation is that the authors did not discuss the methodology regarding how the ROM was measured. Another study assessed active extension in sixty-five breast cancer survivors and found this motion to average 45° seven months after the primary surgical procedure.[246] A large difference in the methodology of this study making comparisons difficult was that Box et al. chose to analyze active extension in the seated position, whereas the present study chose to measure active extension in the prone position. These methodological differences between studies may explain the 15° – 20° difference found between our study and those conducted by Box et al and Cho et al.

In trying to further understand whether the average active extension ROM of 25.78° in the breast cancer survivor group is clinically meaningful, comparisons with other shoulder pathologies can be analyzed. The average extension active ROM in 65 individuals with diagnosed rotator cuff tendinitis was 37.7°, although there was no explanation as to the positioning of these individuals during the recording of this measure.[248] Lombardi and colleagues measured standing active extension ROM in 60 individuals who were diagnosed with shoulder impingement.[249] Active extension ROM measured 45.9° in these individuals. These measures are much greater than the average found in our study for the breast cancer survivors and could be explained in the variability of positioning the individuals when measuring active extension. As noted previously with other ROM findings, it seems to be difficult to make comparisons for measures of ROM between breast cancer survivors and other shoulder pathologies due to differences in methodology and duration of injury symptoms.

Interestingly, passive extension did not differ between the two groups. This might be explained by the positioning of the individual when recording this measure. Individuals were required to lie prone and perform extension against gravity in this study. Of importance to note is two of the breast cancer survivors were unable to assume the prone position due to pain. These differences in passive and active ROM may provide evidence that perhaps it is not just a ROM deficit that exists with extension in breast cancer survivors, but also a strength deficit may exist as well. In future studies, a modification of this position, such as having the patient seated or standing, could be used to eliminate performing this motion entirely against gravity to gain a better understanding of whether this ROM is truly limited.

Several measures were found to not be statistically significant between the two groups in this study; these included active and passive 0° ER, 90° IR, and passive extension ROM. It is difficult to explain why there were no significant differences between the groups for the measures of active and passive 0° ER since no normative data could be found for this measure. Furthermore, there appears to be no literature on this measure for breast cancer survivors and other shoulder pathologies such as impingement, adhesive capsulitis, or rotator cuff pathology. This study revealed averages for active and passive ROM at 90° IR to be 60.71° and 65.09° respectively. In comparison, normative values report active ROM for healthy females to average 51.0°, whereas passive ROM average 61.45° and 60.25°.[245, 252] The active ROM measure of 90° IR has been examined in breast cancer survivors in three previous studies.[55, 247, 250] The results from these studies show that the 90° IR active ROM measure to average 78.56°, 51.4°, and 56.9°. Our results seem to correspond with two of these three studies; however caution must be used when making these comparisons as the measure for 90° IR was measured in the seated position in one study, whereas this study obtained this measure in the supine position. Other shoulder pathologies have revealed 90° IR ROM to average 50.7° in subjects with impingement[172] and only 3° in those with adhesive capsulitis.[253]

The results of this study demonstrate the clinical importance of assessing active and passive shoulder ROM when evaluating a breast cancer survivor. Several ROM measures were shown to be significantly less in the breast cancer survivors when compared to the healthy, matched controls. Having adequate ROM is pertinent in order to perform activities of daily living. Activities of daily living (ADLs) can be defined as activities that describe the functional capacity of patients.[87] ADL's are essential for maintaining independent living, returning to work, and for general quality of life.[87] In daily life, having the ability to achieve functional active flexion is imperative for a large number of different ADL's such as combing hair, reaching, washing the upper back, shampooing hair, and performing other overhead tasks.[87] If the active and passive motions of shoulder flexion, ER at 90°, and extension are not addressed in this population within the first 6 months of finishing their primary treatment, these women may experience upper extremity functional deficits, affecting ADL's, in the future as evidenced by the results of this study. Limitations in shoulder ROM could possibly lead to a variety of future problems including decreased function, difficulty completing ADL's, the development of adhesive capsulitis, rotator cuff pathology, and shoulder impingement.

Although subjectively, is has been reported that breast cancer survivors have decreased muscle strength on the affected extremity, very few studies have quantified these actual deficits.[101] Shamley and colleagues were one of the first to demonstrate a decrease in muscle activity of the upper trapezius, rhomboids, and serratus anterior during arm elevation in the plane of the scapula in breast cancer survivors when their affected extremity was compared to their unaffected extremity.[254] This was the first known study to compare strength measures between breast cancer survivors and healthy, matched controls. Results from this study illustrated that all of the shoulder girdle strength measures of scapula abduction and upward rotation, scapula depression and adduction, humeral flexion, humeral external rotation, humeral internal rotation, scaption, and horizontal adduction were significantly different between the breast cancer survivors and matched healthy controls supporting our hypotheses.

There have been very few studies conducted that assess upper extremity strength in the breast cancer survivor population. Lee et al. conducted a study to examine upper extremity strength in sixty-four breast cancer survivors.[72] Although MVIC's were utilized to assess strength using a digital dynamometer, the results of the study were reported in Newtons and did not appear to be normalized to body weight for the subjects. Along with not normalizing the strength measures, different testing positions were also used in this study. Therefore, it is difficult to make comparisons between the results of our study with those from Lee et al. Another study evaluated upper extremity strength in forty women who had completed all of their treatment for breast with an average of 28 months since initial treatment.[101] Dynamic concentric strength was measured using a 1-repetition maximum (RM) comparing the affected side to the unaffected side. Significant differences were found for the 1RM measures between sides for the shoulder protractors, retractors, and extensors. Comparisons again are difficult to make regarding the results from this study to the study conducted by Merchant et al. because of the different method utilized to assess strength, dissimilar muscles assessed, and a significant longer period, 22 months versus 6 months, since initial treatment.

To gain a better understanding of the observed differences in strength between the breast cancer survivors and healthy, matched controls in this study, comparisons can be made with other shoulder pathologies regarding strength measures. Razmjou and colleagues examined 170 individuals who were candidates for rotator cuff repair surgery.[251] Strength measures were recorded in the scapular plane using an unsecured tensiometer.[251] Results revealed a statistically significant difference between the affected (2.89 lbs) and unaffected (7.81 lbs) sides, explaining a 73% difference between sides.[251] This is a very large difference between the sides and may not be a representative comparison with our study. This is because, the subjects with rotator cuff pathology were not only surgical candidates, but had reported symptoms for an average of 45 months. Forty-five subjects with impingement syndrome were compared with 45 subjects without known pathology or impairments at the shoulder in a recent study.[19] Measures of force were assessed using the "break test method" for external rotation, internal rotation and scaption.[19] Results showed all strength measures were statistically significant between the two groups for all three of these strength measures.[19] Further analysis shows a 35% difference in strength measures between the groups for scaption, 23% for external rotation, and an 18% difference for the strength measure of internal rotation.[19] Jurgel and colleagues examined 10 individuals with adhesive capsulitis and compared several measures of isometric maximal force with 10 healthy, matched controls.[255] Isometric maximal force of the shoulder was measured by a hand-held dynamometer in a variety of positions including flexion, adduction, internal rotation, and external rotation.[255] Of these measures, there was a statistically significant difference, reflecting a decrease in upper extremity strength when comparing those with adhesive capsulitis to the matched controls for the strength measures of shoulder flexors (33%), adductors (25%), and external rotators (33%).[255] The above studies help to demonstrate strength differences exist in several different shoulder pathologies.

No other study has compared upper extremity strength in the breast cancer survivor population with healthy controls making comparisons of this measure difficult. Furthermore, understanding the clinical significance of strength deficits proves difficult. To gain a better appreciation of the differences that were found for strength measures in this study, percent deficits can be calculated for all of the statistically significant strength measures between the two groups. Of all the strength measures that demonstrated significant differences between the breast cancer survivor population and the healthy, matched controls, the percent deficit is greatest for scapula depression and adduction at 31%, followed by both scaption and adduction at 28%, internal rotation at 26%, external rotation at 25%, flexion at 24%, and scapula abduction and upward rotation at 20%. The percentage of difference for strength measures in the shoulder pathologies discussed above including impingement syndrome and adhesive capsulitis range from 18% to 33%, similar to the findings in this study, further demonstrating the importance of strength measure deficits in the breast cancer survivor population. To continue to emphasize not only the statistical significance of these differences, but also the clinical significance, effect sizes can be examined. For all of the above significant strength measures between the breast cancer survivors and healthy, matched controls, the effect sizes ranged from 0.82 – 1.29, reflecting a large difference for these measures between the two groups.

Decreases in strength will often affect function, the ability to perform ADL's, and affect overall quality of life. It is evident that strength is an important clinical measure that needs to be evaluated in the breast cancer survivor population. Results from this study showed clinically meaningful differences in strength measures of scapula abduction and upward rotation, scapula depression and adduction, humeral flexion, humeral external rotation, humeral internal rotation, scaption, and horizontal adduction between the two groups. Clinicians should focus on assessing these strength measures in the breast cancer survivor population, as large deficits are present in this group.

Researchers believe that impairments of the cervical spine may contribute to shoulder pain and disability.[173] It is also thought that movement of the shoulder can cause direct or indirect secondary movement of the cervical spine.[256] Because of this, it is important to assess cervical spine ROM in those presenting with an upper extremity dysfunction. This is the first study known to the authors to assess cervical spine active ROM in the breast cancer population. No significant differences were found between the two groups for cervical spine measures of cervical flexion, extension, left side bending, right side bending, left rotation, and right rotation. Further analysis was conducted to determine if rotating or side bending away from the affected extremity demonstrated any differences between groups. This analysis was performed because these two motions would cause the pectoralis, a muscle often compromised in breast cancer treatment to be lengthened. Again, no statistically significant difference was found for these measures. There is limited research investigating the relationship between cervical spine ROM and shoulder pathologies.

In order to try and better understand the relationships between functional outcomes and physical characteristics in breast cancer survivors correlation analyses were performed. This study examined the relationship between two self report outcome measures for the shoulder, the DASH and PSS, and the following dependent variables; affected active and passive shoulder ROM, affected shoulder girdle strength, and cervical active ROM. Several negative relationships were found between the DASH and the aforementioned variables analyzed in this study which was partially in agreement with our hypotheses. The DASH is a 30 item self report questionnaire asking the subject to rate his/her difficulty performing a wide variety of tasks that involve the use of the upper extremity.[257] A higher score on the DASH reflects greater disability. Therefore, negative correlations would represent decreased measures on the dependent variable relating to higher scores on the DASH.

Two of the five active shoulder ROM measures examined in this study showed marked correlations with the DASH, flexion (r = -0.62) and 90° ER (r = -0.65). The same passive ROM measures also illustrated marked correlations with the DASH, flexion (r = -0.54) and 90° ER (r = -0.64). These findings indicate that decreased shoulder flexion and 90° ER ROM were associated with decreased shoulder function as measured by the DASH. The first 21 of the 30 questions on the DASH ask the respondent to "rate their ability to do the following activities within the past week". The Likert scale used in the DASH is as follows: 1 = no difficulty, 2 = mild difficulty, 3 = moderate difficulty, 4 = severe difficulty, and 5 = unable. When analyzing each question on the DASH independently, approximately 17 of the first 21 questions require the motion of shoulder flexion. (Table 28) Some of the 17 tasks on the DASH that requires active flexion include: "prepare a meal", "push a heavy door", "place an object on a shelf above your head", and "change a light bulb overhead". External rotation ROM was also markedly correlated to scores on the DASH. Approximately 10 of the first 21 questions on the DASH require external rotation to complete effectively. Some of the questions on the DASH that require active external rotation include: "opening a tight or new jar", "turning a key", "wash or blow dry your hair", and "washing your back". Surprisingly, internal rotation measures were not correlated with DASH scores, even though approximately 14 of the first 21 questions appear to require internal rotation motion such as “opening a tight or new jar”, “preparing a meal”, “doing heavy household chores such as washing the floor”, and “making your bed” to name a few. Perhaps this is because; anecdotally many people tend to hold their arms close to their body in an internally rotated position after receiving treatment on their upper extremities. It should also be noted that there was not a statistically significant difference between the breast cancer survivors and healthy, matched controls regarding internal rotation active ROM.

Six of the seven strength measures displayed correlations with the DASH: scapula abduction and upward rotation (r = -0.48), scapula depression and adduction (r = -0.64), humeral flexion (r = -0.51), humeral internal rotation (r = -0.52), scaption (r = -0.56), and adduction (r = -0.60). Clinically, these findings indicate that decreased strength of scapula abduction and upward rotation, scapula depression and adduction, humeral flexion, humeral internal rotation scaption, and adduction were associated with decreased shoulder function as measured by the DASH. Scapula depression and adduction, the highest correlated strength measure in this study with the DASH, is needed to complete approximately 8 of the 21 questions on the DASH. The second strength measures to show a marked correlation with the DASH was adduction. Only approximately 5 of the 21 questions on the DASH require the use of adductor strength. The next correlated strength measure, scaption, is needed to perform 10 of the 21 tasks on the DASH. With the remaining correlations found to be significant, roughly, 12 of the 21 tasks involve internal rotation strength, 16 require flexion strength, and approximately 3 tasks call for use of abduction and upward rotation.

To our knowledge, there have been no studies assessing ROM or strength relationships with the DASH in any population with shoulder dysfunction. However, there has been one recent study that assessed the relationship between arm morbidity and disability in 347 breast cancer survivors who were 6-12 months after surgery.[75] In this study, lymphedema, pain, and ROM were assessed to determine if these were associated with disability as measured by the DASH.[75] Pearson correlation coefficients revealed that of those measures, abduction ROM was the strongest correlation with scores on the DASH.[75] Although this study utilized different measures than our study, it demonstrates an association between ROM and disability, similar to what was found in our study.

Since both ROM and strength variables appear to be correlated to DASH scores, the results from this study could be used to assist clinicians when treating a breast cancer survivor. Specifically, the ROM measures of flexion and 90 of ER° were shown to correlate with DASH scores. This provides some initial evidence to suggest that clinicians should address these ROM deficits when treating breast cancer survivors who have a loss of function and/or deficits in the shoulder region. Along with ROM, strength measures of scapula abduction and upward rotation, scapula depression and adduction, humeral flexion, humeral internal rotation, scaption, and adduction were also shown to correlate with the DASH. Once again, results from this study provide preliminary support to suggest that clinicians should focus on these specific strength measures when working with breast cancer survivors who have recently completed their primary treatment of surgery, chemotherapy, and radiation.

Several positive relationships were found between the PSS and the dependent variables of affected active shoulder ROM, affected passive shoulder ROM, affected shoulder girdle strength, and cervical active ROM which was partially in agreement with our hypotheses. The PSS is a self report measure that has 3 subjective portions assessing function, pain, and satisfaction with a lower score reflecting greater disability. The function portion on the PSS contains 20 questions with a four category Likert scale. The Likert scale ranges from “no difficulty”, “some difficulty”, “much difficulty”, and “can’t do at all”. Positive correlations would represent decreased measures on a dependent variable relating to lower scores on the PSS.

Of the five active ROM measures, flexion (r = 0.59) was the only significant relationship found for the breast cancer survivors and scores on the PSS. When analyzing each functional question on the PSS, 14 of these 20 questions require an individual to move their arm into flexion. Some of these tasks include: “washing the back of your opposite shoulder”, “combing hair”, “dressing, including pulling a shirt off overhead”, “placing a soup can at shoulder level”, and “placing a gallon jug at shoulder level”. Similar to the DASH, no relationship was found between the PSS and active internal rotation ROM even though approximately 8 of the 20 questions on the PSS require internal rotation. However, as mentioned above, there was no statistical significant difference between the breast cancer survivors and controls for active internal rotation. Also, internal rotation tends to be the static position held by those who have had shoulder pain and dysfunction, possibly many of the functional tasks that these people perform are conducted in this internally rotated position.

Two of the five passive ROM measures demonstrated moderate relationships with the PSS: shoulder flexion (r = 0.60) and ER at 90° (r = 0.42). As mentioned previously, 14 of the 20 function questions on the PSS require flexion. However, it remains unclear to the authors of this study, why active ER at 90° did not correlate to the PSS, although passive ER at 90° did. Approximately 7 of the 20 questions on the PSS require the motion external rotation. These questions include: “placing your hand behind your head with your elbow straight out to the side”, “performing a usual hobby”, “cooking”, and “performing overhead/swim/overhand racquet sport”.

Four of the shoulder girdle muscle strength measures were found to be moderately correlated to the PSS: shoulder flexion (r = 0.46), internal rotation (r = 0.44), scaption (r = 0.44), and adduction (r = 0.45). When analyzing each question on the PSS for strength requirements, approximately 13 of the 20 functional questions require flexion strength to complete effectively. Scaption strength is needed for 50% of the tasks, whereas both internal rotation and adduction strength are utilized in approximately 25% and 15% of the tasks respectively.

To the authors' knowledge, this is the first study to examine the relationship between impairment measures (ROM and strength) with scores on the PSS in breast cancer survivors. There has been one recent study that examined the relationship between impairment measures in persons who had recently undergone arthroscopic repair for rotator cuff tears with scores on the SPADI and PSS.[16] Strength measures were assessed in three positions: external rotation, internal rotation, and scaption with internal rotation. Range of motion measures were taken in standing for flexion, external rotation at 0 and 90 of abduction, and internal rotation measured by spinal level. Strength and ROM measures were compared to the uninvolved side and were reported as percentage scores. A pearson product moment correlation was conducted and found the relationship for the strength, (internal rotation, external rotation, and scaption) (r = 0.44) and ROM (humeral flexion, humeral 0º of ER, 90 º of ER, and IR using the thumb up the back) (r = 0.50) measures showed a moderate correlations. Although the two percentage scores for strength and ROM in this study seemed to demonstrate moderate correlations with the DASH, the authors concluded that there was a large amount of variance in the study's population self-reported function scores to be unexplained by impairment scores.[16]

Of interest when reviewing both the DASH and PSS correlations in this study requires discussion of the presence of 2 outliers in the group of breast cancer survivors. These two subjects were the same outliers for both the DASH and PSS. These outliers scored a 71.3 and 43.1 on the DASH and a 41.6 and 57.6 on the PSS. A separate analysis was performed excluding these two subjects, and although there continues to be a statistically significant difference in scores on both the DASH and PSS between the breast cancer survivors and healthy, matched controls, a different picture is presented for the correlation analysis. With this new analysis, there were no clinical measures that demonstrated relationships with scores on the DASH. Of all of the ROM measures, the clinical measures that demonstrated the highest relationship with the DASH, although not significant were 90° ER active (r = -0.32) and passive (r = -0.34) measures. Again, with this new analysis, none of the strength measures demonstrated a relationship with scores on the DASH. The highest correlation strength measure with the removal of these two outliers on the DASH was adduction (r = 0.35). When these two outliers were removed for analysis of the PSS, there was only one marked relationship that was shown, this was the measure of passive flexion (r = 0.45). Removal of these 2 outliers presents a very different picture when trying to assess what relationships exist between clinical measures and scores on the DASH and PSS.

Due to the small sample size, and covariates such as type of treatment (systemic and surgical), as well as stage of breast cancer that were not separately analyzed in this study, caution should be used when trying to interpret the clinical significance of these results. Regardless, findings from the above correlation analyses suggest that more research is needed to understand what physical characteristics are influencing functional outcomes. The results from this study suggest that shoulder external rotation and flexion ROM combined with other strength measures are associated with shoulder function as measured by the DASH and PSS. These findings suggest that clinicians may need to pay particular attention when addressing these physical characteristics to achieve optional functional outcomes when rehabilitating an individual recovering from breast cancer. Future research investigating interventions aimed specifically at addressing these physical characteristics is needed to better understand whether rehabilitation programs targeting these physical deficits facilitate better functional outcomes.

5.3 Scapular Kinematics

This is the first known study to compare scapular kinematics on the affected side in a breast cancer survivor population with healthy, matched controls. A significant limitation occurred during the kinematic data collection in this study. The breast cancer survivor cohort had difficulty in consistently elevating their humerus above 90 degrees in all three of the tasks. The kinematic data was originally planned to be analyzed at 30 degree increments beginning from the starting position up to 120 degrees. However, we learned that this was not feasible as the breast cancer survivors were not consistently reaching this point. Because of this, the kinematic analysis was altered. As a result the data for the tasks of flexion and scaption were analyzed at start, 30°, 60°, and 90 degrees.

Because the breast cancer survivors had difficulty consistently elevating up to 90 degrees during the reaching task, the kinematic analyses was performed at start, 30°, 60°, and maximal humeral elevation angle. A further explanation of why the breast cancer survivors had difficulty elevating above 90° and how this may have impacted the study's findings will be discussed below.

Scapula kinematics were analyzed during three tasks of flexion, scaption, and reaching. Analyses revealed a main effect for group for the translation of protraction/retraction during the scaption task. The results showed that the breast cancer survivors demonstrated greater protraction when compared to the healthy, matched controls. More specifically, the breast cancer survivor cohort demonstrated 4 – 5 degrees greater protraction throughout the scaption motion when compared to the healthy, matched controls regardless of humeral angle. An interaction effect for group x angle was found during the reaching task for internal/external rotation. Post hoc testing did not reveal a statistically significant difference for the interaction effect of internal/external rotation during the reaching task. No other significant differences were found between the breast cancer survivors and healthy, matched controls for the scapula rotations of anterior/posterior tipping, upward/downward rotation, and internal/external rotation during the tasks of flexion, scaption, and reaching. Similarly, no other significant differences were found between the two groups for the translations of elevation/depression and retraction/protraction during these three tasks.

Modest differences in scapula kinematics, all less than 5 degrees were found between the two groups during all three tasks. Because of these small differences, the clinical significance is difficult to assess. Some researchers believe that a 4 - 5 degree difference in scapula and clavicular joint position between groups is clinically meaningful.[18, 254] During flexion only small effect sizes were observed in this study for all of the scapula rotations and translations throughout humeral elevation. While there have been no studies examining kinematics during flexion for the breast cancer survivor population, other shoulder pathologies have investigated these motion patterns. A study conducted by McClure and colleagues examined 45 individuals with impingement syndrome and compared 3D kinematics during three cycles of active flexion with 45 healthy, matched controls.[19] Small differences (less than 5 degrees) in kinematics were demonstrated between groups.[19] Specifically, during flexion the individuals with impingement syndrome showed a pattern of slightly greater posterior tipping, greater internal rotation, greater upward rotation, increased elevation and decreased protraction when compared to the healthy controls.[19] The only statistically significant differences between those with impingement and those without were increases in upward rotation and elevation at 90° and 120° of flexion.[19] The average difference between these two groups during the flexion task was 4.9° for upward rotation and 2.9° for elevation.[19] It is difficult to make comparisons with our study since the breast cancer survivors had difficulty consistently elevating greater than 90°. However, the average differences found in our study between the breast cancer survivors and healthy matched controls was 3.8° at 90° of elevation, just slightly less than what was found in the study conducted by McClure and colleagues. As seen in the study by McClure and colleagues, differences found between the two groups occurred when elevating above 90°. Bagg and Forrest described motion between 80° – 140° of elevation to be the middle phase.[184] It is believed that this phase is the most stressful on the upper extremity during arm elevation.[184, 186] Because the breast cancer survivors were unable to consistently reach this middle range during our study, important differences in scapula kinematics may not have been identified.

A recent study conducted by Fayad and colleagues demonstrated similar difficulties with consistently elevating the affected upper extremity greater than 90° in individuals with shoulder dysfunction.[197] Thirty-two individuals with a diagnosis of glenohumeral osteoarthritis or adhesive capsulitis performed two repetitions of flexion. Individuals with glenohumeral arthritis demonstrated an average of 95.7° for maximal humeral elevation, whereas those with adhesive capsulitis averaged 66.4°.[197] Despite this difficulty in elevating above 90°, statistically significant differences were observed for external rotation in both groups and protraction in those with frozen shoulder.[197] Specifically, individuals with osteoarthritis demonstrated increased external rotation, whereas those with adhesive capsulitis showed not only increased internal rotation, but decreased protraction when compared to the unaffected extremity.[197] These differences in kinematics are dissimilar from the results of this study. It may not be appropriate to compare the variables analyzed in our study with individuals who have shoulder pathologies such as impingement syndrome, osteoarthritis, or adhesive capsulitis. The methods and subject characteristics in the study conducted by Fayad and colleagues differs significantly from those in the present study. The average age of the individuals in the study conducted by Fayad and colleagues of 60.6 years was much higher than the average age of individuals in our study at 50.6 years.[197] The average duration of symptoms was much greater, 35.2 months, compared to the duration since the breast cancer survivors completed their treatment of no greater than 6 months.[197] The different results obtained in our study may also be attributable to differences in measurement methods. In the study conducted by Fayad and colleagues, the thorax sensor was mounted on the sternum and the humeral sensor was attached just below the insertion of the deltoid.[197] During flexion, it appears scapula motion is highly variable, as evidenced by large standard deviations, in individuals with shoulder dysfunction and multiple studies have found only modest (<5°) differences between a pathologic and healthy controls. Further research should be conducted to gain a more clear understanding of scapula movement patterns in individuals with shoulder pathology including breast cancer survivors.

Scapula plane elevation is one of the most common studied motions for kinematic analysis. The results found in this study revealed a main effect for group during scaption for the translation of protraction/retraction with the breast cancer survivor cohort demonstrating 4 – 5 degrees greater protraction throughout the scaption motion when compared to the healthy, matched controls regardless of humeral angle. There has been one recent study that examined a group of breast cancer survivors' three-dimensional scapulothoracic motion.[254] In this study conducted by Shamley and colleagues, 152 women treated for unilateral carcinoma of the breast were included.[254] Only one task, scaption, was analyzed, and only 3 repetitions were performed.[254] Results revealed a statistically significant difference when comparing the affected side to the unaffected side for all kinematic motions analyzed in the study.[254] Shamley and colleagues found increased protraction on breast cancer survivors who were affected on their left side.[258] Our study found an average difference between the two groups for the protraction measure to range from 4.9° – 5.5° during elevation. The average difference found in the study conducted by Shamley in colleagues was ~2.5°. Also, we observed a significant group by angle interaction for internal/external rotation, although post hoc analysis was not able to detect significant differences between groups. This does suggest that our findings are in partial agreement with Shamley and colleagues. The study conducted by Shamley and colleagues had a large sample, 131 breast cancer survivors, thus our study may have been underpowered to show statistical significance.

Some caution should be exercised when comparing our study as variations existed in methodology. Specifically the "control" used in the study by Shamley and colleagues was the unaffected side of the breast cancer survivor, not a healthy, matched control as utilized in our study. Using the unaffected side of a breast cancer survivor might not be a true representation of a "healthy" side due to the systemic effects of treatments such as chemotherapy and radiation. Also, all of the breast cancer survivors examined in the study conducted by Shamley and colleagues had mastectomies and had a greater duration since surgery (~3 years) compared to no more than 6 months for the breast cancer survivors in our study.[254] It is believed that the type of breast cancer surgery may affect upper extremity function reflecting differences in outcome measures, although more research is needed to further explain this phenomenon. Three repetitions were used in the study by Shamley and colleagues, compared to 10 repetitions performed in our study. As mentioned previously, all of the seven strength measures were significantly weaker when compared to the healthy controls. Performing 10 repetitions, for three different tasks is a significant amount of work required, and although we did not record rate of perceived exertion, it is hypothesized that the breast cancer survivors fatigued easily due to decreases in strength, therefore causing difficulty in performing the tasks consistently above 90°. Finally, a significant difference existed between our study and theirs with regards to subjects receiving chemotherapy. Only 16.6% of the breast cancer survivors in the study conducted by Shamley and colleagues received chemotherapy, compared to 87.5% in our study.[254] Although further research is needed to elaborate on this hypothesis, researchers believe chemotherapy might affect a breast cancer survivor differently when compared to those who did not receive chemotherapy.[259] Another factor affecting comparisons between the two studies is the low sample size used in our study (n = 22), compared to the large sample size analyzed in the study by Shamley and colleagues (n = 152) for the scapula rotations of anterior/posterior tipping, upward/downward rotation, and internal/external rotation.[254]

Even though several differences existed between the current study and the work of Shamley et al, the findings from these studies do suggest that scapula kinematics are altered in breast cancer survivors. In particular, protraction was demonstrated to be increased in the breast cancer survivors. The clinical implications of increased protraction could include the development of impingement like symptoms as protraction can cause a decrease in subacromial space.[260] Furthermore, the pectoral muscles and anterior shoulder girdle soft tissue are largely affected with breast cancer treatments and could be contributing to restricting shoulder motion as evidenced with decreased shoulder flexion and 90 ER observed in this study. Although this was not directly measured in this study, it should be considered in future research with breast cancer survivors. As a result the scapula may be forced to move into a more protracted position to compensate for these tissue changes. Research has shown that increased scapula protraction could be related to scapula dyskinesis.[261] Although this was not analyzed in our study, future investigations regarding scapula dyskinesis should be examined in the breast cancer survivor population.

Kinematic analysis of scaption has been assessed in several different studies in individuals with impingement syndrome. A study conducted by Lukasiewicz and colleagues examined scapula kinematics during 2 trials of upper extremity elevation in the scapula plane in 17 individuals with impingement syndrome and 20 individuals without shoulder pathology.[18] The subjects did not move continuously through their available range but held 3 static positions: rest, 90°, and maximum elevation for 30 seconds each.[18] Results revealed statistically significant differences at 90° and maximum elevation for the scapula measures of posterior tilting.[18] Individuals with impingement demonstrated significantly less posterior tilt that differed from those who did not have shoulder pathology by approximately 8 and 9 degrees.[18] It is difficult to compare our study to the study conducted by Lukasiewicz and colleagues because static positions were studied rather than continuous motion. The study mentioned above conducted by McClure and colleagues also examined motion in the scapular plane in those 45 individuals with and without impingement syndrome.[19] During elevation in the scapular plane individuals with impingement syndrome demonstrated greater posterior tilt, upward rotation, external rotation, elevation, and clavicular retraction.[19] Statistically significant differences were found in this study at 90° for upward rotation and at 120° for posterior tilting and retraction.[19] The results showed a substantial amount of variability among subjects and although statistical significant differences were found, these differences between groups were all less than 4°.[19] As mentioned previously, it is difficult to make comparisons with our study since the breast cancer survivors had difficulty consistently elevating greater than 90°. Future studies should be conducted to examine scapula kinematics when the humerus is above 90° in individuals who have had breast cancer to examine if alterations in scapula kinematics exist as it does appear to in individuals with other shoulder pathologies such as impingement syndrome.

Reaching is a relatively new motion that is being examined using three dimensional analyses. A group x angle interaction effect was found during the reaching task for internal/external rotation, although post hoc analysis revealed no statistically significant differences between groups. Statistical results demonstrate the breast cancer survivor cohort and control groups were different and only small effect sizes were shown, as this difference was dependent upon the angular position, specifically at maximal humeral elevation during reaching. Although a group x angle interaction was found during internal/external rotation, the effect sizes were small for all of the four humeral positions examined. This could be attributed to our study being underpowered. Similar to the elevation tasks described above, the small changes found during the reaching tasks, all less than 5 degrees between the two groups, afford difficulty in assessing clinical significance. Moderate effect sizes ranging from .45 - .53 were found for the scapula variable of anterior/posterior tipping. All other scapula motions analyzed during the reaching task revealed only small effect sizes. One explanation for a lack of larger differences in scapula kinematics is perhaps only a small subset of women who have recently undergone treatment for breast cancer truly have abnormal scapula motion. Breast cancer treatment varies greatly from person to person, and because of this, future research is needed to further investigate whether a subset of women exist who present with scapular movement abnormalities.

As previously indicated we believe that the inability for breast cancer survivors to consistently elevate beyond 90-degrees may have limited our ability to observe significant differences in scapula and clavicle kinematics. Thus, it is important to understand factors that may have influenced the ability to study kinematic differences above 90-degrees of humeral flexion. The mean (±SD) maximal active humeral flexion angle in those with breast cancer during the flexion task was 122.5° (13.92), while not statistically significant ($p = 0.051$) when compared to 130.1° (10.84) in the healthy, matched controls the difference in maximal humeral flexion during the flexion task may have affected the results. However, the observed difference of approximately 8-degrees may be important as it was associated with a moderate effect size of .55. Differences in humeral elevation were not close to reaching statistical significance during scaption ($p = 0.27$) as there was approximately a 5 degree difference between the groups for this measure: 122.3° (13.14) for the breast cancer survivors and 127.14° (15.19) for the control group with a small effect size of .32. During the reaching task, the breast cancer survivors revealed 96.54° (13.43) whereas the controls demonstrated 104.4° (12.14) for maximal humeral elevation, which was statistically significant ($p = .05$) . The different in humeral elevation during reaching was approximately 8-degrees and was associated with a moderate effect size of .66. When comparing the active shoulder flexion ROM values to the maximal humeral elevation values achieved during kinematics testing, differences are apparent as breast cancer survivors achieve more active flexion ROM compare to humeral elevation during kinematics testing. This is most likely due to the positioning of the subjects during each measure. For ROM measures, the subjects were supine where gravity could help with the last several degrees of motion. Kinematics were assessed with the subjects in standing, where gravity would have the opposite effect on end range motion. Thus, during ROM assessment gravity was able to assist humeral flexion whereas during kinematics testing subjects worked against gravity. We believe that the inability of the breast cancer survivors to consistently achieve 90-degrees of humeral flexion may have been influenced by our findings of decreased shoulder girdle strength, and pain. Although not specifically measured in this study, fatigue may have also been a factor affecting the breast cancer survivors ability to consistently move above 90 degrees..

During kinematics testing the subjects appeared to be able to elevate their arm beyond 90-degrees of elevation. However, humeral flexion angles during kinematic testing did not support this visual observation. Lack of humeral flexion during kinematics testing may have been influenced by landmarks used to define humeral flexion as well as compensatory movement patterns during humeral elevations tasks. The landmarks used to define the humerus involve the shoulder joint center and the medial / lateral epicondyles of the humerus. Humeral flexion was measured as the angle formed by the humerus relative to the thorax. We did not measure kinematics of the forearm and hand segments. Thus, individuals may have been able to elevate the forearm and hand segments to appropriate heights relative to the global coordinate system, but unable to produce greater than 90-degrees of humeral flexion relative to the thorax. Also, compensatory movement patterns in breast cancer survivors may have allowed for sufficient elevation of the hand relative to the world, but not true humeral flexion as measured relative to the thorax. Thorax motion substitutions may have occurred to position the forearm and hand segments in sufficient elevation relative to the global coordinate system thus limiting the need for greater humeral flexion relative to the thorax. These factors should be considered in future research studying breast cancer survivors. It may be necessary to study scapula and clavicle kinematics as a function of the position of the hand relative to the global coordinate system rather than as a function of humeral flexion. Also, researchers should closely monitor for compensatory motions of the thorax during testing or perhaps include thorax position as a variable of interest.

Another potential factor that may have influenced our ability to identify differences between groups was the number of repetitions performed during testing. Our study required all participants to complete three separate tasks, requiring 10 repetitions for each task. As mentioned previously, all of the seven strength measures were significantly weaker when compared to the healthy controls. Performing 10 repetitions, for three different tasks is a significant amount of work required, and although we did not record rate of perceived exertion, it is hypothesized that the breast cancer survivors fatigued easily due to decreases in strength, therefore causing in performing the tasks consistently above 90°. Perhaps the breast cancer survivors did consistently move greater than 90°, but through compensatory thorax motions as previously mentioned. Visually and verified using a goniometer, the breast cancer survivors appeared to achieve elevation consistently greater than 120°. Compensatory mechanisms occurring at the humerus and thorax may have occurred causing the breast cancer survivors to appear to move above 90°. Ludewig and Cook found that the humeral laterally rotates relative to the scapula throughout most of scaption.[17] Unfortunately, these kinematic variables were not assessed in this study. Finally, a data collection error occurred causing the removal of 11 participants, along with their matched counterparts, reducing the total number of subjects in each group to 15 for kinematic analysis, therefore decreasing the sample size and power in our study.

5.4 Future Research

Understanding upper extremity deficits in the breast cancer survivor population continues to garner attention and the research to explain why these deficits occur has just begun. It is also important for clinicians to have a better understanding about the relationship between shoulder dysfunction and quality of life when working with breast cancer survivors. At the present time, there has been minimal research conducted examining outcome measures and quality of life in the breast cancer survivor population. Future research is needed to try and explain the relationships between a domain specific measure such as the DASH and PSS with clinical measures such as ROM and strength. It is also important to continue to explore the relationships that may exist between quality of life with clinical measures and functional outcome measures. Based on the ROM, strength and functional deficits revealed in this study, future research should be conducted to further examine the best rehabilitation practices needed in order to decrease functional deficits and impairments in this population. Research should continue to try and better understand what factors of breast cancer treatment (ie: surgical and systemic treatment) impact on upper extremity function. Finally, future research utilized to examine scapula kinematics in the breast cancer survivor population should be aware of the effects of fatigue, and perform the minimal amount of repetitive motion, as well as examine any compensatory mechanism that may be occurring in this group of women in order to understand if abnormalities in motion exist.

5.5 Clinical Significance

There are several clinical implications that can be taken from the findings found in this study. Specifically the, ROM measures of humeral flexion and humeral ER at 90º appear to be affected in the breast cancer survivor population. All seven of the strength measures assessed in this study were found to be decreased in the breast cancer survivor cohort. Finally, increased scapula protraction is another key finding. The results from this study provide preliminary evidence to suggest that clinicians focus on these particular ROM and strength measures when treating a breast cancer survivor who has recently completed their primary treatment.

Women who have recently completed their primary breast cancer treatment appear to have function deficits as revealed in this study when using outcome measures such as the DASH and PSS. Results from this study help to lay preliminary ground work describing functional limitations as well as impairments women may experience who have recently completed their primary breast cancer treatment of surgery, chemotherapy, and/or radiation. Outcomes from this study could be used to further develop evidenced based guidelines to provide the most effective treatment when rehabilitating breast cancer survivors.

5.6 Conclusions

In conclusion, this is a novel study that provides valuable information to the rehabilitation profession regarding shoulder active and passive ROM, upper extremity strength, and function for breast cancer survivors who have recently (within the past 6 months) completed their primary surgical and systemic treatments. The results of this study may help to guide clinicians in the appropriate direction when treating a breast cancer survivor who is experiencing decreased function of the affected upper extremity. In summary, clinicians should utilize self-report functional assessments such as the DASH and PSS, as well as pay special attention to the shoulder ROM measures of flexion and 90° ER. Furthermore, upper extremity strength measures need to be examined in the breast cancer survivor population as the results from this study revealed weaknesses in the following shoulder girdle strength measures: abduction and upward rotation, depression and adduction, flexion, external rotation, internal rotation, scaption, and horizontal adduction. Finally, clinicians should examine scapula protraction during scapular plane movements in breast cancer survivors.

Table 1. Upper extremity active ROM and passive ROM ICC's

Glenohumeral Joint Active & Passive ROM ICC				
	ICC		**SEM**	
	Affected		**Affected**	
	AROM	**PROM**	**AROM**	**PROM**
Flexion	0.98	1.00	1.37	0.52
0° External Rotation	1.00	0.99	0.77	0.90
90° External Rotation	0.99	0.99	1.34	12.9
90° Internal Rotation	0.99	0.97	1.21	1.89
Extension	0.98	0.97	1.48	1.74

Table 2. Shoulder Girdle Strength ICC's

Strength ICC		
	Affected	**SEM**
Scapular Abduction & upward Rotation	0.99	0.79
Scapular Depression & Adduction	0.77	2.01
Humeral Flexion	0.99	0.90
Humeral External Rotation	0.91	0.76
Humeral Internal Rotation	0.97	0.80
Shoulder Scaption	0.99	0.65
Shoulder Horizontal Adducation	0.87	1.48

Table 3. Cervical active ROM ICC's

Cervical Active ROM ICC		
	ICC	**SEM**
Flexion	0.97	2.22
Extension	0.97	1.68
Left Side Bending	0.87	1.93
Right Side Bending	0.98	1.32
Left Rotation	0.87	6.82
Right Rotation	0.99	1.90

Table 4. Shoulder active ROM power calculation

Shoulder AROM				
	Effect Size		# of subject for .80 power	
	Affected	Unaffected	Affected	Unaffected
Flexion	0.98	1.89	13	9
External Rotation - 0°	0.05	0.42	1237	78
External Rotation -90°	1.75	0.35	7	108
Internal Rotation - 90°	0.002	2.51	1237	7
Extension	1.05	1.14	13	13

Table 5. Shoulder strength power calculation

	Shoulder Strength			
	Effect Size		# of subject for .80 power	
	Affected	**Unaffected**	**Affected**	**Unaffected**
Scapular Abduction & Upward Rotation	0.27	0.28	138	138
Scapular Depression & Adduction	1.47	2.43	7	7
Shoulder Flexion	0.56	0.69	35	26
Shoulder Internal Rotation	0.28	0.51	138	50
Shoulder External Rotation	1.21	0.96	9	13
Shoulder Scaption	0.57	0.23	35	310
Shoulder Horizontal Adduction	1.08	0.53	13	50

Table 6. Cervical spine active ROM power calculation

Cervical Spine AROM		
	Effect Size	**# of subject for .80 power**
Flexion	0.38	78
Extension	0.85	20
Left Side Bending	3.26	7
Right Side Bending	0.64	35
Left Rotation	0.36	78
Right Rotation	0.18	310

Table 7. Scapula kinematics power calculation

Scapular Position Based on Maximum Humeral Elevation					
Article	**Plane**	**Population**	**Scapular Motion**	**Effect Size**	**# of subject for .80 power**
Rundquist 2007	Scapular	Idiopathoathic loss of Shoulder ROM	Upward/ Downward Rotation	0.23	310
			Internal/ External Rotation	0.78	20
			Anterior/ Posterior Tipping	0.42	78
Fayad et al 2008	Frontal	Osteoarthritis	Upward/ Downward Rotation	0.99	13
			Internal/ External Rotation	0.69	26
			Anterior/ Posterior Tipping	0.09	1237
Fayad et al 2008	Frontal	Frozen Shoulder	Upward/ Downward Rotation	0.57	35
			Internal/ External Rotation	0.93	13
			Anterior/ Posterior Tipping	0.05	1237
Fayad et al 2008	Sagittal	Osteoarthritis	Upward/ Downward Rotation	1.10	11
			Internal/ External Rotation	0.48	50
			Anterior/ Posterior Tipping	0.17	310
Fayad et al 2008	Sagittal	Frozen Shoulder	Upward/ Downward Rotation	0.78	20
			Internal/ External Rotation	1.10	11
			Anterior/ Posterior Tipping	0.52	50

Table 8. Subject Descriptive Data

Subject Descriptive Data		
	Breast Cancer Survivor	**Control**
Age (years)	50.8 ± 9.51	50.4 ± 9.97
Height (cm)	65.2 ± 2.71	65.2 ± 2.94
Weight (kg)	75.6 ± 15.1	73.2 ± 15.1
BMI (kg/m^2)	27.6 ± 5.49	26.9 ± 5.47

Table 9. Mean, SD, 95% CI, p value, and effect size for the DASH and PSS

	Breast Cancer Survivor			Control				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
DASH	19.4 (n = 23)	16.79	14.4, 24.3	1.56 (n = 23)	1.71	-3.07, 6.01	<0.001*	1.08
PSS	77.1 (n = 22)	17.7	71.8, 82.5	97.5 (n = 22)	3.37	92.3, 102.6	<0.001*	1.15

* Significant differences

Table 10. Mean, SD, 95% CI, p value, and effect size for subscales of PSS (scores)

	Breast Cancer Survivor (n = 22)			**Control (n = 22)**				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
Pain	25	5.11	23.5, 27.8	29.4	1.19	27.8, 30.9	0.000*	0.84
Satisfaction	5.74	2.88	4.80, 6.68	9.39	1.35	8.45, 10.3	0.000*	1.27
Function	0.78	0.23	0.71, 0.85	0.98	0.03	0.91, 1.05	0.000*	0.87

* Significant differences

Table 11. Mean, SD, 95% CI, p value, and effect size for active shoulder ROM (degrees)

	Breast Cancer Survivor (n = 23)			Control (n = 23)				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
Flexion	156.5	10.28	153.1, 160.0	168.2	5.950	164.8, 171.7	<0.001*	1.138
0° External Rotation	75.69	15.68	70.40, 80.99	77.72	9.307	72.43, 83.02	0.588	0.129
90° Exrnal Rotation	87.64	19.25	81.30, 93.98	98.36	10.28	92.02, 104.7	0.020*	0.557
90° Internal Rotation	60.71	11.51	55.96, 65.46	66.40	11.61	61.65, 71.15	0.095	0.49
Extension	25.78	6.65	23.09, 28.48	31.53	6.177	28.89, 34.17	0.004*	0.864

* Significant differences

Table 12. Mean, SD, 95% CI, p value, and effect size for passive shoulder ROM

	Breast Cancer Survivor (n = 23)			Control (n = 23)				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
Flexion	160.5	10.79	157.0, 164.0	171.9	5.270	168.4, 175.3	<0.001*	1.057
0° External Rotation	78.85	14.68	74.06, 83.63	80.53	7.473	75.74, 85.31	0.620	0.114
90° External Rotation	91.64	16.92	85.91, 97.37	102.2	10.14	96.44, 107.9	0.012*	0.624
90° Internal Rotation	65.09	10.21	60.80, 69.39	70.10	10.69	65.80, 74.39	0.104	0.469
Extension	32.38	16.48	24.24, 40.52	40.49	21.88	32.35, 48.63	0.162	0.370

* Significant differences

Table 13. Mean, SD, 95% CI, p value, and effect size for cervical spine active ROM

	Breast Cancer Survivor (n = 24)			Control (n = 24)				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
Flexion	47.5	7.88	44.0, 50.9	46.7	8.95	43.2, 50.2	0.75	0.09
Extension	60.6	7.25	56.8, 64.5	64.8	11.0	61.0, 68.6	0.13	0.38
Left Sidebending	33.8	8.82	32.1, 38.3	36.3	8.06	33.2, 39.5	0.61	0.28
Right Sidebending	35.2	7.1	30.3, 37.4	35.3	8.58	31.7, 38.9	0.56	0.01
Left Rotation	66.5	10.8	62.5, 70.1	69.6	8.61	65.6, 73.6	0.29	0.29
Right Rotation	67.6	9.94	63.9, 71.3	71.3	7.73	63.9, 71.3	0.16	0.37

* Significant relationship

Table 14. Mean, SD, 95% CI, p value, and effect size for shoulder girdle strength (normalized to body weight)

	Breast Cancer Survivor (n = 23)			Control (n = 23)				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
Abduction and Upward Rotation	0.12	0.04	0.10, 0.13	0.15	0.04	0.13, 0.17	0.006*	0.82
Depression and Adduction	0.11	0.05	0.09, 0.13	0.16	0.03	0.14, 0.18	<0.001*	1.10
Flexion	0.13	0.04	0.12, 0.15	0.17	0.04	0.15, 0.18	0.004*	0.82
External Rotation	0.09	0.02	0.08, 0.10	0.12	0.03	0.11, 0.13	0.001*	0.88
Internal Rotation	0.14	0.04	0.13, 0.16	0.19	0.05	0.17, 0.21	0.003*	0.87
Scaption	0.13	0.04	0.12, 0.15	0.18	0.05	0.16, 0.19	<0.001*	1.02
Adduction	0.13	0.04	0.12, 0.15	0.18	0.04	0.17, 0.20	< 0.001*	1.29

* Significant relationship

Table 15. Summary of scapula kinematic ANOVA analyses. F-values, p-values, partial eta-squared (eta^2), and observed power for the flexion task analyses.

Variable	Comparison	F-Value	P-Value	Eta^2	Power
anterior/posterior tipping	Group	2.145	0.150	0.049	0.299
	Angle	44.75	<0.001	0.516	1.000
	Group x Angle	0.380	0.990	0.001	0.057
Upward/downward rotation	Group	2.183	0.147	0.049	0.303
	Angle	142.8	<0.001	0.773	1.000
	Group x Angle	0.132	0.941	0.003	0.074
Internal/external rotation	Group	1.129	0.294	0.026	0.180
	Angle	88.87	<0.001	0.679	1.000
	Group x Angle	1.164	0.326	0.027	0.307
Elevation/depression	Group	1.357	0.354	0.046	0.203
	Angle	202.2	<0.001	0.878	1.000
	Group x Angle	0.842	0.475	0.029	0.226
Protraction/Retraction	Group	0.340	0.564	0.012	0.087
	Angle	55.19	<0.001	0.663	1.000
	Group x Angle	0.918	0.436	0.032	0.244

Table 16. Mean, SD, 95% CI, and effect size for scapula kinematics (degrees) during the flexion task

		Breast Cancer Survivor (n = 22)			Control (n = 22)			
		Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**ES**
anterior/posterior tipping	**Start**	-11.1	7.00	-14.3, -7.91	-14.6	7.79	-17.8, -11.5	0.45
	30 º	-11.3	8.02	-14.8, -7.79	-14.9	8.19	-18.4, -11.4	0.45
	60 º	-15.4	9.73	-19.4, -11.3	-19.4	9.10	-23.5, -15.4	0.42
	90º	-19.0	10.9	-23.8, -14.3	-22.8	11.3	-27.6, -18.0	0.33
upward/downward rotation	**Start**	7.14	7.25	4.17, 10.1	3.62	6.56	0.64, 6.59	0.49
	30 º	11.3	5.38	8.46, 14.2	8.98	7.74	6.12, 11.9	0.30
	60 º	21.3	6.72	18.0, 24.7	18.6	8.70	15.3, 22.0	0.31
	90º	32.1	12.4	26.8, 37.4	28.3	12.2	23.0, 33.7	0.30
internal/external rotation	**Start**	34.3	14	29.4, 39.2	37.8	8.02	32.9, 42.7	0.25
	30 º	38.8	16.4	33.3, 44.4	42	8.58	36.4, 47.6	0.2
	60 º	43.2	18.7	36.7, 49.6	48.2	9.99	41.7, 54.6	0.27
	90º	45.6	21.0	38.5, 52.8	51.6	10.76	44.4. 58.7	0.29
elevation/depression#	**Start**	14	5.22	11.0, 17.0	16	6.16	13.0, 19.0	0.32
	30 º	16.2	5.36	12.9, 19.5	18.1	6.89	14.9, 21.4	0.26
	60 º	21.4	6.24	17.9, 25.0	24.5	7.10	20.9, 28.0	0.43
	90º	27.9	6.23	23.8, 31.8	31.5	8.78	27.5, 35.5	0.41
protraction/retraction#	**Start**	-22.1	13.1	-27.5, -16.7	-18.8	6.08	-24.2, -13.4	0.25
	30 º	-22.0	13.5	-27.6, -16.4	-19.4	6.44	-25.1, -13.8	0.19
	60 º	-23.4	14.6	-29.6, -17.3	-21.2	7.41	-27.3, -15.0	0.16
	90º	-28.2	16.8	-34.9, -21.4	-26.9	6.44	-33.6, -20.2	0.08

(n = 15) for each group

Table 17. Summary of scapula kinematic ANOVA analyses. F-values, p-values, partial eta-squared (eta2), and observed power for the scaption task analyses.

Variable	Comparison	F-Value	P-Value	Eta^2	Power
anterior/posterior tipping	Group	3.568	0.066	0.078	0.455
	Angle	19.69	<0.001	0.319	1.000
	Group x Angle	0.251	0.861	0.006	0.097
Upward/downward rotation	Group	1.454	0.235	0.033	0.218
	Angle	133.4	<0.001	0.761	1.000
	Group x Angle	0.130	0.942	0.003	0.073
Internal/external rotation	Group	0.285	0.597	0.007	0.082
	Angle	49.45	<0.001	0.541	1.000
	Group x Angle	0.026	0.994	0.001	0.054
Elevation/depression	Group	0.309	0.583	0.013	0.083
	Angle	215.6	<0.001	0.900	1.000
	Group x Angle	0.040	0.989	0.002	0.057
Protraction/Retraction	Group	5.153	0.032*	0.177	0.587
	Angle	96.87	<0.001	0.801	1.000
	Group x Angle	0.171	0.915	0.007	0.080

* Significant relationship

Table 18. Mean, SD, 95% CI, and effect size for scapula kinematics during the scaption task.

		Breast Cancer Survivor (n = 22)			Control (n = 22)			
		Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**ES**
anterior/posterior tipping	Start	-10.3	6.74	-13.5, -7.08	-14.8	8.10	-18.0, -11.6	0.55
	30 º	-10.1	7.60	-13.4, -6.74	-14.9	7.82	-18.3, -11.6	0.62
	60 º	-12.6	9.87	-16.5, -8.71	-17.8	8.33	-21.7, -13.9	0.52
	90º	-16.6	11.3	-21.1, -12.1	-20.3	9.59	-24.8, -15.8	0.33
upward/downward rotation	Start	6.37	8.31	3.00, 9.74	2.52	7.32	-0.85, 5.89	0.46
	30 º	10.8	6.96	7.60, 13.9	7.64	7.74	4.47, 10.8	0.40
	60 º	19.5	9.07	15.6, 23.4	16.9	9.24	12.9, 20.8	0.28
	90º	29.8	13.8	24.0, 35.6	27.5	13.2	21.7, 33.3	0.17
internal/external rotation	Start	33.7	10.6	29.3, 37.6	35.7	7.18	31.8, 39.6	0.19
	30 º	37.4	12.0	32.8, 41.5	38.7	7.64	34.3, 43.0	0.11
	60 º	41.1	14.1	36.0, 46.1	42.9	8.60	37.9, 47.9	0.13
	90º	44.2	18.3	37.7, 50.7	46.0	10.9	39.5, 52.5	0.1
elevation/depression#	Start	14.1	5.54	10.7, 17.5	15.7	6.32	12.3, 19.1	0.26
	30 º	17.1	5.99	13.3, 20.8	18.4	7.15	14.6, 2.1	0.18
	60 º	22.5	6.68	18.5, 26.6	23.8	7.60	19.7, 27.9	0.17
	90º	28.5	6.00	24.4, 32.6	29.9	8.08	25.8, 34.0	0.17
protraction/retraction#	Start	-25.6	5.67	-28,9, -22.7	-20.1	5.96	-23.5, -16.8	0.92
	30 º	-26.2	5.67	-29.5, -22.7	-21.1	6.14	-24.5, -17.7	0.81
	60 º	-27.9	6.18	-31.3, -24.5	-23	5.64	-26.4, -19.7	0.79
	90º	-32.6	6.38	-36.0, -29.3	-27.6	5.38	-31.0, -24.2	0.79

(n = 13) for each group

Table 19. Summary of scapula kinematic ANOVA analyses. F-values, p-values, partial eta-squared (eta2), and observed power for the reaching task analyses

Variable	Comparison	F-Value	P-Value	Eta^2	Power
anterior/posterior tipping	Group	3.067	0.087	0.068	0.402
	Angle	33.23	<0.001	0.442	1.000
	Group x Angle	0.507	0.678	0.012	0.151
Upward/downward rotation	Group	0.885	0.352	0.021	0.151
	Angle	113.5	<0.001	0.730	1.000
	Group x Angle	0.090	0.966	0.002	0.066
Internal/external rotation	Group	0.483	0.491	0.011	0.104
	Angle	125.1	<0.001	0.749	1.000
	Group x Angle	2.953	0.035*	0.066	0.669
Elevation/depression	Group	0.358	0.555	0.015	0.089
	Angle	93.01	<0.001	0.795	1.000
	Group x Angle	0.264	0.851	0.011	0.098
Protraction/Retraction	Group	0.212	0.649	0.009	0.073
	Angle	8.419	<0.001	0.260	0.991
	Group x Angle	2.400	0.075	0.091	0.577

* Significant relationship

Table 20. Mean, SD, 95% CI, and effect size for scapula kinematics (degrees) during the reaching task.

		Breast Cancer Survivor (n = 22)			Control (n = 22)			
		Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**ES**
anterior/posterior tipping	**Start**	-12.6	6.69	-15.7, -9.47	-16.1	7.73	-19.2, -12.9	0.45
	30 º	-12.8	7.78	-16.2, -9.43	-17	7.95	-20.4, -13.6	0.53
	60 º	-15.7	9.55	-19.9, -11.6	-20.7	9.72	-24.8, -16.6	0.51
	Max	-19.7	12.5	-25.0, -14.5	-25.3	12.00	-30.6, -20.1	0.45
upward/downward rotation	**Start**	6.04	7.47	3.09, 8.98	4.23	6.17	1.28, 7.18	0.24
	30 º	12.1	6.80	9.21, 15.0	9.76	6.61	6.87, 12.7	0.34
	60 º	21.2	8.29	17.6, 24.9	19.5	8.66	15.9, 23.2	0.19
	Max	31.6	15.7	25.3, 38.0	28.6	13.8	22.2, 34.9	0.19
internal/external rotation	**Start**	34.4	10.7	30.7, 38.3	35.1	6.54	31.3, 39.0	0.07
	30 º	37.8	12.0	33.4, 42.1	38.5	7.87	34.2, 42.9	0.06
	60 º	43.5	14.3	38.3, 48.7	45.5	9.40	40.3, 50.7	0.14
	Max	50.2	19.5	43.4, 56.9	56.1	10.5	49.4, 62.9	0.31
elevation/depression#	**Start**	15.7	5.58	12.6, 19.2	16.5	6.5	13.0, 20.0	0.12
	30 º	18.9	5.46	15.4, 22.3	20.1	6.57	16.6, 23.5	0.19
	60 º	23.9	5.59	20.3, 27.4	25.8	6.74	22.2, 29.3	0.28
	Max	26.9	8.03	22.3, 31.5	28.9	8.03	24.3, 33.5	0.24
protraction/retraction#	**Start**	-20.6	16.6	-27.3, -13.8	-21.7	3.30	-28.6, -14.9	0.07
	30 º	-21.4	16.9	-28.4, -14.4	-22.7	3.04	-29.7, -15.8	0.08
	60 º	-22.1	18.2	-29.6, -14.6	-24.4	3.37	-31.9, -16.9	0.13
	Max	-22.2	20.3	-30.6, -13.9	-26.7	3.02	-35.0, -18.4	0.22

(n = 13) for each group

Table 21. Mean, SD, 95% CI, p value, and effect size for maximum humeral elevation angle during the tasks (flexion, scaption, and reaching)

	Breast Cancer Survivor			**Control**				
	Mean	**SD**	**95%CI**	**Mean**	**SD**	**95%CI**	**P**	**ES**
Flexion	122.5	13.92	117.2, 127.9	130.1	10.84	124.7, 135.4	0.051	0.546
Scaption	122.3	13.14	116.2, 128.4	127.1	15.19	121.0, 133.2	0.266	0.316
Reaching	95.54	13.43	91.03, 102.0	104.4	12.14	98.86, 109.9	0.049*	0.660

* Significant differences

Table 22. Correlations among the DASH and active shoulder ROM

	Breast Cancer Survivor	
	r	**p**
Flexion	-0.615	0.002*
0° External Rotation	-0.133	0.544
90° External Rotation	-0.653	0.001*
90° Internal Rotation	-0.271	0.211
Extension	-0.294	0.184

*Significant relationship

Table 23. Correlations among the DASH and passive shoulder ROM

	Breast Cancer Survivor	
	r	**p**
Flexion	-0.544	0.007*
0°External Rotation	-0.013	0.954
90°External Rotation	-0.637	0.001*
90° Internal Rotation	-0.165	0.451
Extension	0.091	0.686

*Significant relationship

Table 24. Correlations among the DASH and shoulder girdle strength

	Breast Cancer Survivor	
	r	**p**
Abduction and Upward Rotation	-0.477	0.021*
Depression and Adduction	-0.635	0.001*
Flexion	-0.507	0.014*
External Rotation	-0.350	0.102
Internal Rotation	-0.523	0.010*
Scaption	-0.558	0.006*
Adduction	-0.603	0.002*

*Significant relationship

Table 25. Correlations among the DASH and active cervical spine

	Breast Cancer Survivor	
	r	**p**
Flexion	-0.073	0.741
Extension	-0.363	0.089
Left Sidebending	-0.269	0.215
Right Sidebending	-0.135	0.540
Left Rotation	-0.476	0.022*
Right Rotation	-0.213	0.330

*Significant relationship

Table 26. Correlations among the PSS and active shoulder ROM

	Breast Cancer Survivor	
	r	**p**
Flexion	0.615	0.004*
0° External Rotation	0.086	0.704
90° External Rotation	0.416	0.054
0° Internal Rotation	-0.004	0.985
Extension	0.292	0.199

*Significant relationship

Table 27. Correlations among the PSS and passive shoulder ROM

	Breast Cancer Survivor	
	r	**p**
Flexion	0.600	0.003*
0° External Rotation	0.003	0.989
90° External Rotation	0.424	0.049*
90 °Internal Rotation	-0.101	0.656
Extension	-0.077	0.738

*Significant relationship

Table 28. Correlations among the PSS and shoulder girdle strength

	Breast Cancer Survivor	
	r	**p**
Abduction and Upward Rotation	0.393	0.070
Depression and Adduction	0.377	0.084
Flexion	0.458	0.032*
External Rotation	0.300	0.176
Internal Rotation	0.441	0.043*
Scaption	0.436	0.043*
Adduction	0.449	0.036*

*Significant relationship

Table 29. Correlations among the PSS and active cervical spine ROM

	Breast Cancer Survivor	
	r	**p**
Flexion	0.324	0.142
Extension	0.408	0.059
Left Sidebending	0.449	0.036*
Right Sidebending	0.303	0.171
Left Rotation	0.517	0.014*
Right Rotation	0.542	0.009*

*Significant Relationship

Table 30. Item analysis of the DASH

	DASH	
		Corresponding Items
ROM	Fexion	1,2,4,5,6,7,8,9,12,13,15,16,17,18,19,20,21
	External Rotation at 0°	6,12
	External Rotation at 90°	1,3,7,8,9,12,13,14,16,17,18,19,20
	Internal Rotation	1,2,4,7,8,912,13,14,16,17,18,19,20
	Extension	-
Strength	Scapular Abducation & Upward Rotation	5,6,7
	Scapular Depression & Adduction	1,3,5,6,10,11,18,19
	Humeral Flexion	1,3,4,5,6,7,8,9,11,12,13,15,18,19,20,21
	Humeral External Rotation	1,3,6,7,8,10,12,13,14,15,18,19
	Humeral Internal Rotation	1,3,7,8,9,10,11,12,13,14,15,18,19
	Shoulder Scaption	4,5,6,7,8,9,11,12,13,15
	Shoulder Horizontal Adduction	1,7,8,11,18

Table 31. Item analysis of the PSS

PSS		
		Corresponding Items
ROM	Fexion	3,4,5,6,7,9,12,13,14,15,16,17,18,19
	External Rotation at 0°	-
	External Rotation at 90°	3,6,7,16,17,18,19
	Internal Rotation	1,2,3,4,5,17,18,19
	Extension	1,2,3
Strength	Scapular Abducation & Upward Rotation	9,16,18
	Scapular Depression & Adduction	11,16
	Humeral Flexion	4,5,6,7,9,12,13,14,15,16,17,18,19
	Humeral External Rotation	5,6,7,11,15,16,17,18,19
	Humeral Internal Rotation	4,5,11,17,18
	Shoulder Scaption	5,6,7,9,12,13,14,15,16,18
	Shoulder Horizontal Adduction	4,17,18

Figure 1. Electromagnetic tracking sensor placement

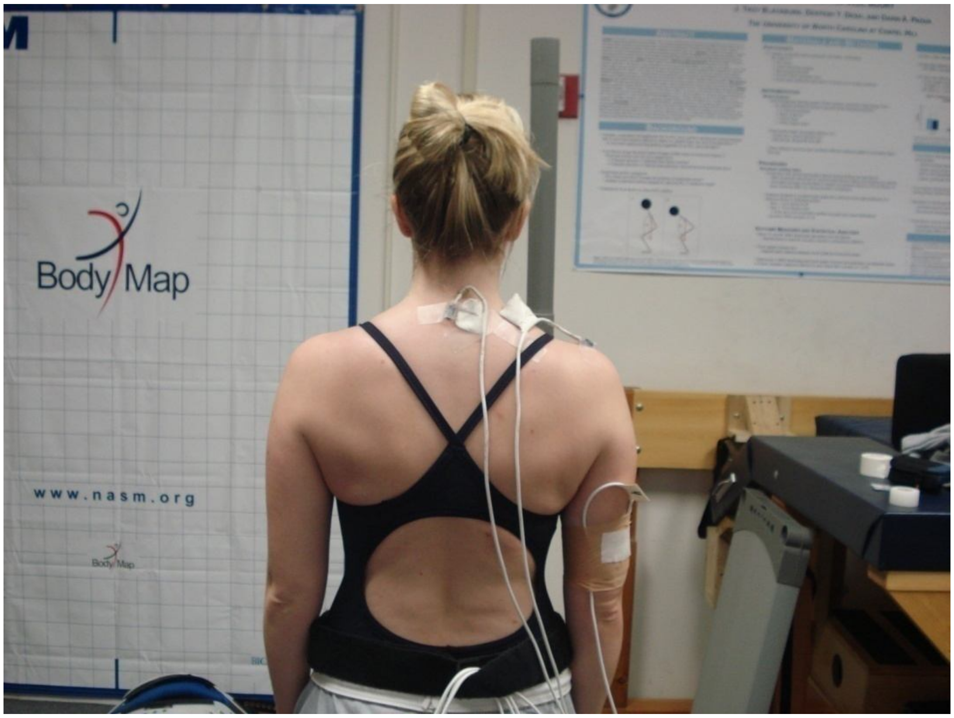


Figure 2 Reaching task demonstration 1

Figure 3. Reaching task demonstration 2

Figure 4   Humeral elevation task in the sagittal plane demonstration 1

Figure 5 Humeral elevation task in the sagittal plane demonstration 2

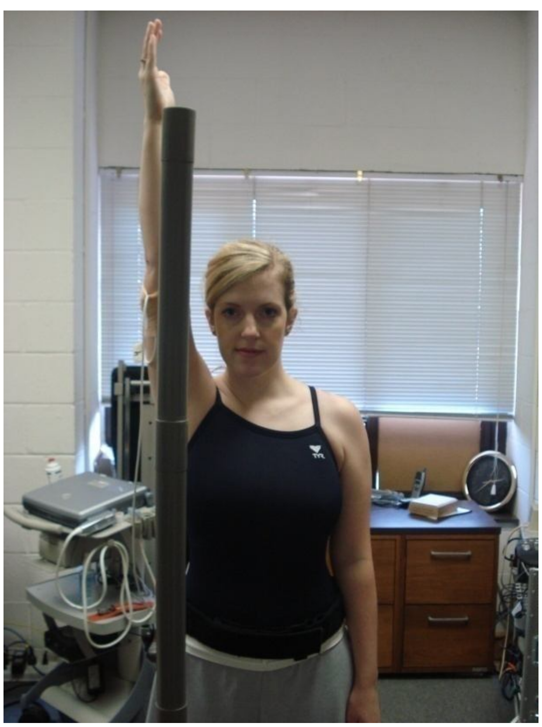


Figure 6. Humeral elevation task in the scapula plane

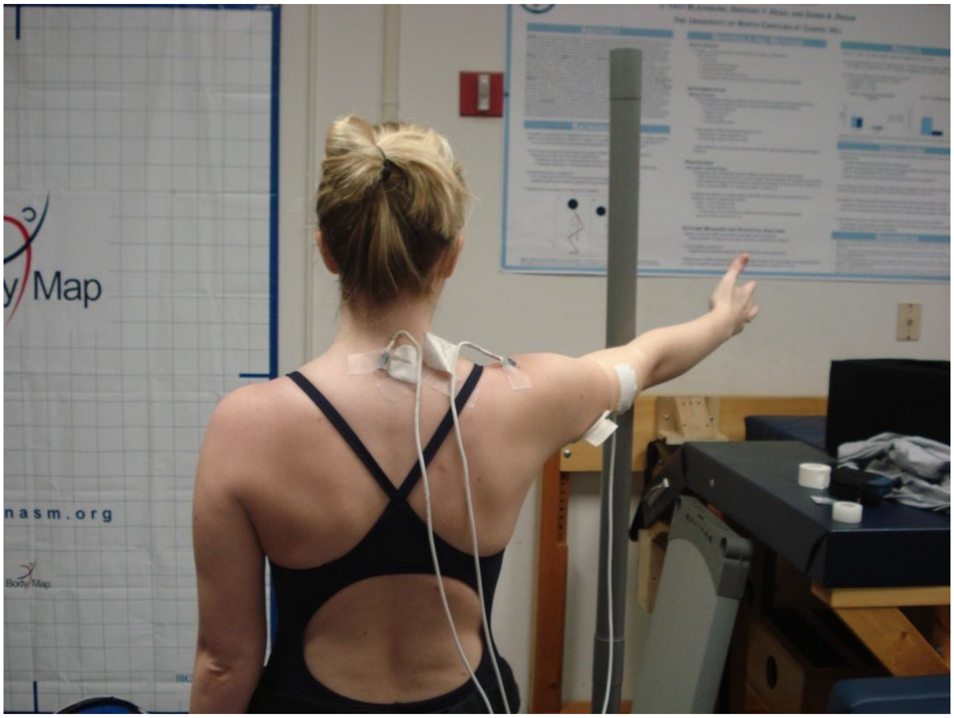


Figure 7. Supine flexion ROM

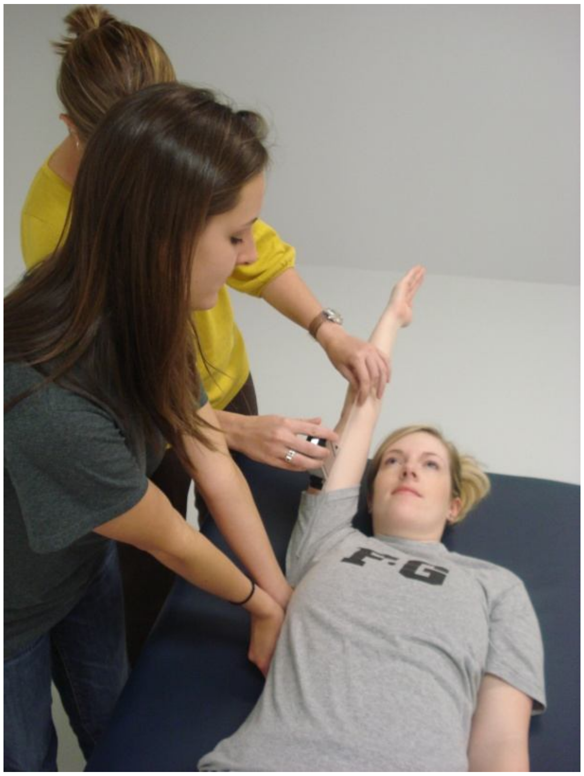


Figure 8. Supine ER at 0° ROM

Figure 9. Supine ER at 90° ROM

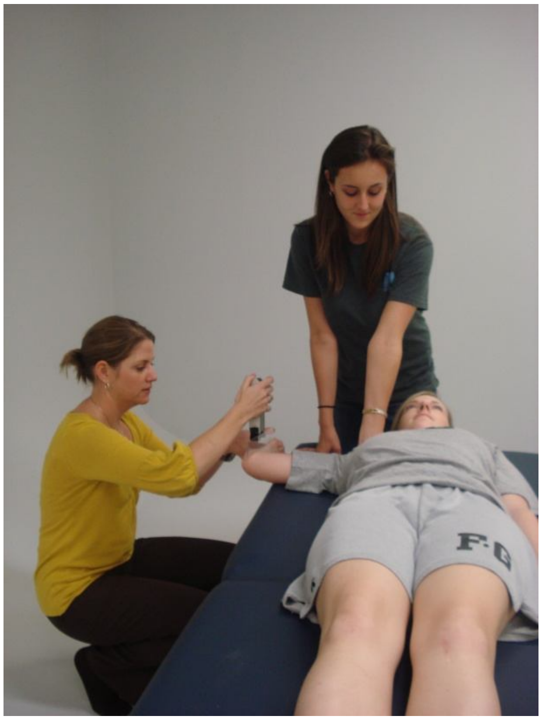


Figure 10. Supine IR at 90° ROM

Figure 11. Prone extension ROM

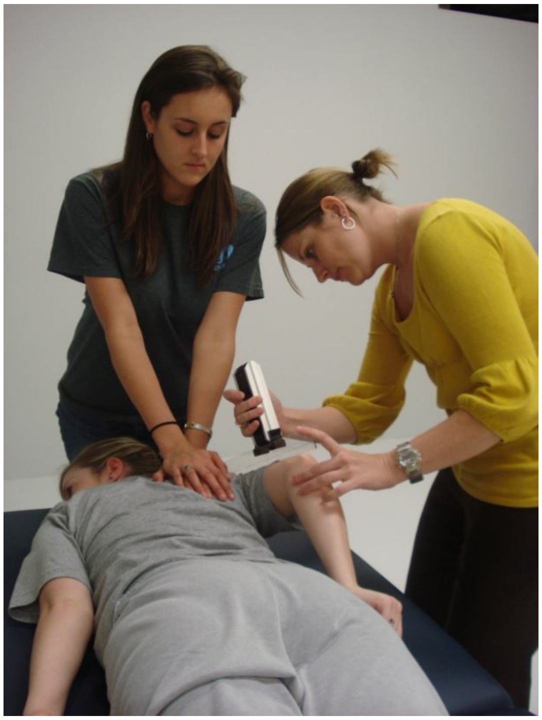


Figure 12. Scapula abduction and upward rotation strength assessment

Figure 13. Scapula depression and adduction strength assessment

Figure 14. Shoulder flexion strength assessment

Figure 15. Shoulder external rotation strength assessment

Figure 16. Shoulder internal rotation strength assessment

Figure 17. Shoulder scaption strength assessment

Figure 18. Shoulder horizontal adduction strength assessment

Figure 19. Cervical flexion ROM

Figure 20. Cervical extension ROM

Figure 21. Cervical left side bending ROM

Figure 22. Cervical right side bending ROM

Figure 23. Cervical left rotation ROM

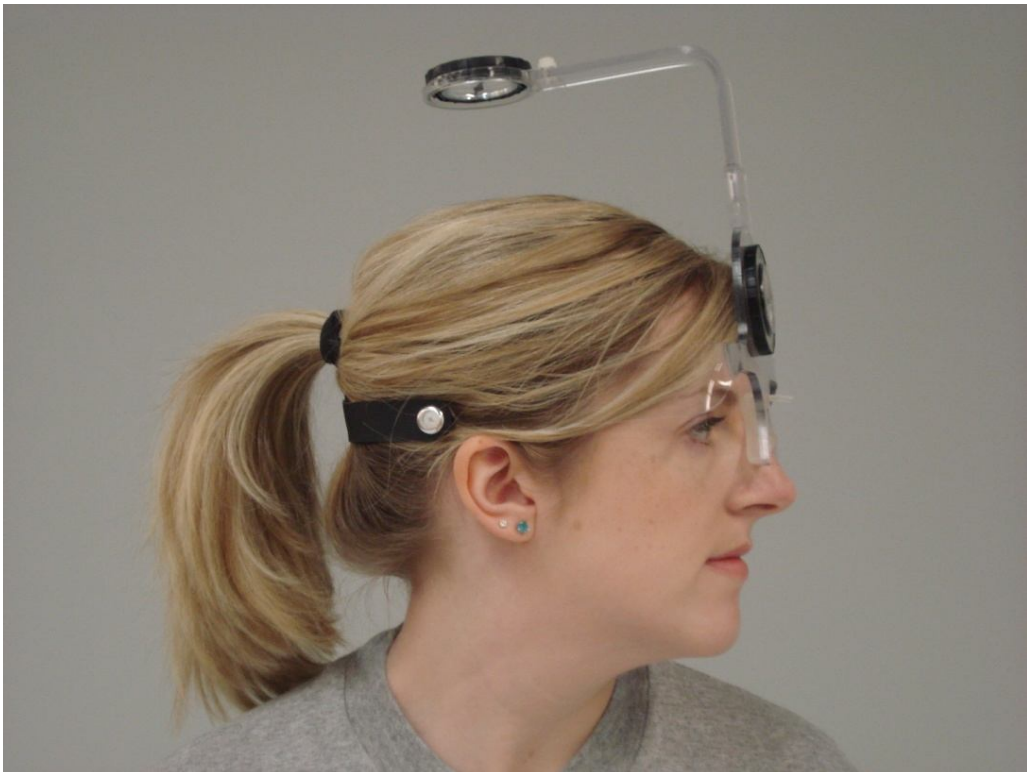


Figure 24. Cervical right rotation ROM

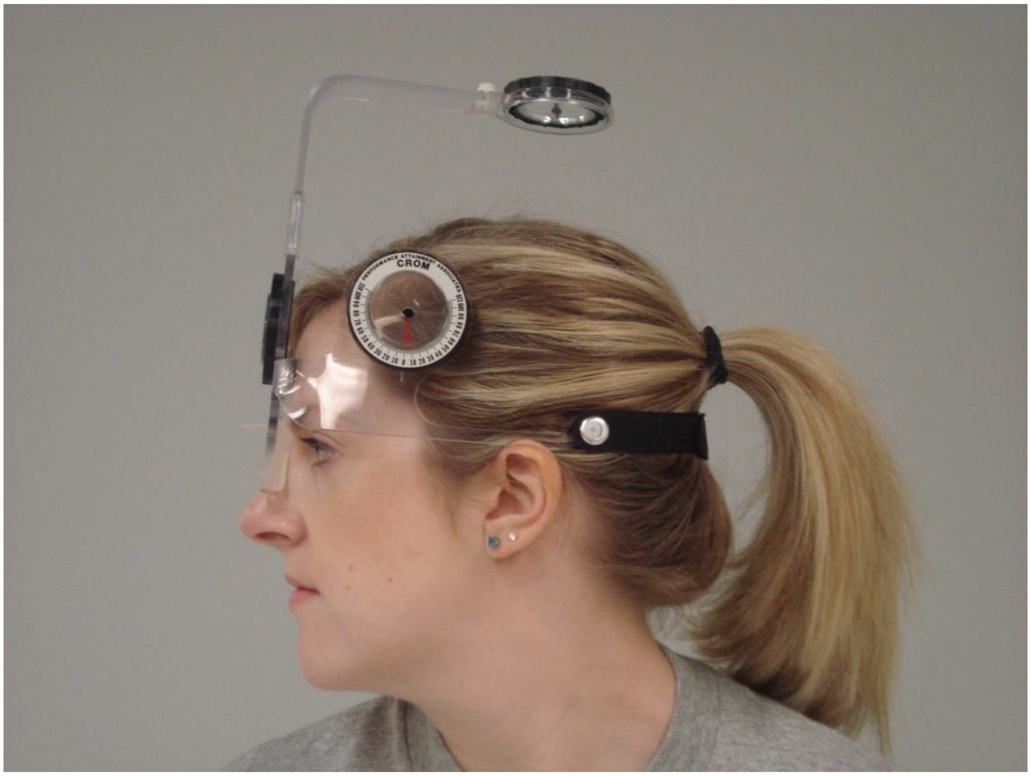


Figure 25. Scapula orientation and axes

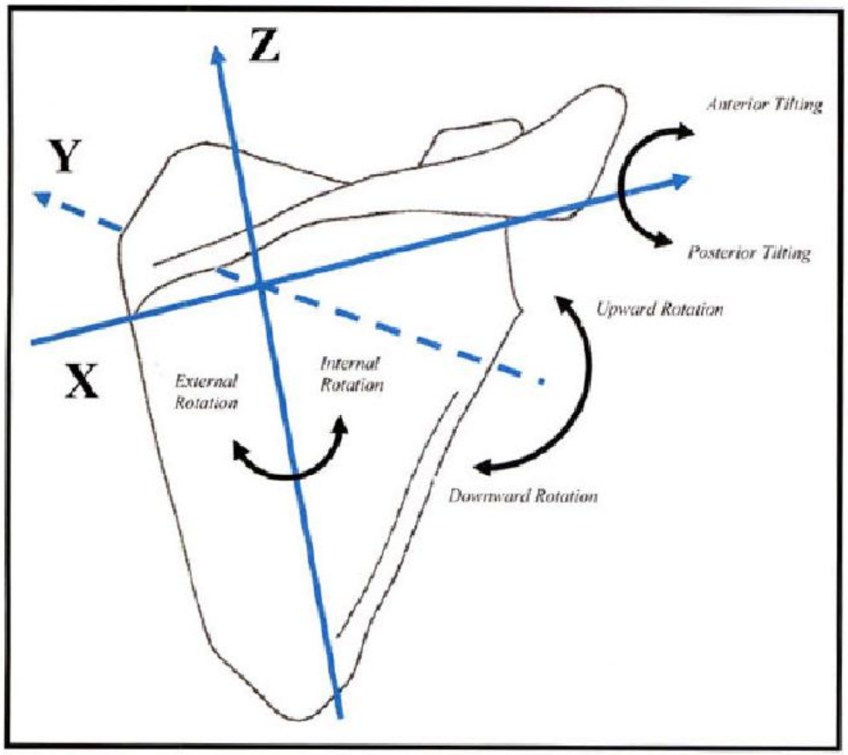


Figure 26. Mean scapula posterior tipping during the flexion task

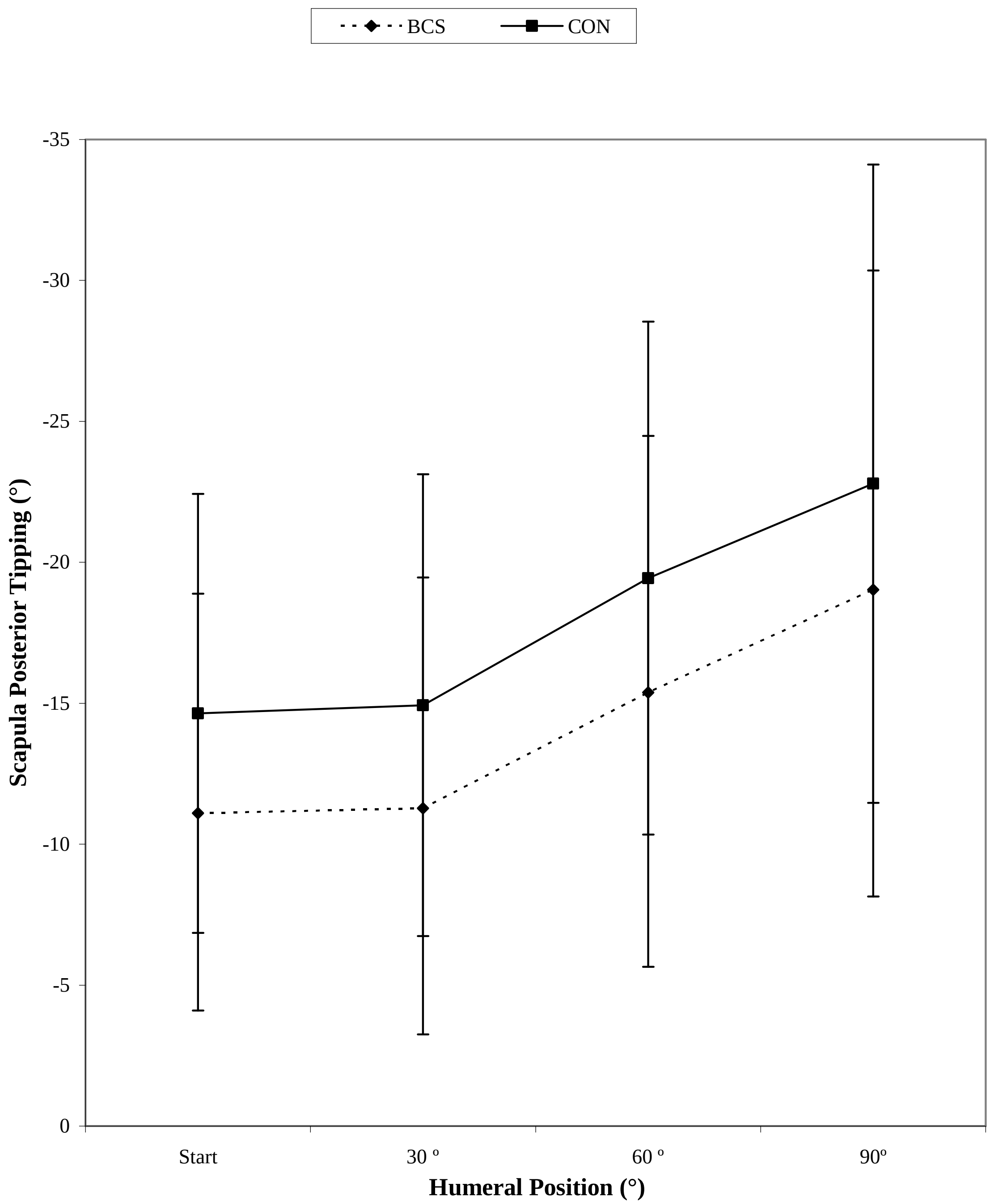


Figure 27. Mean scapula upward rotation during the flexion task

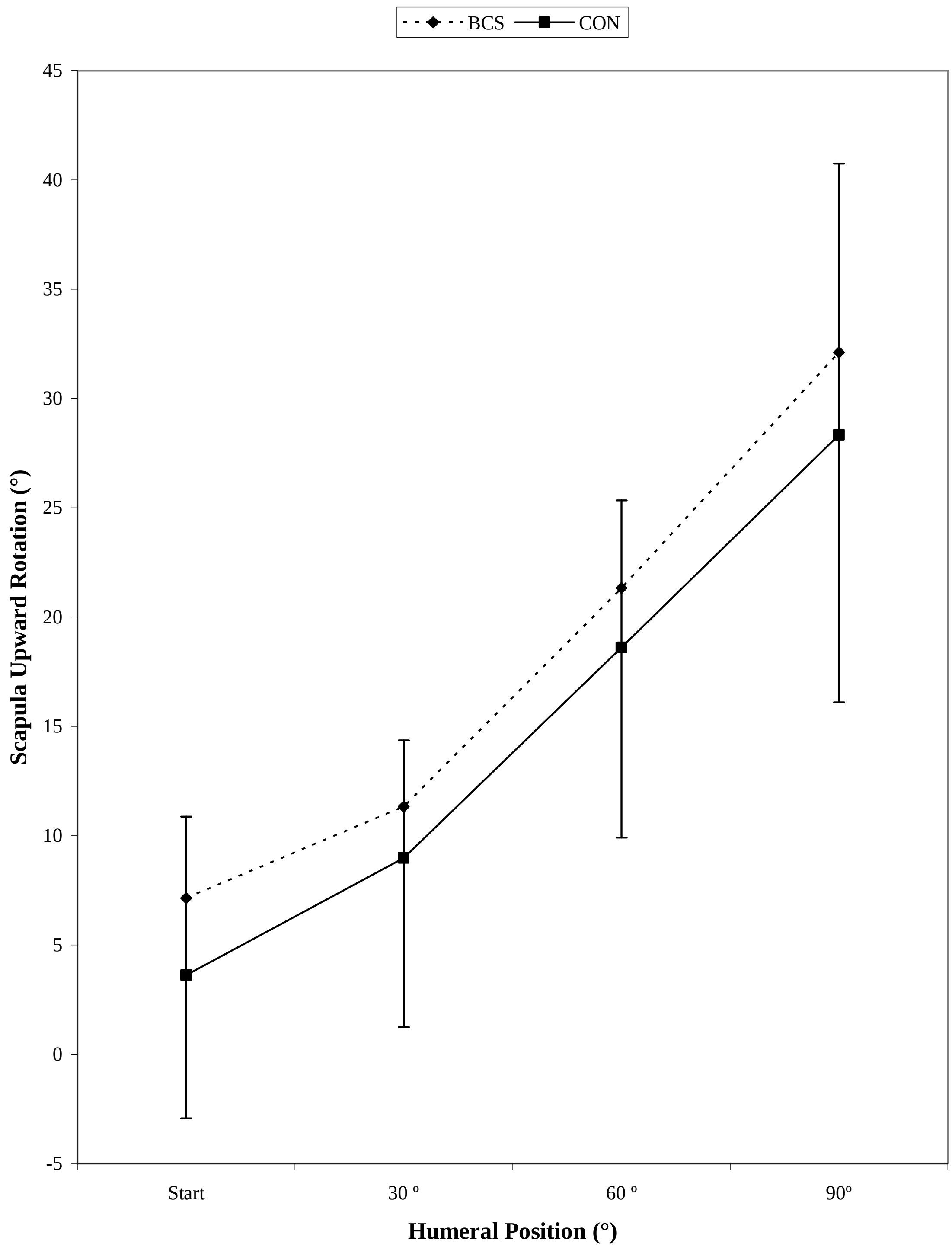


Figure 28. Mean scapula external rotation during the flexion task

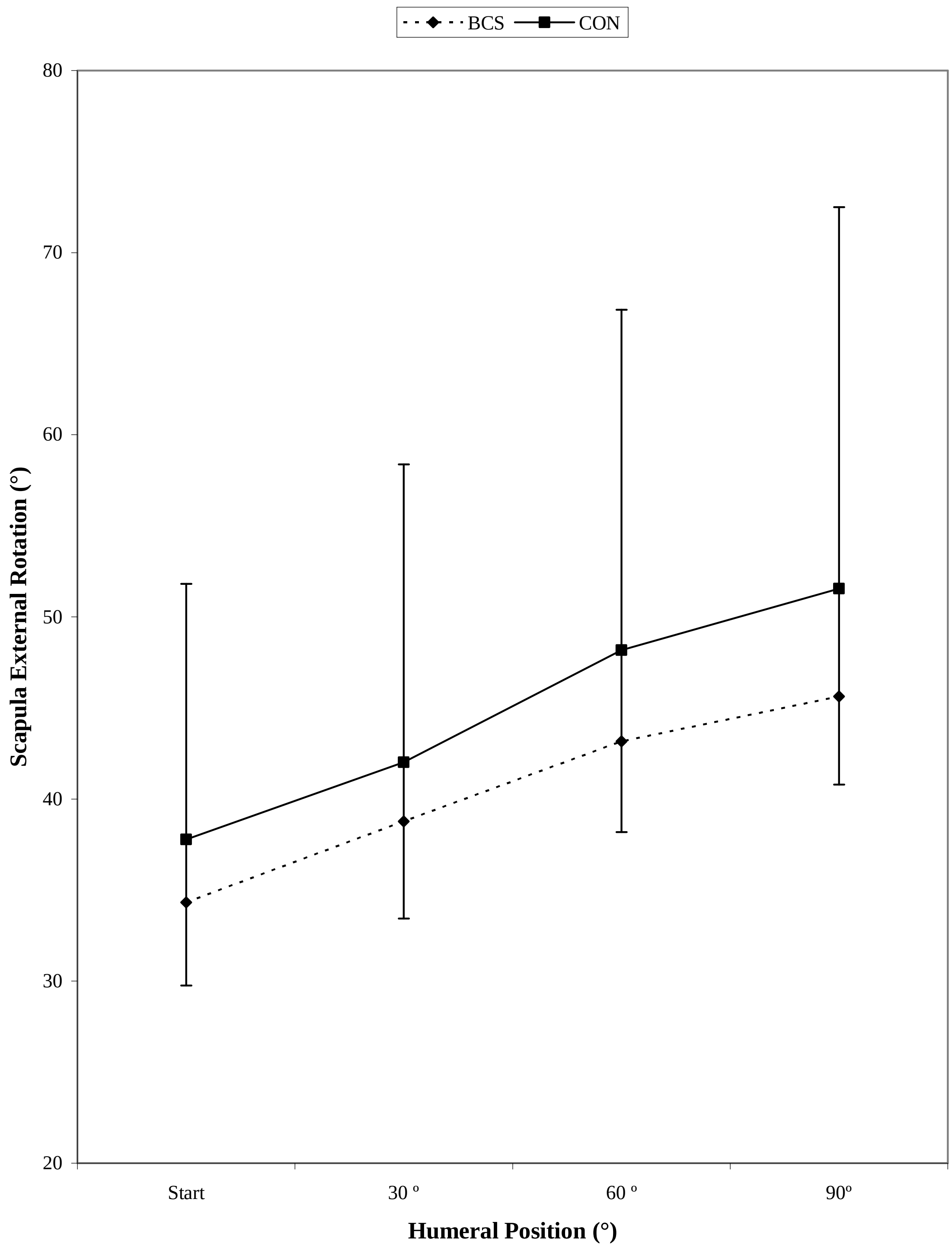


Figure 29. Mean scapula elevation during the flexion task

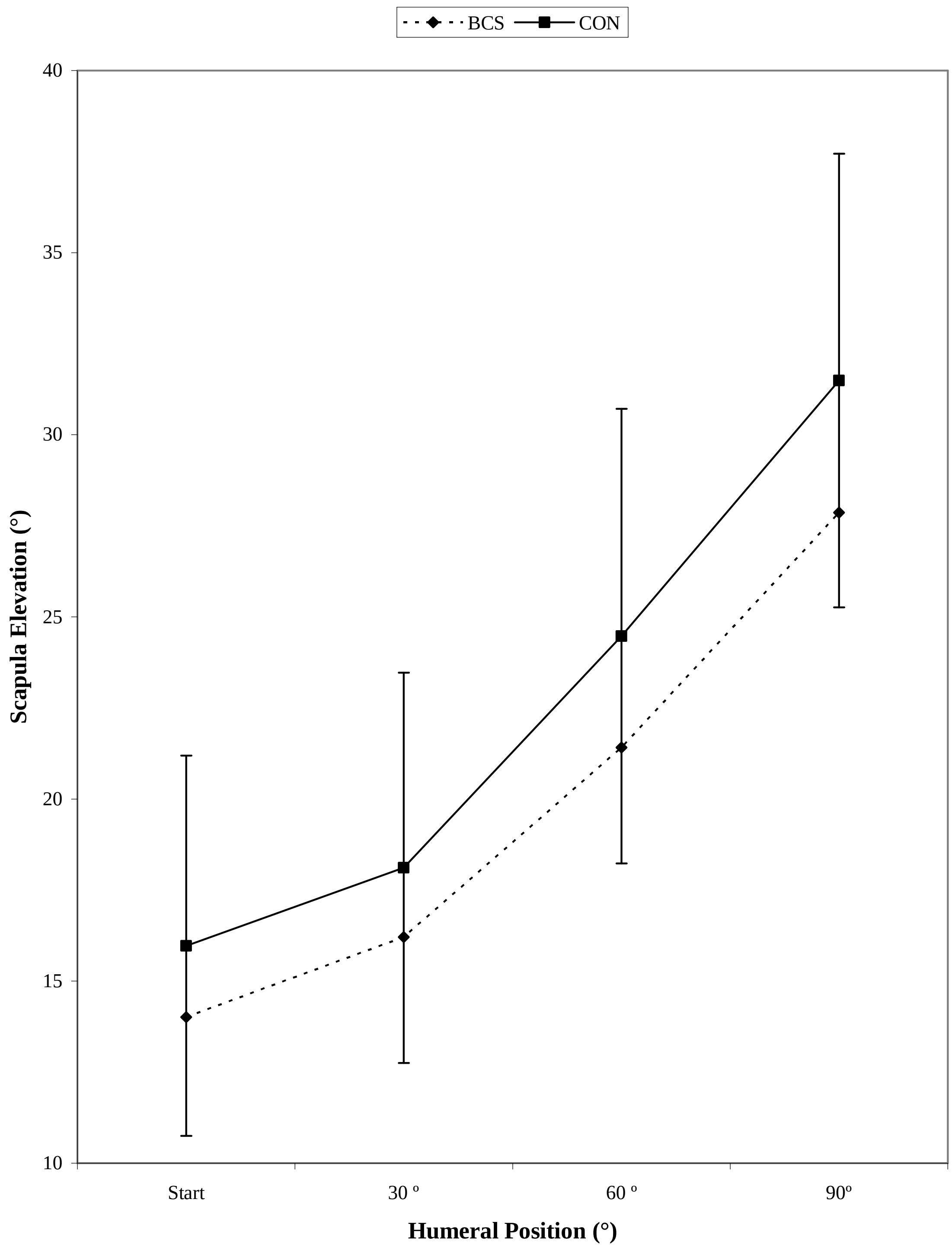


Figure 30. Mean scapula protraction during the flexion task

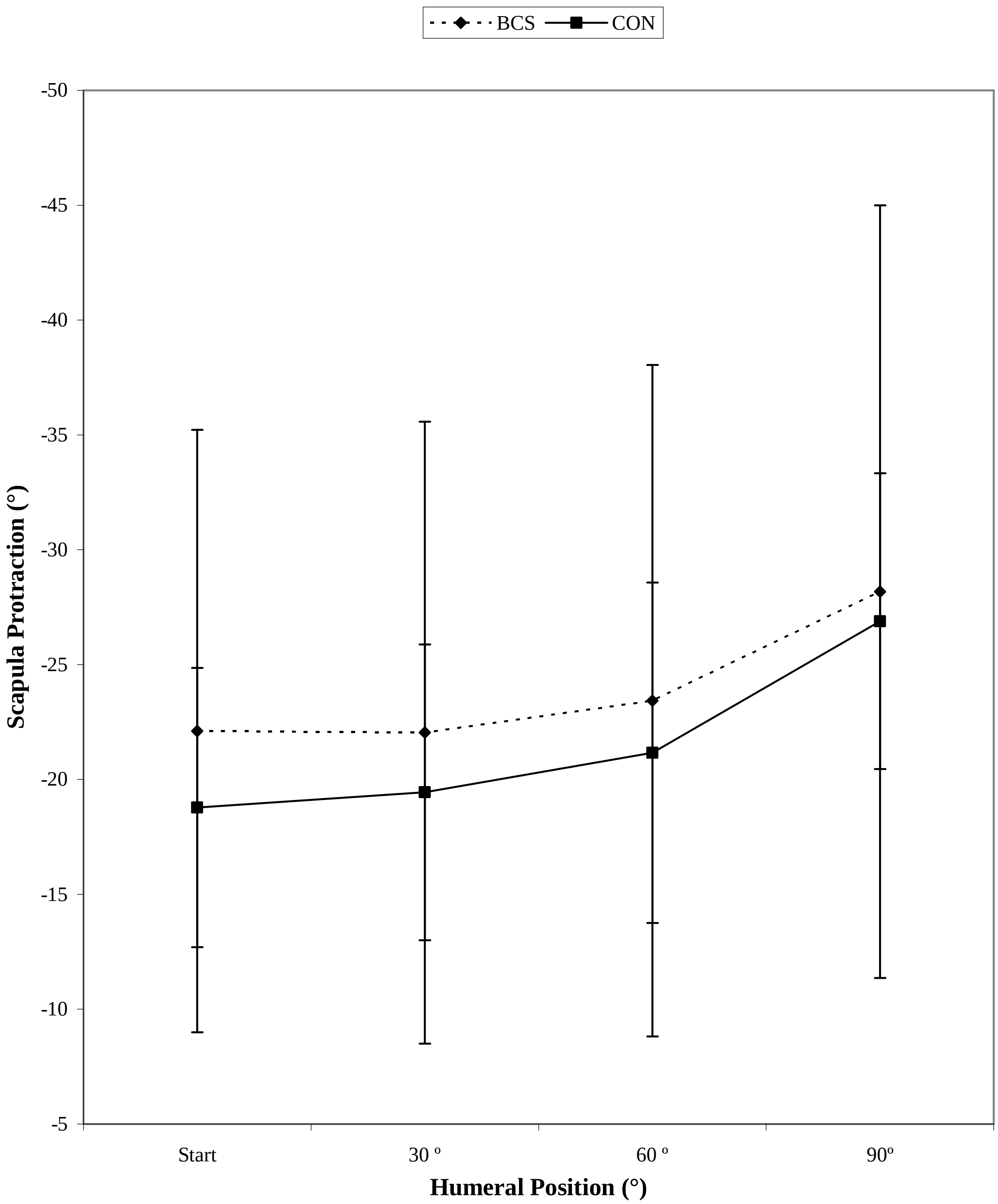


Figure 31. Mean scapula posterior tipping during scaption task

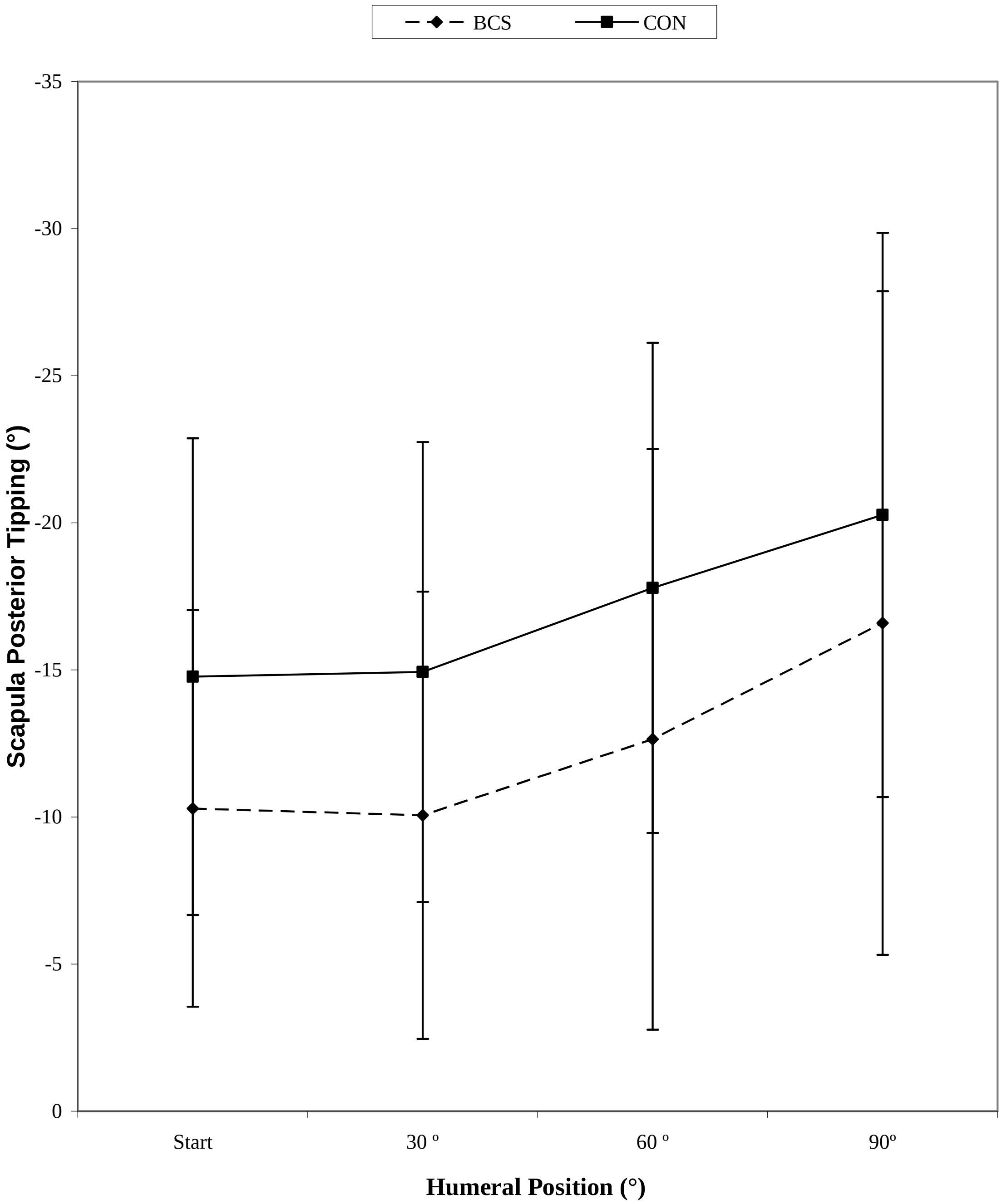


Figure 32. Mean scapula upward rotation during the scaption task

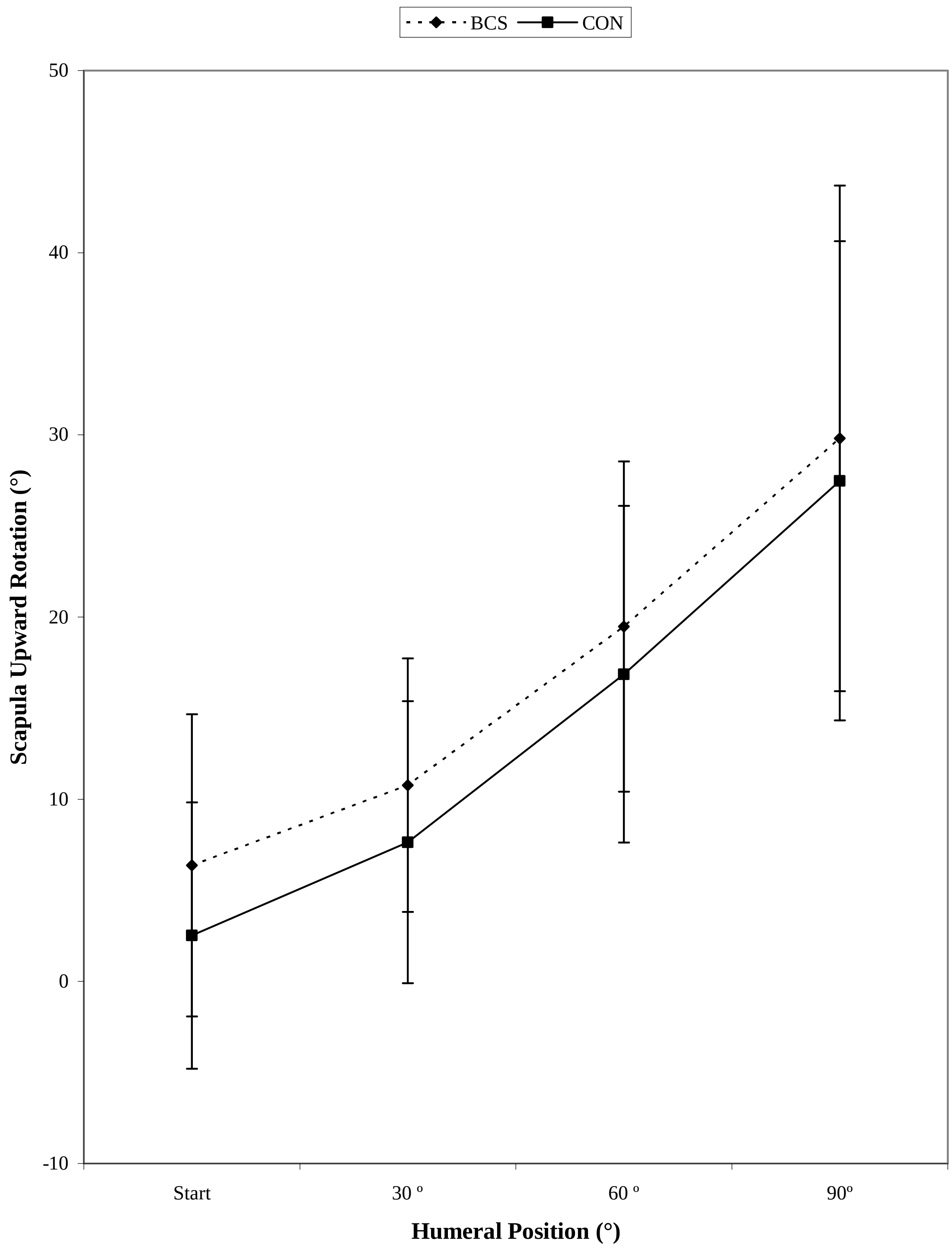


Figure 33. Mean scapula external rotation during the scaption task

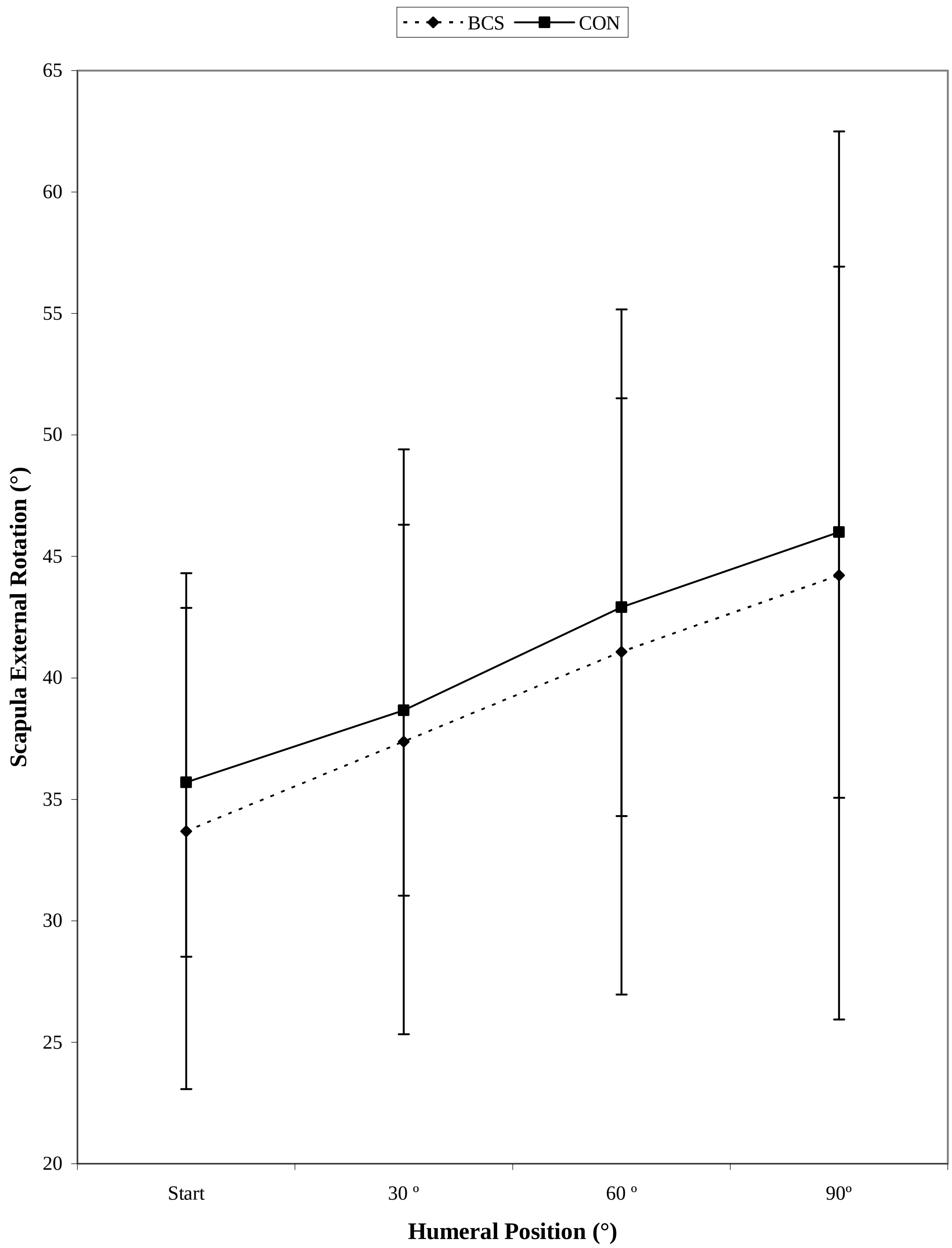


Figure 34. Mean scapula elevation during the scaption task

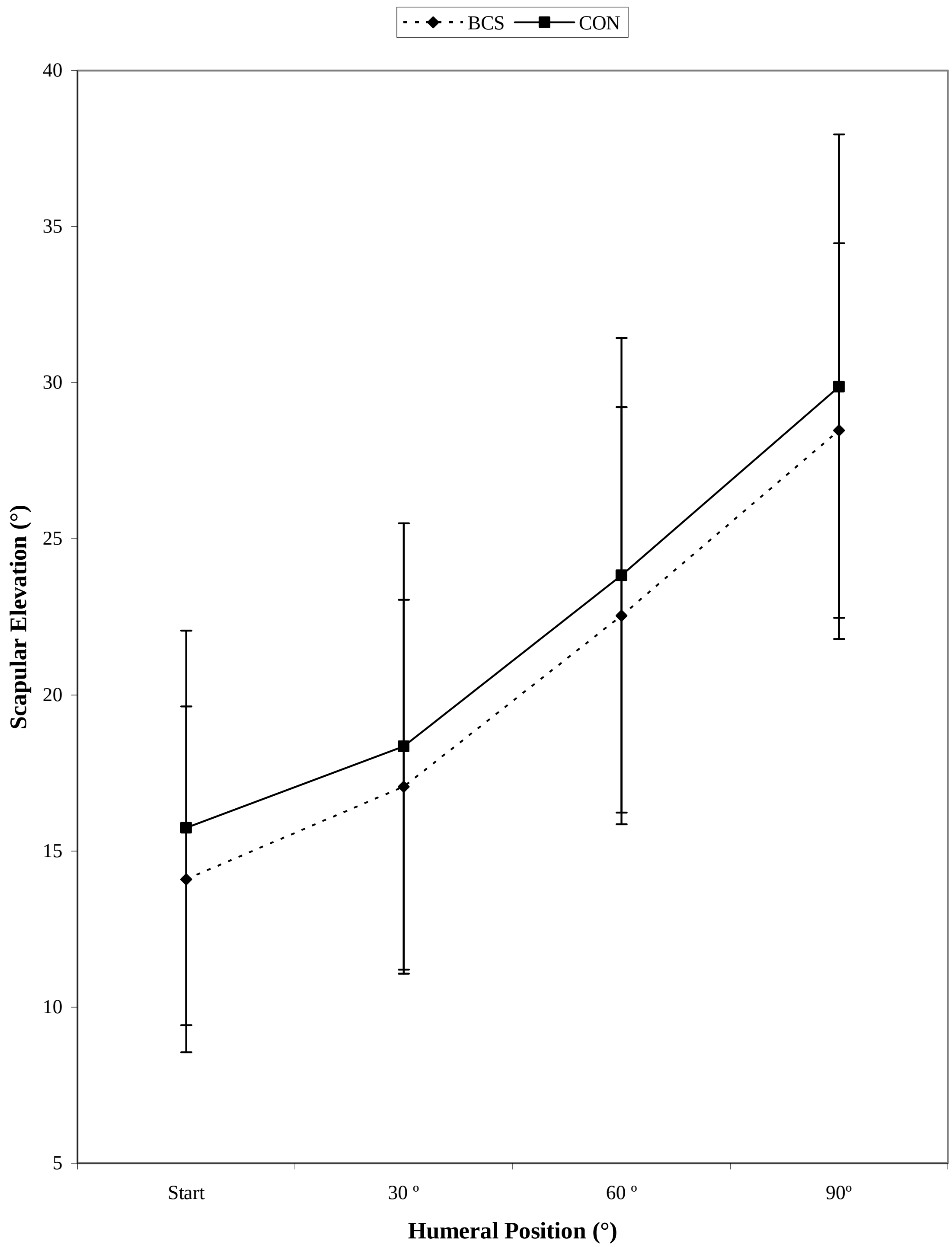


Figure 35. Mean scapula protraction during the scaption task

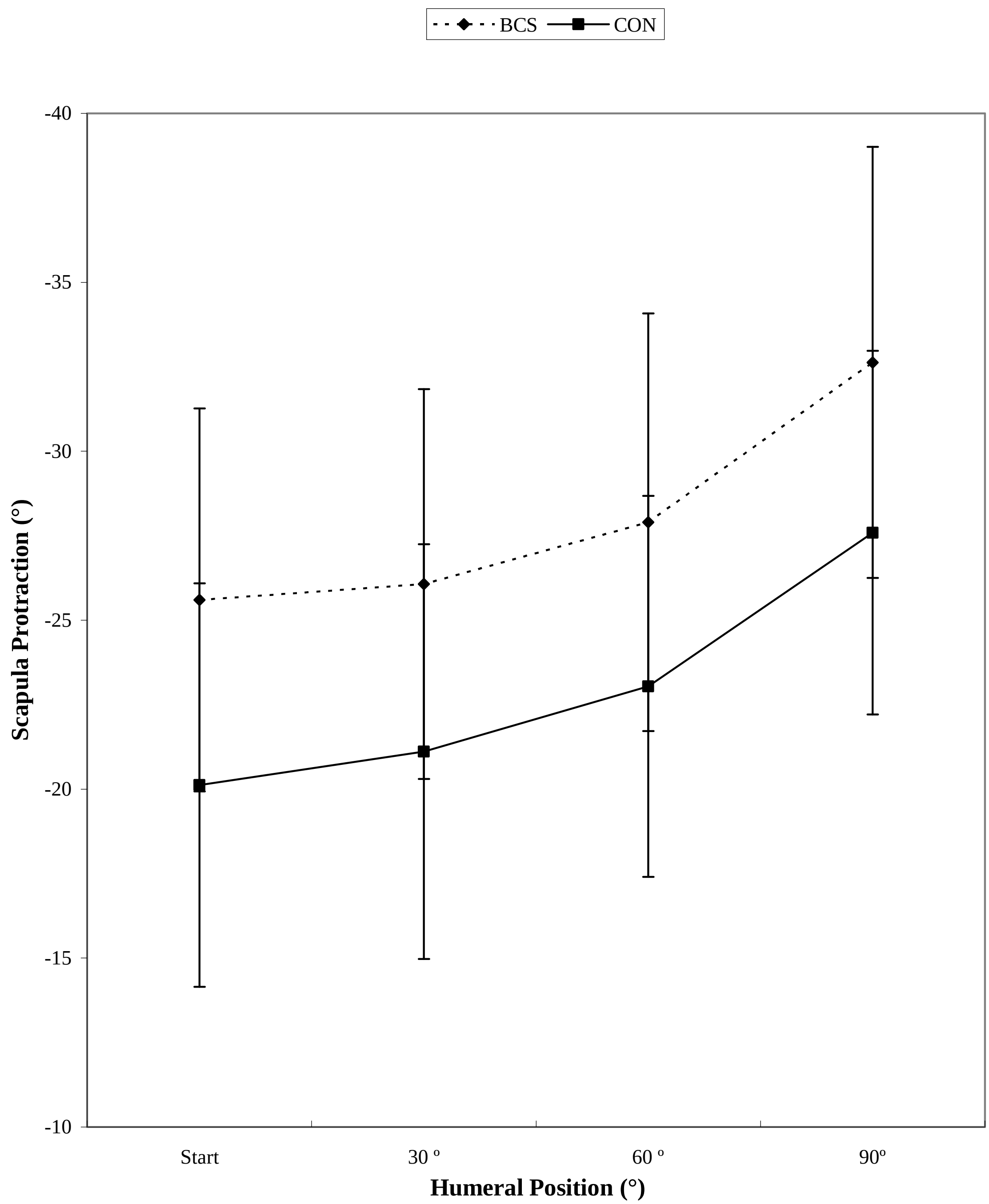


Figure 36. Mean scapula posterior tipping during the reaching task

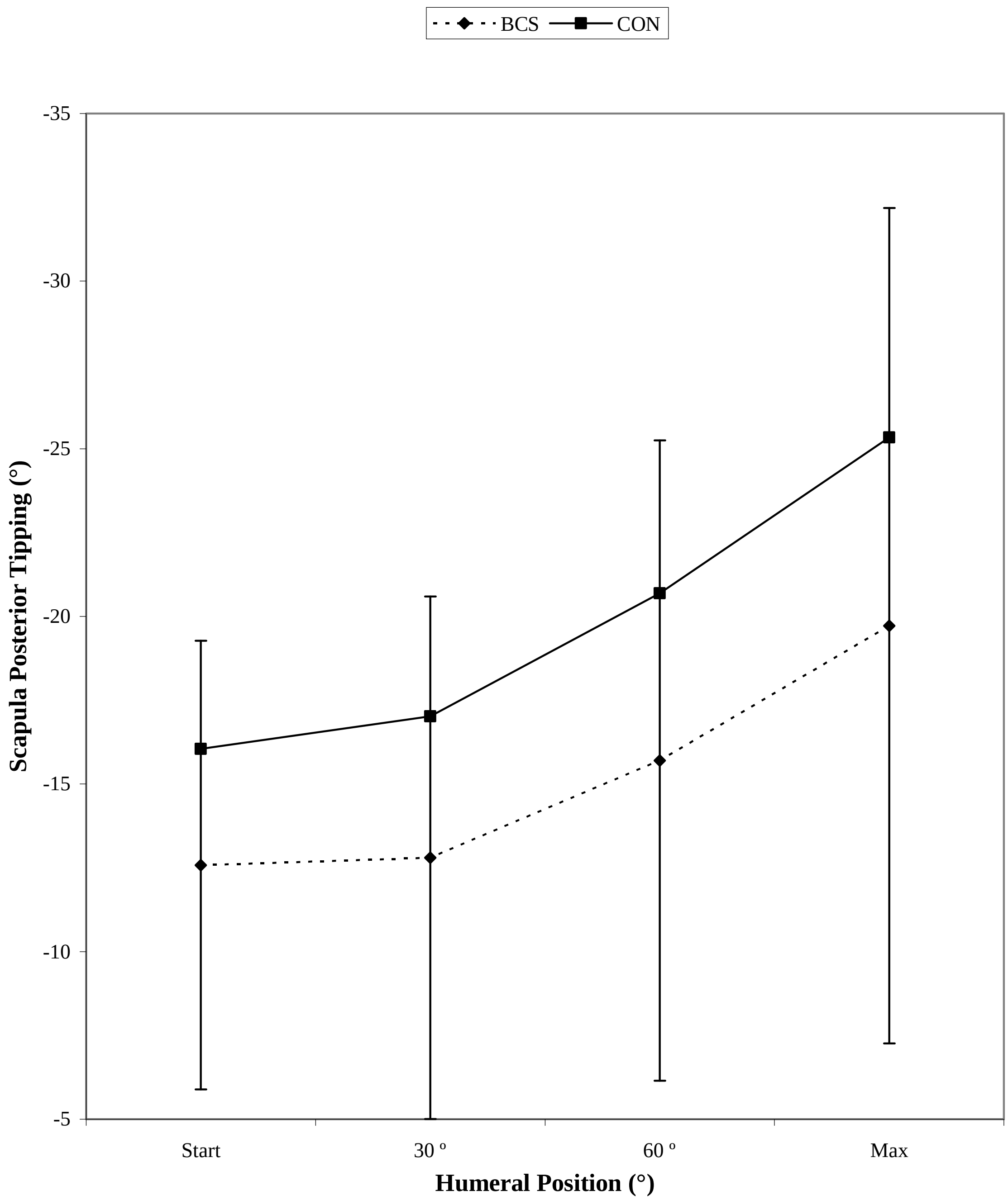


Figure 37. Mean scapula upward rotation during the reaching task

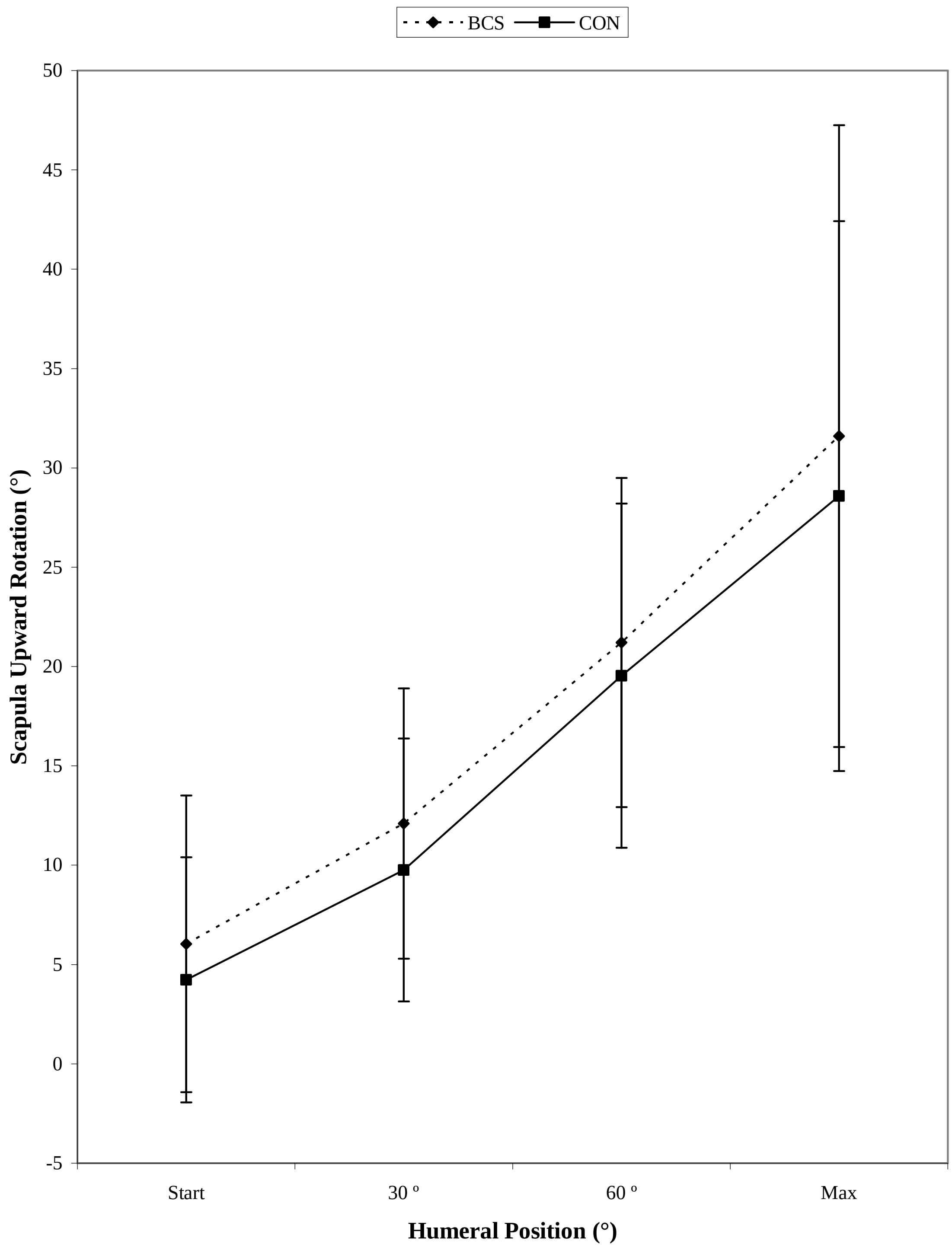


Figure 38. Mean scapula external rotation during the reaching task

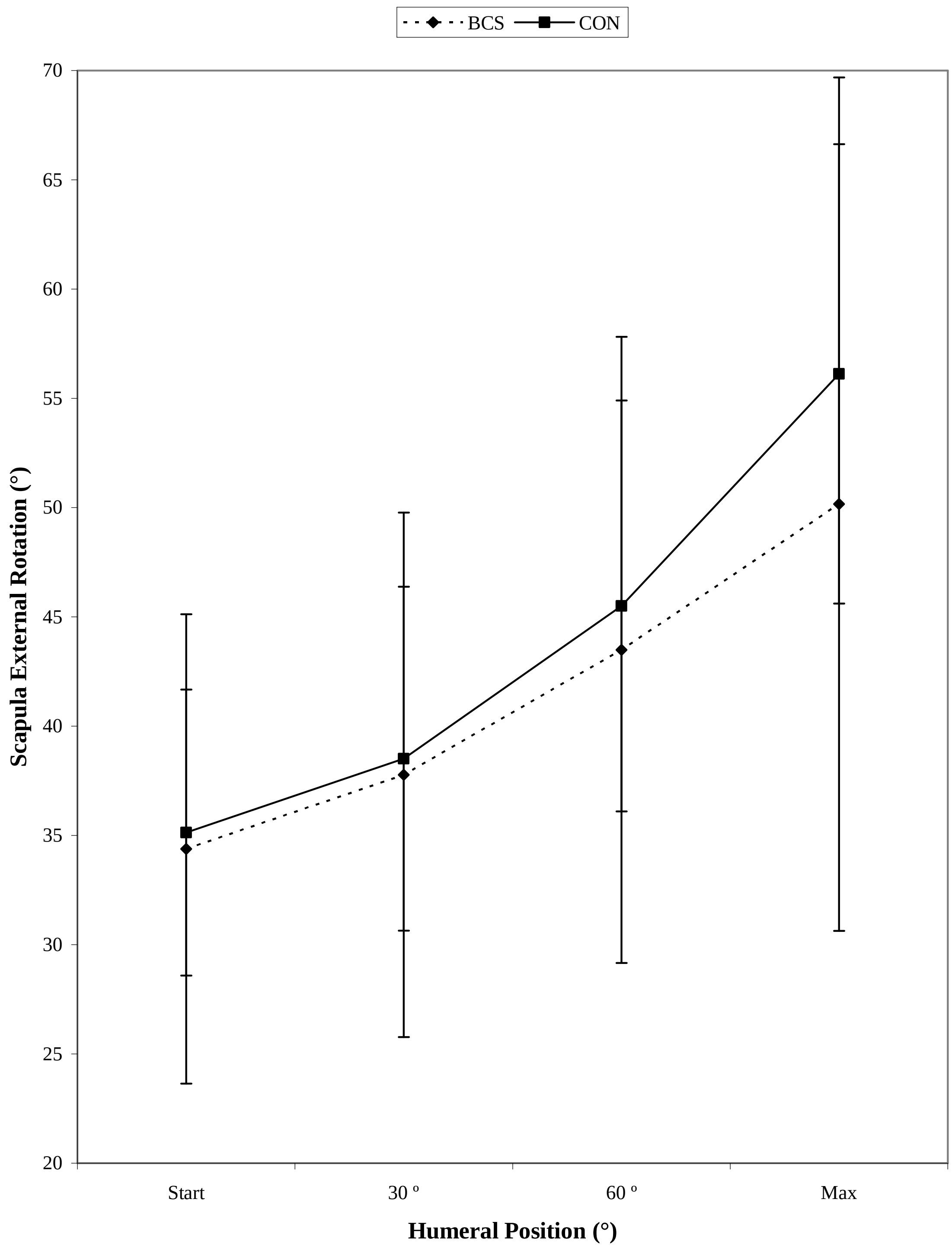


Figure 39. Mean scapula elevation during the reaching task

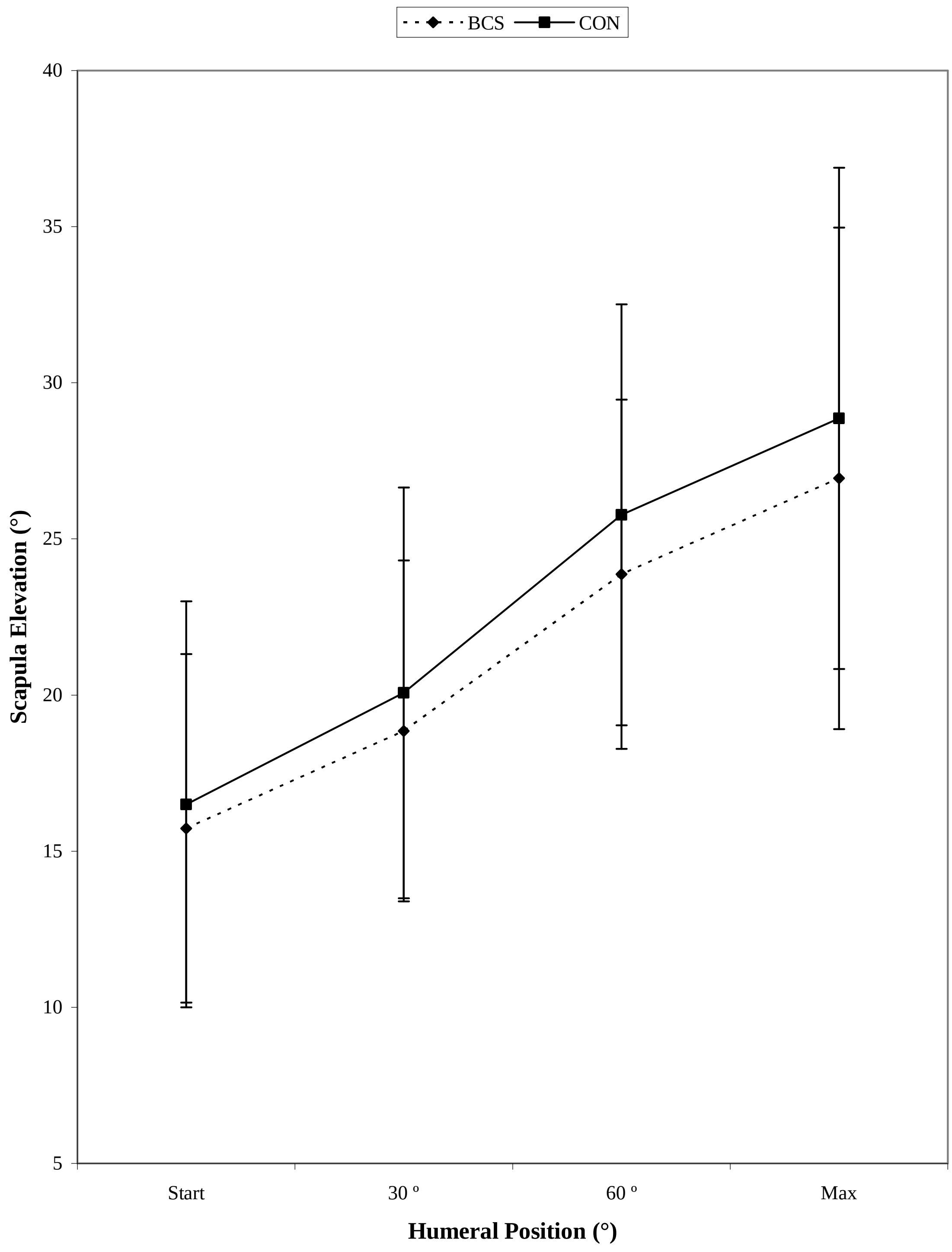


Figure 40. Mean scapula protraction during the reaching task

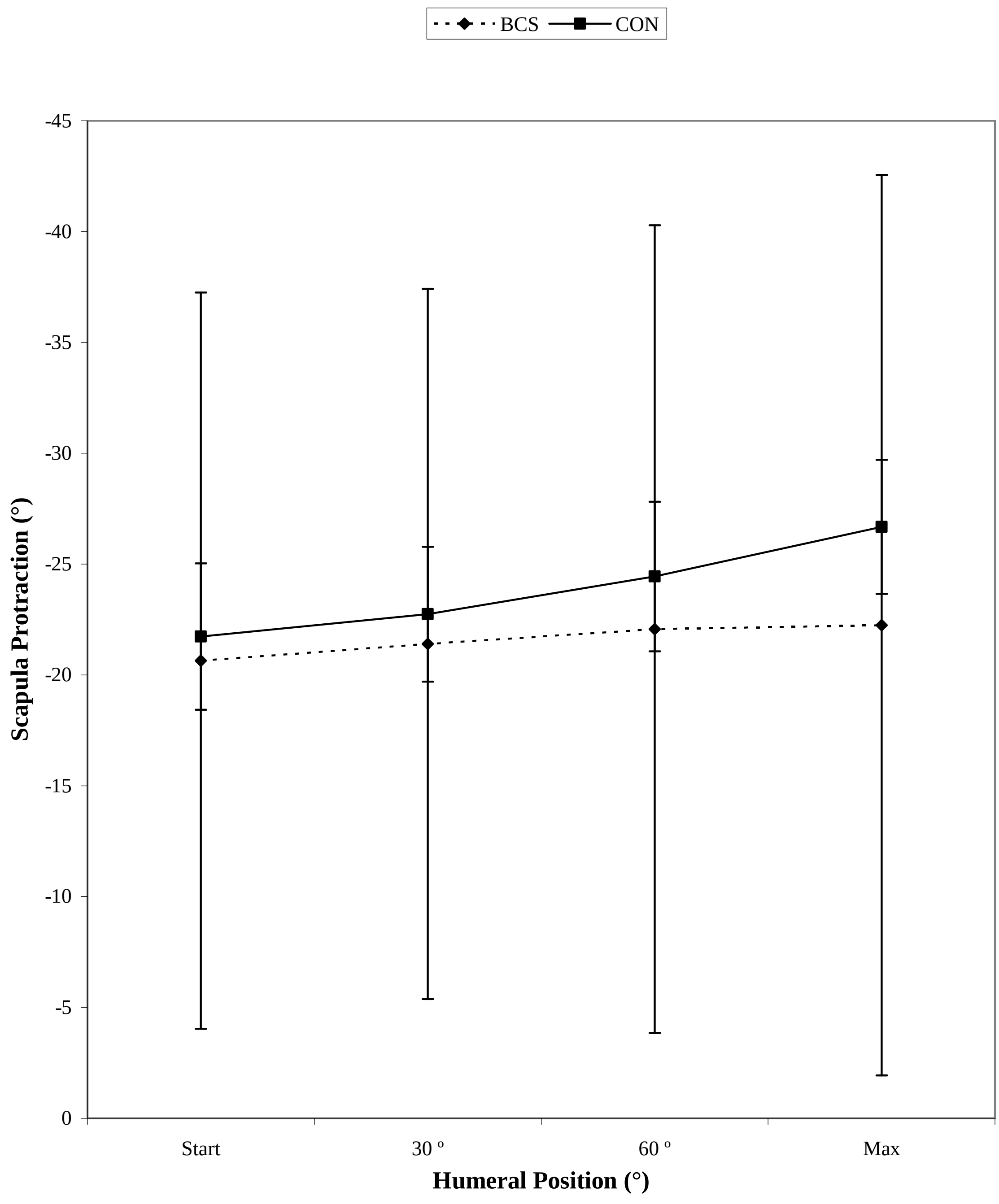


Figure 41. Scatterplot for correlation between the DASH and active flexion ROM

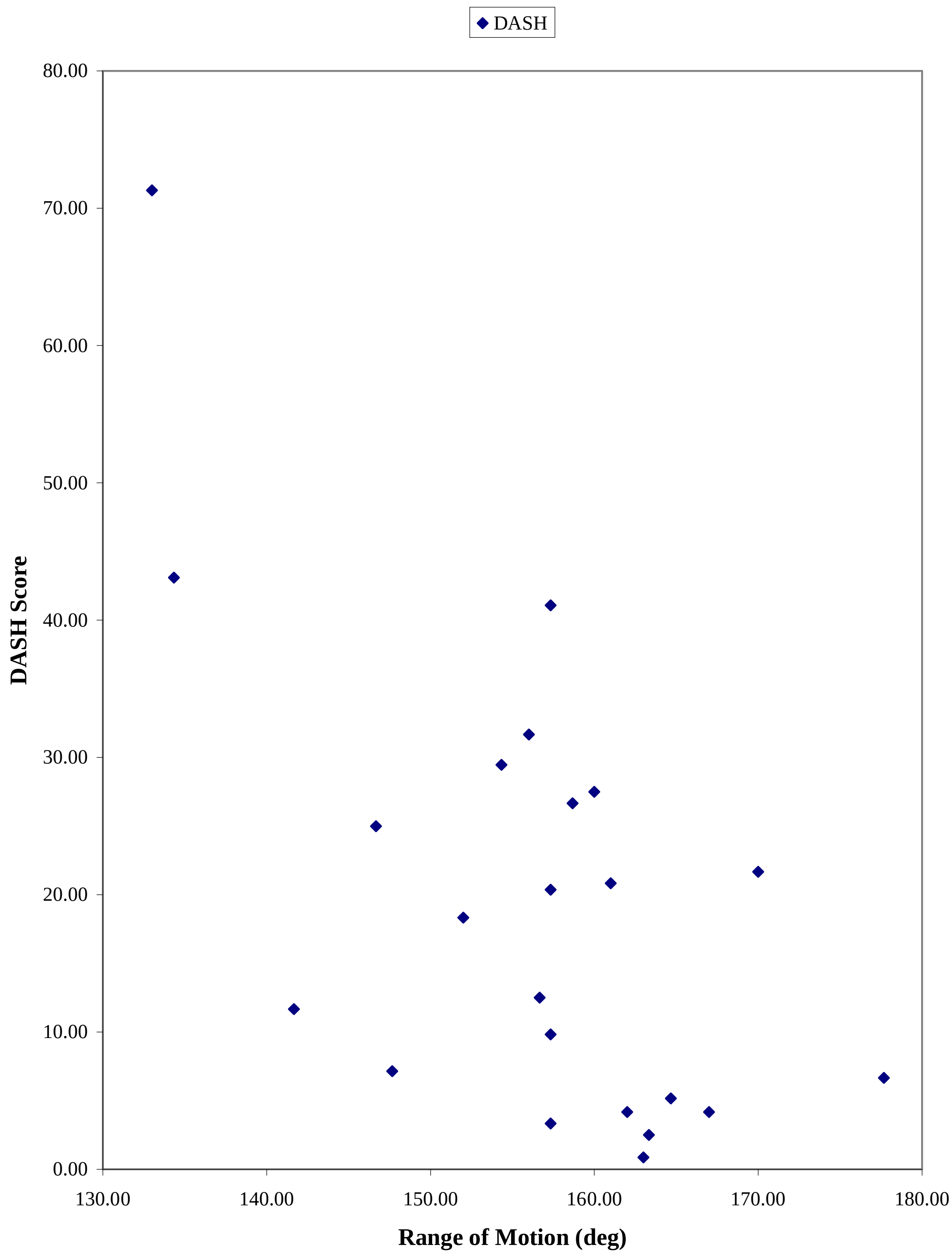


Figure 42. Scatterplot for correlation between DASH and active 90° external rotation ROM

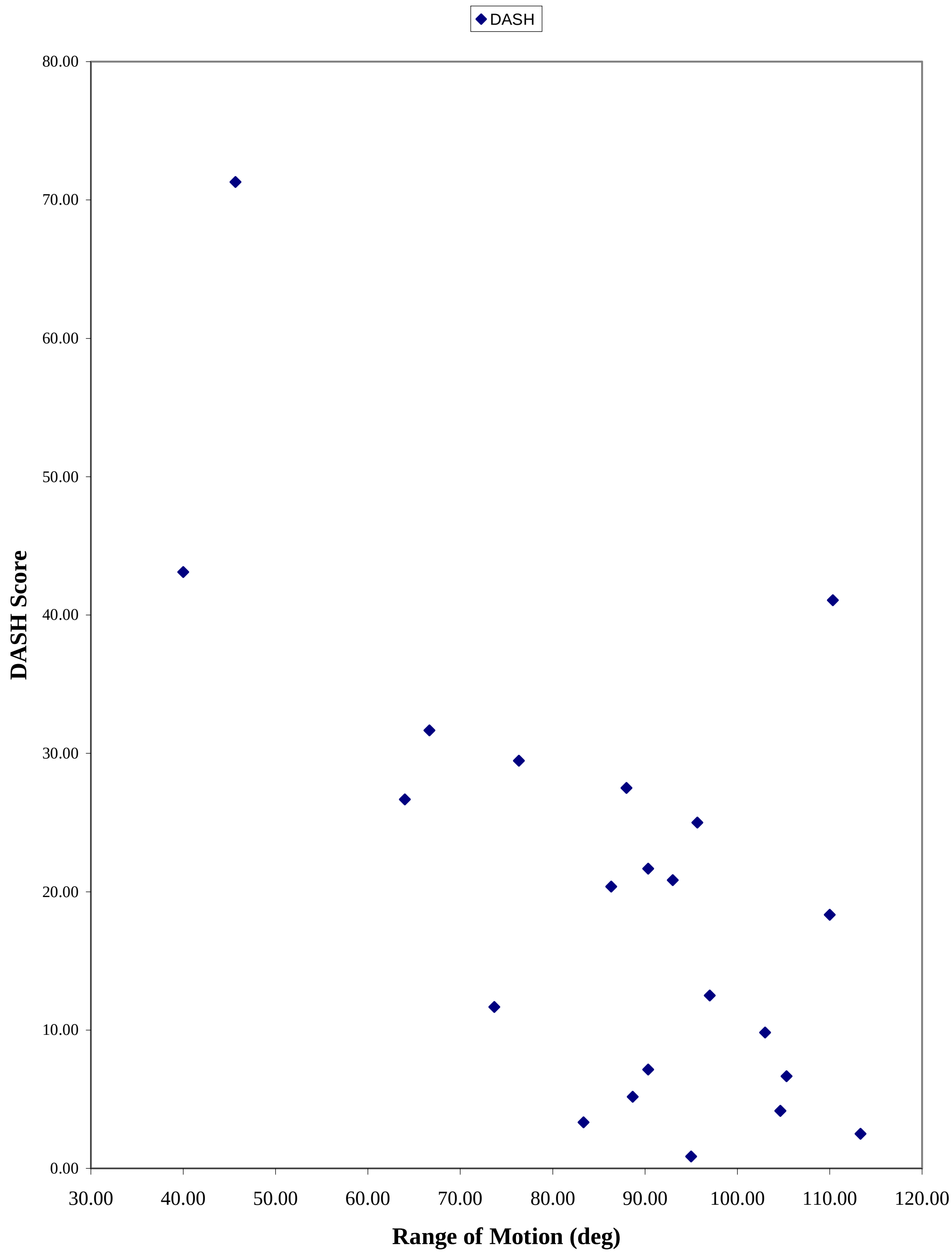


Figure 43. Scatterplot for correlation between the DASH and passive flexion ROM

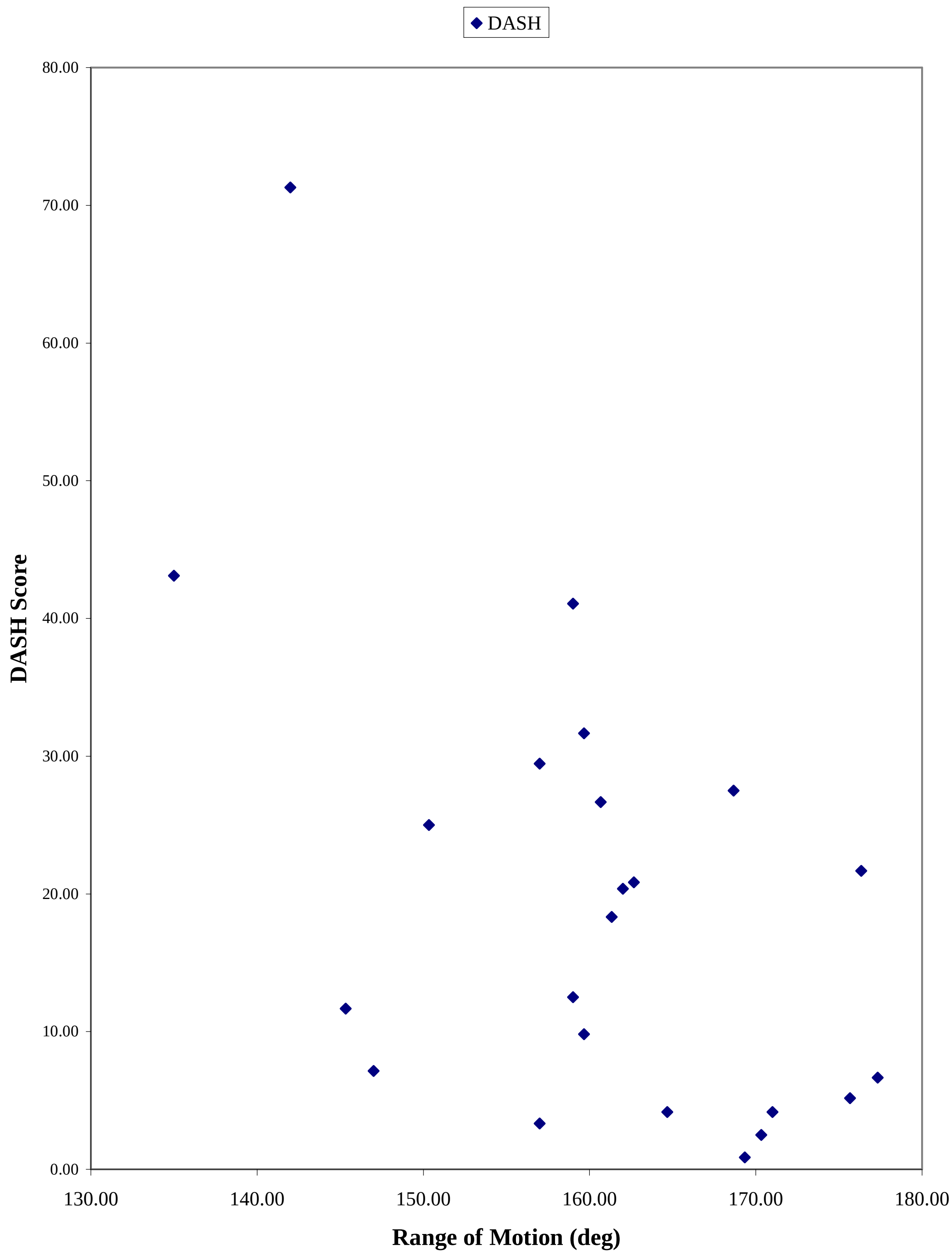


Figure 44. Scatterplot for correlation between the DASH and passive 90° external rotation ROM

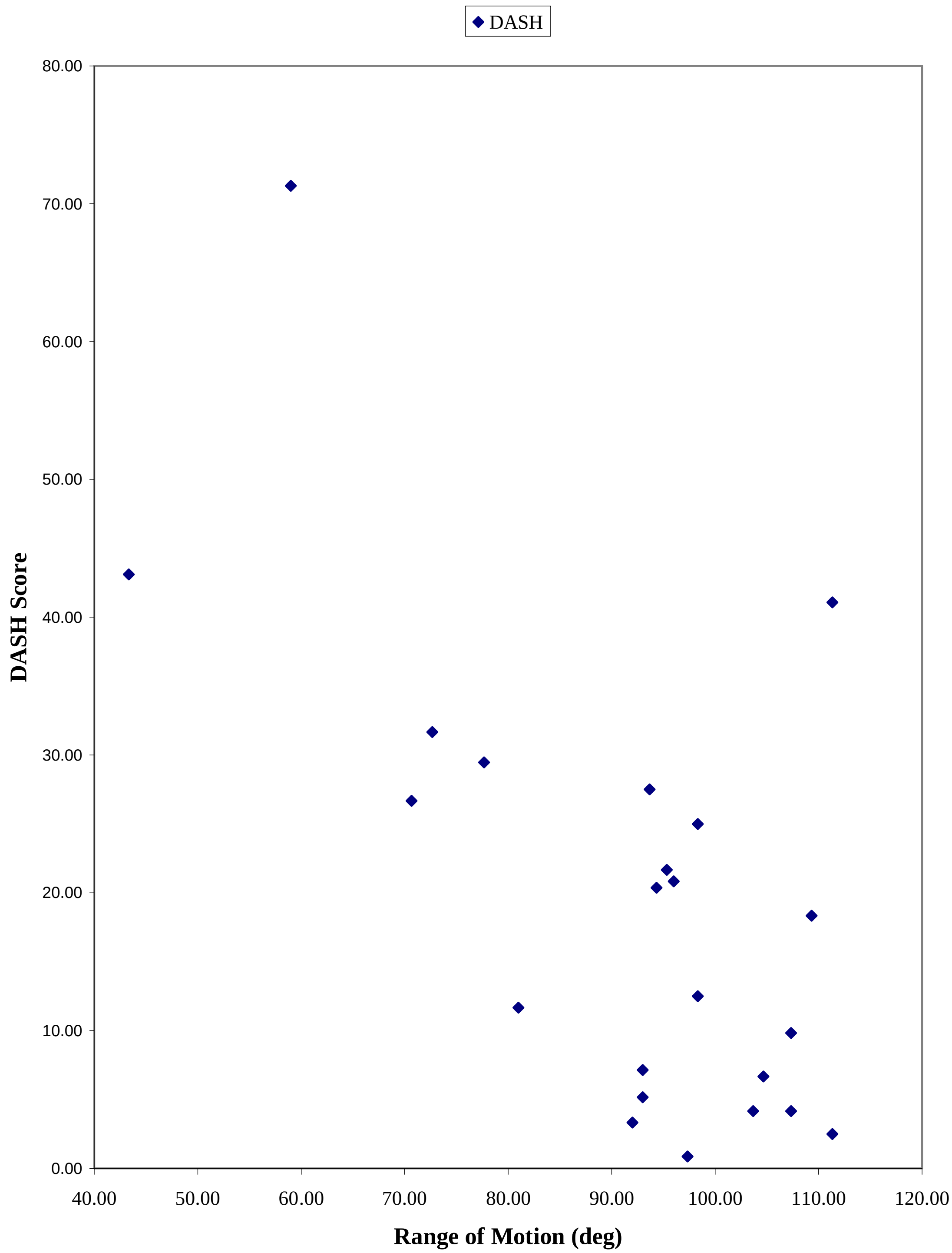


Figure 45. Scatterplot for correlation between the DASH and scapula abduction and upward rotation strength

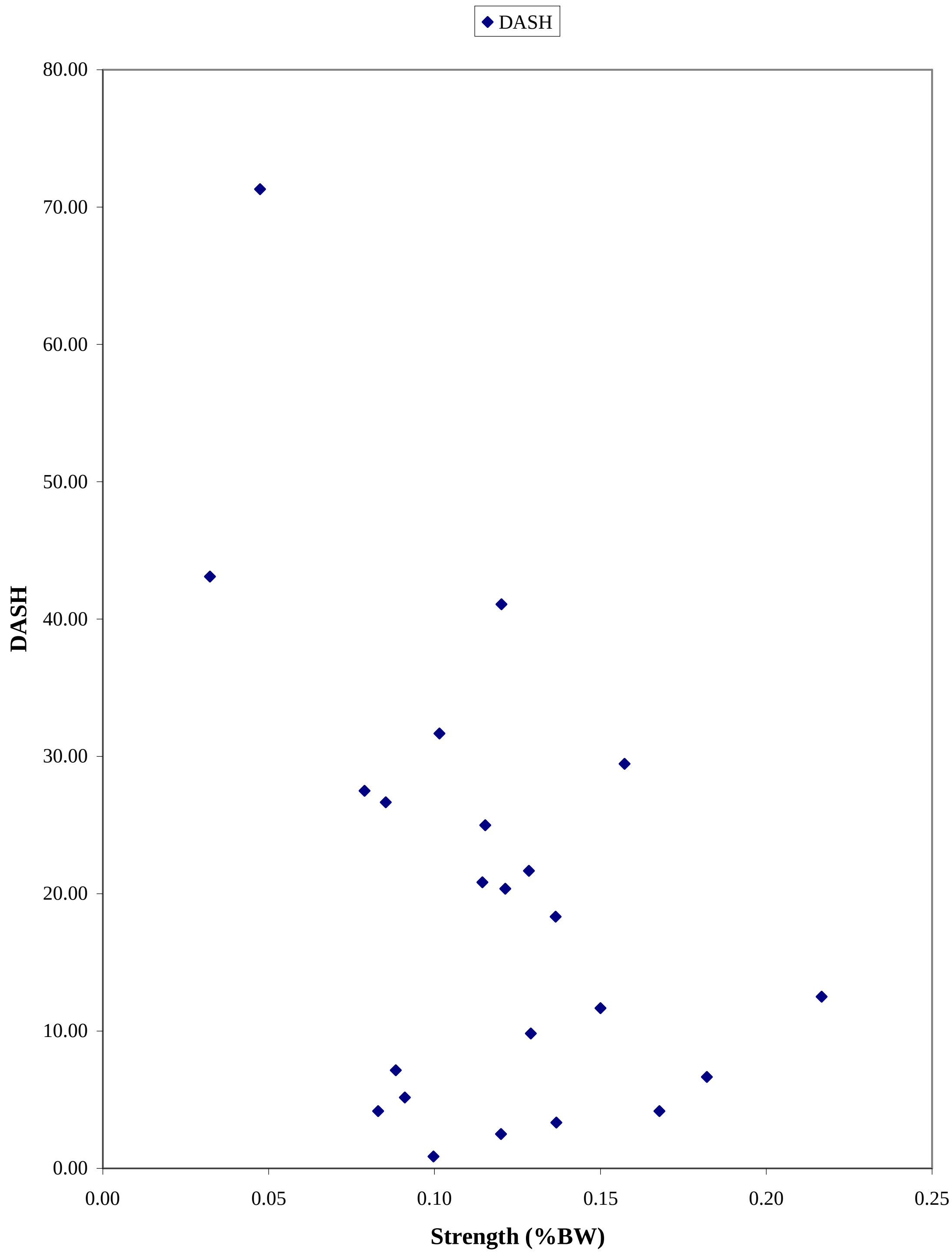


Figure 46. Scatterplot for correlation between the DASH and scapula depression and adduction strength

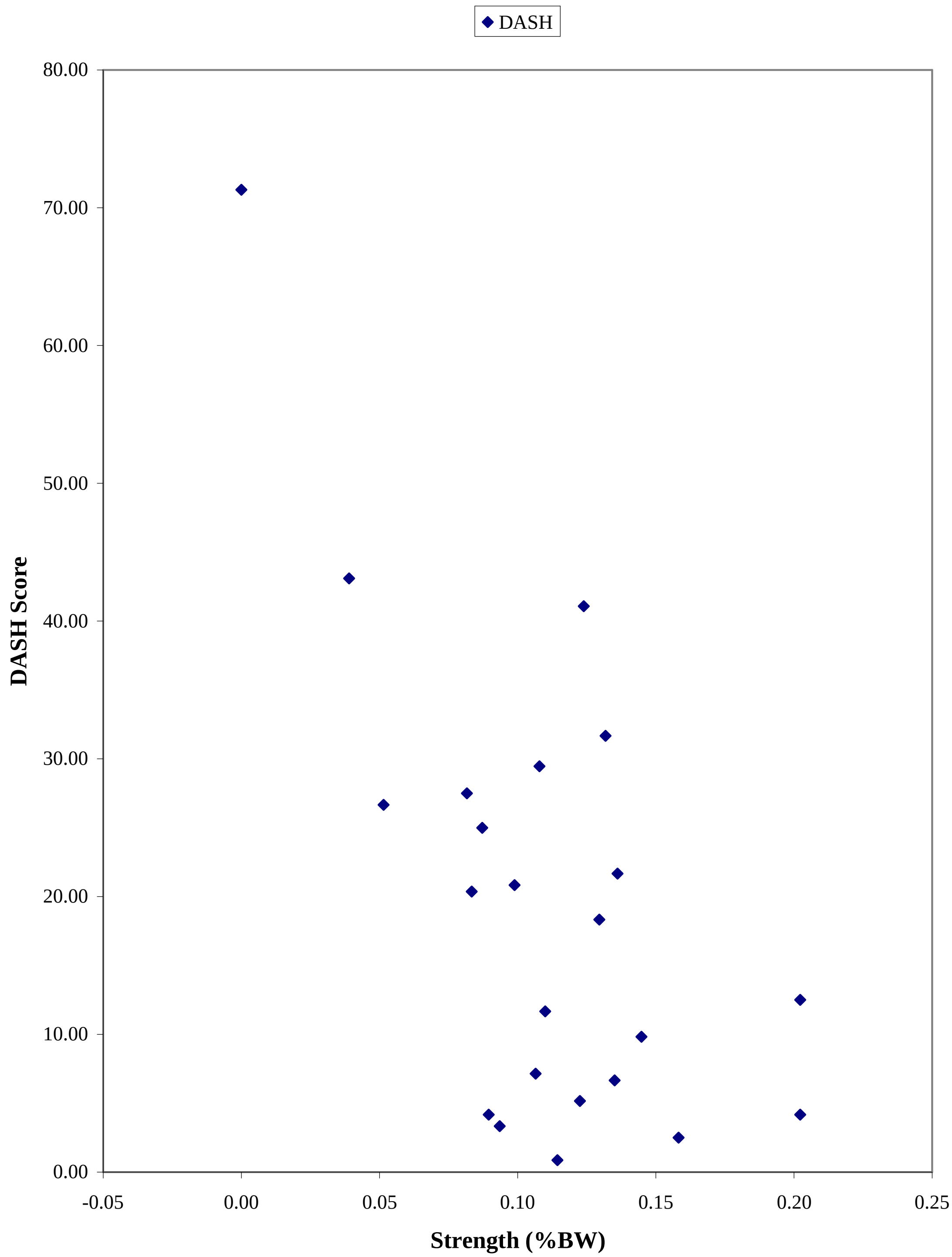


Figure 47. Scatterplot for correlation between the DASH and flexion strength

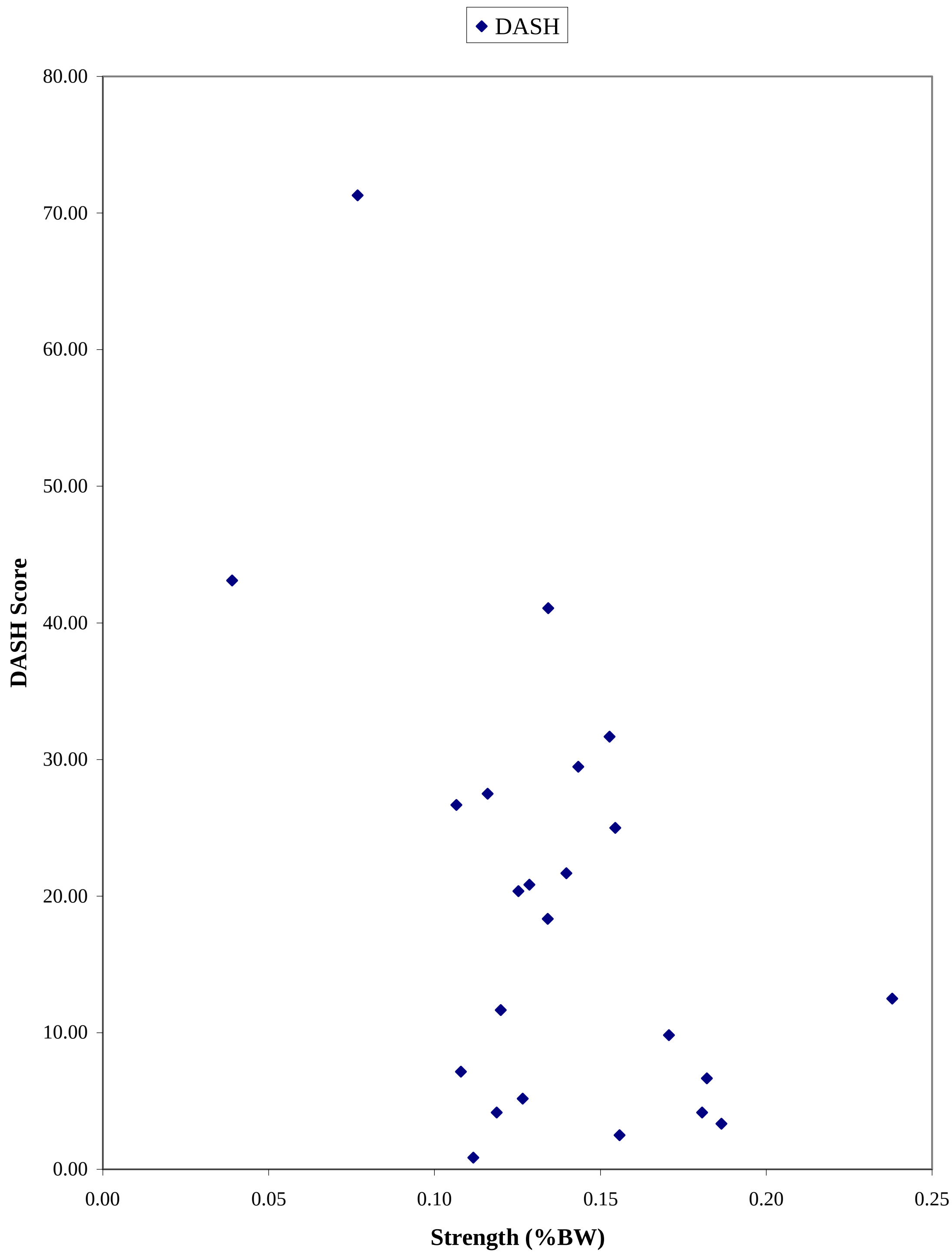


Figure 48. Scatterplot for correlation between the DASH and internal rotation strength

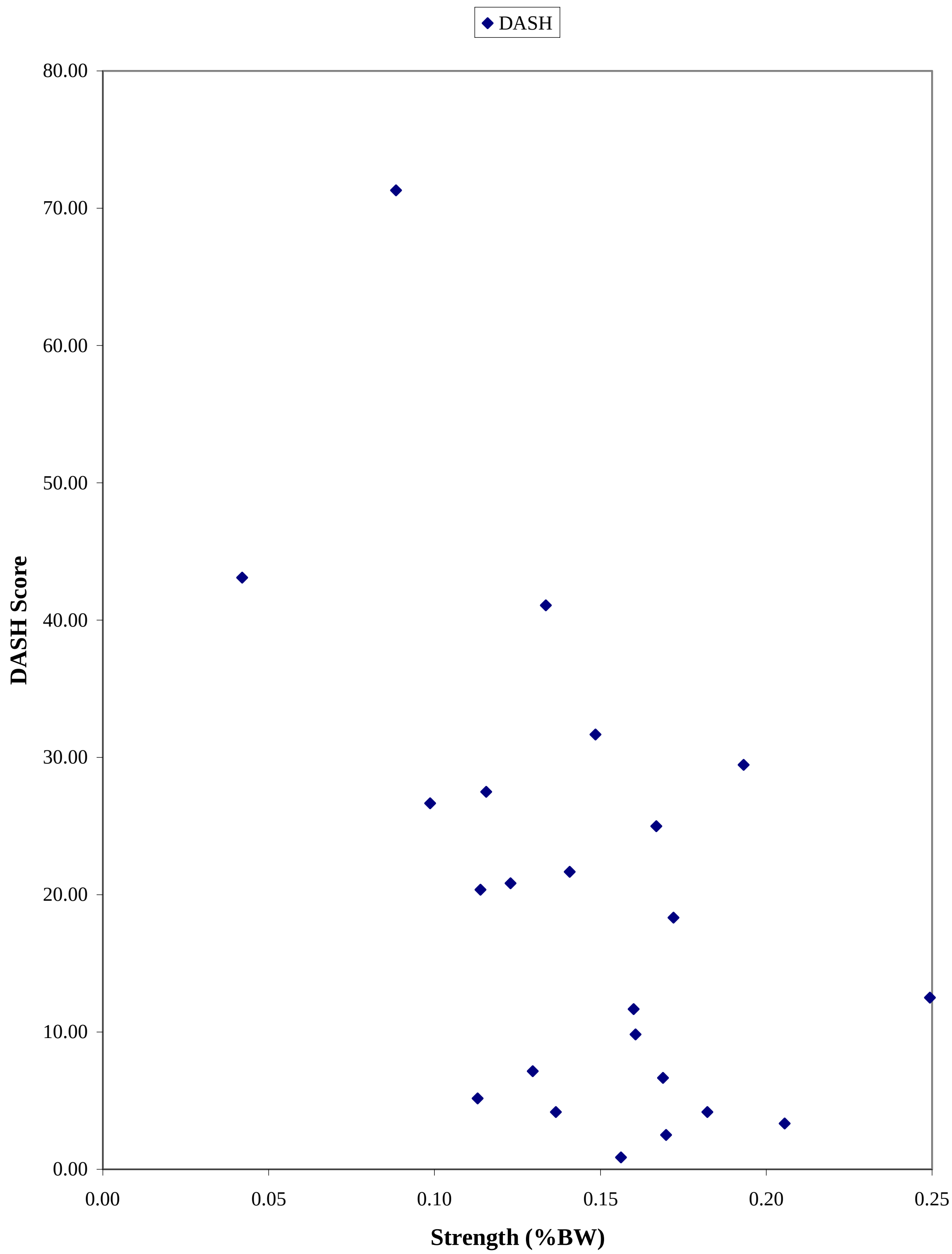


Figure 49. Scatterplot for correlation between the DASH and scaption strength

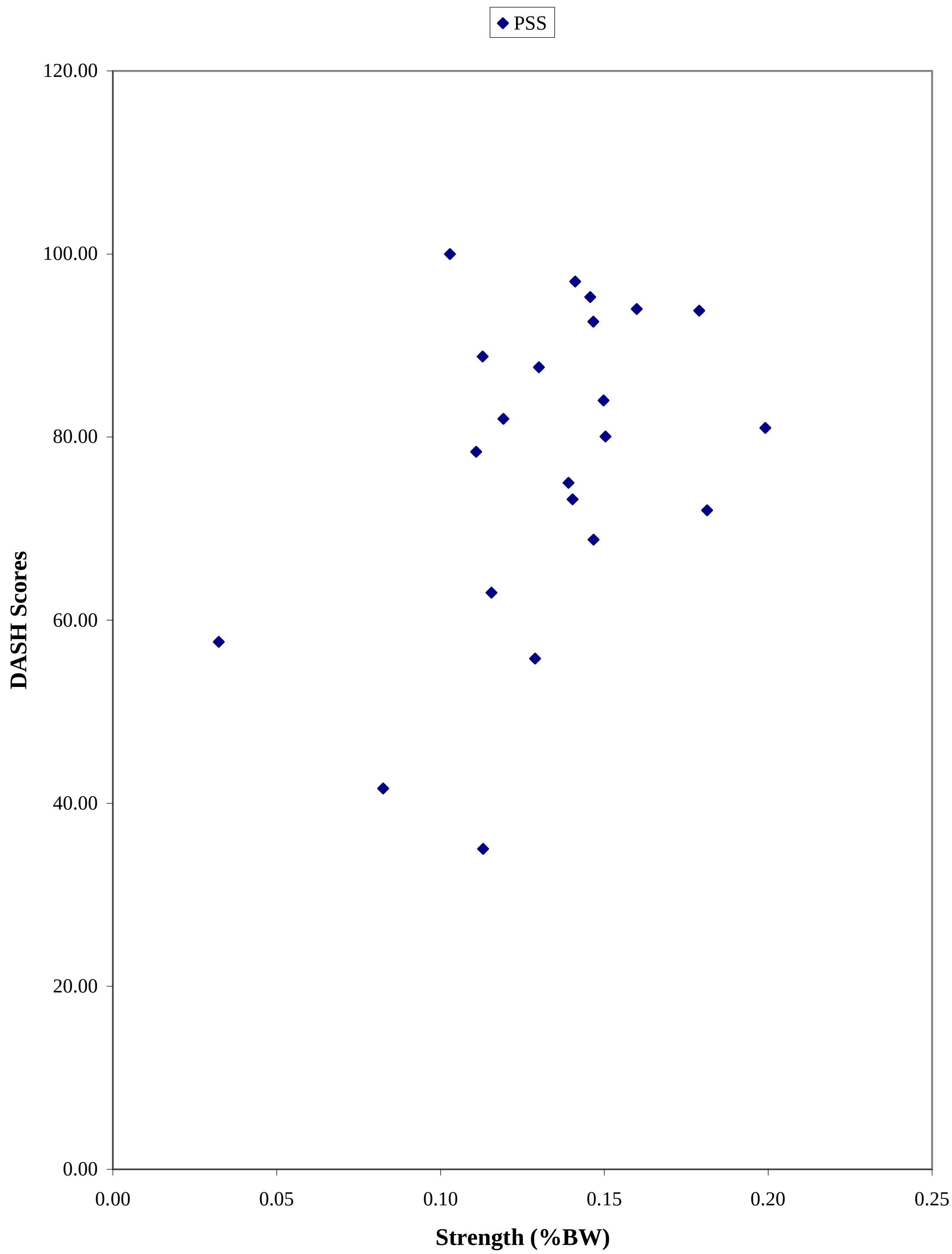


Figure 50. Scatterplot for correlation between the DASH and adduction strength

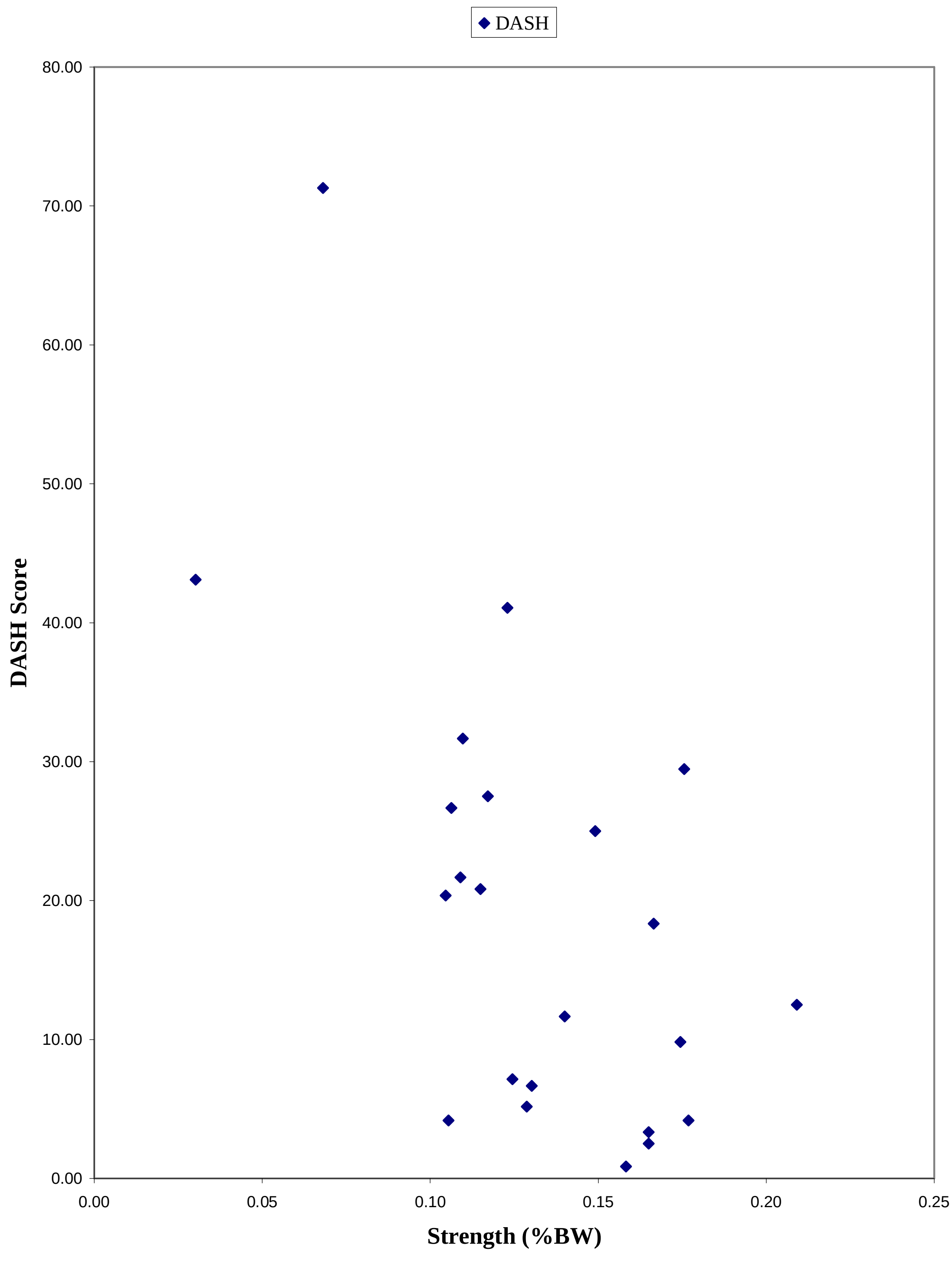


Figure 51. Scatterplot for correlation between the DASH and cervical left rotation

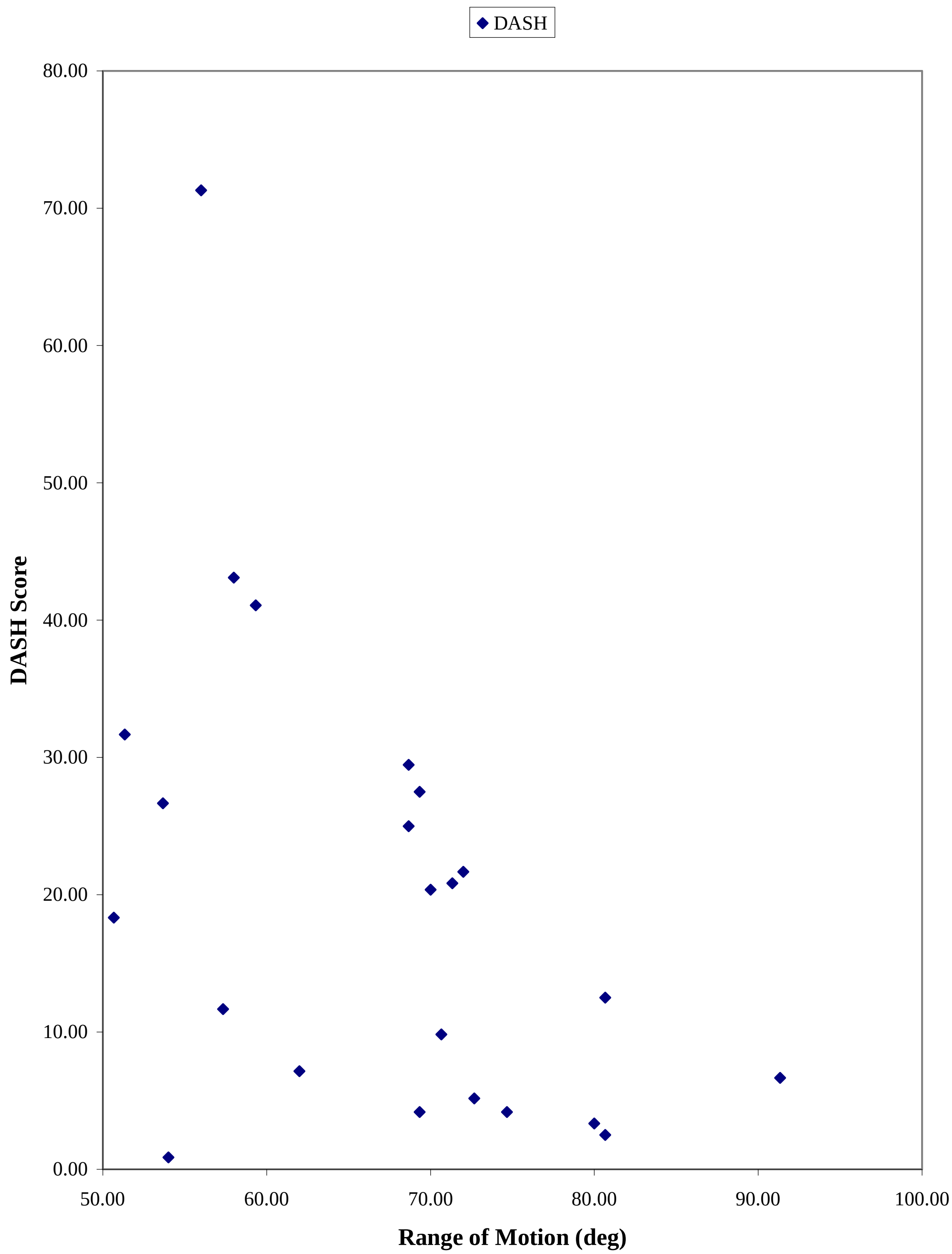


Figure 52. Scatterplot for correlation between the PSS and active flexion ROM

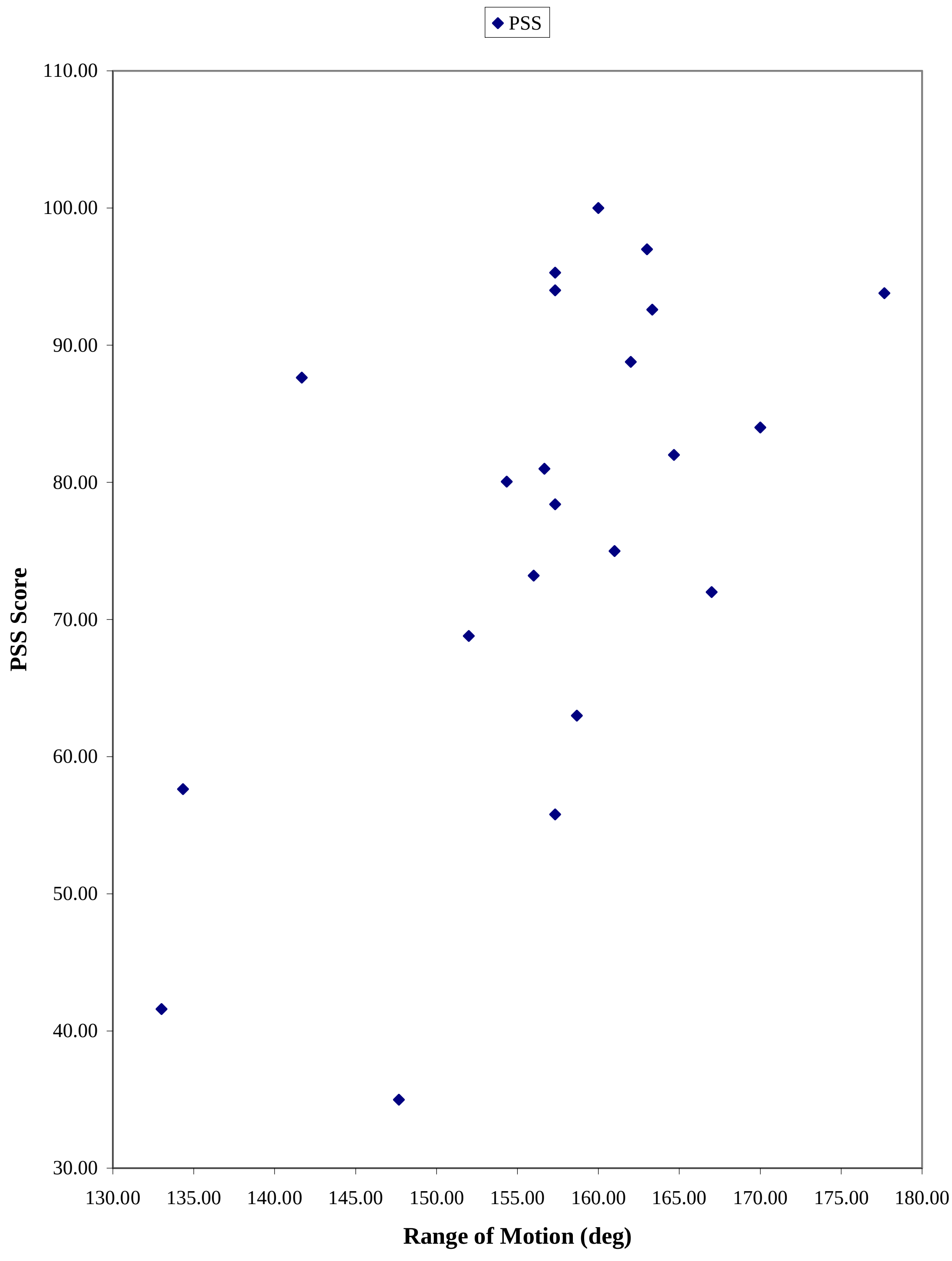


Figure 53. Scatterplot for correlation between PSS and passive flexion ROM

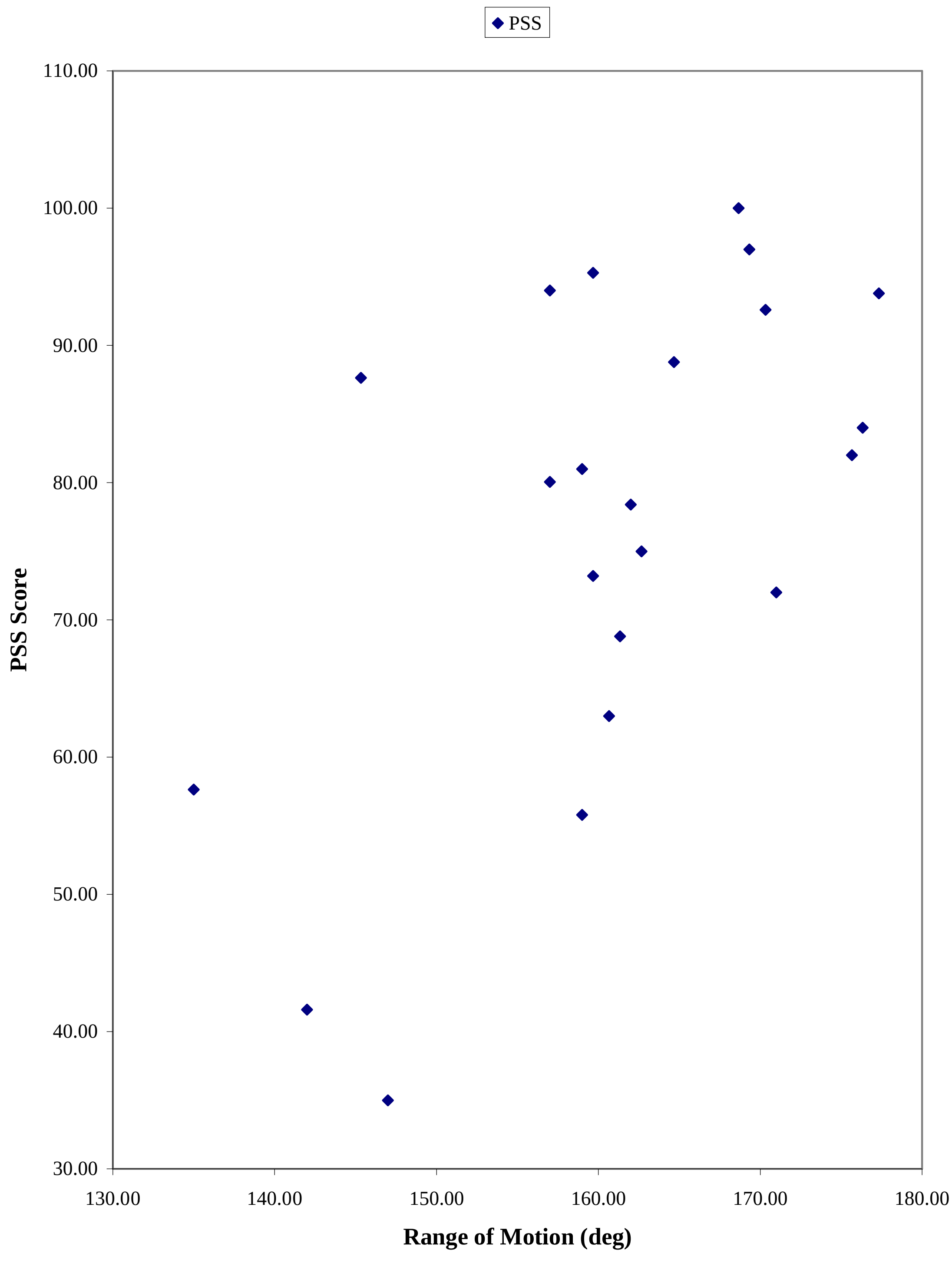


Figure 54. Scatterplot for correlation between the PSS and passive 90° external rotation ROM

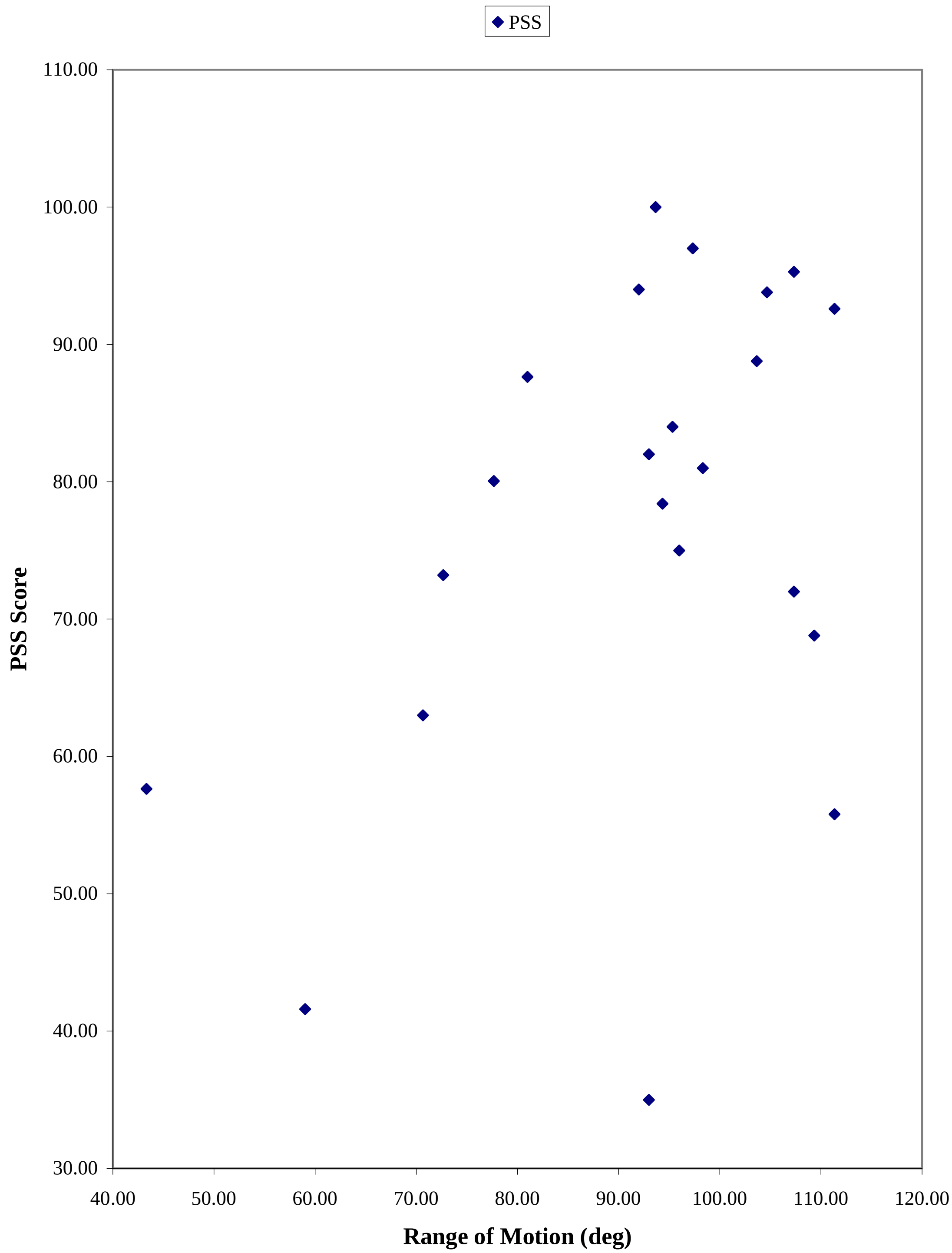


Figure 55. Scatterplot for correlation between the PSS and flexion strength

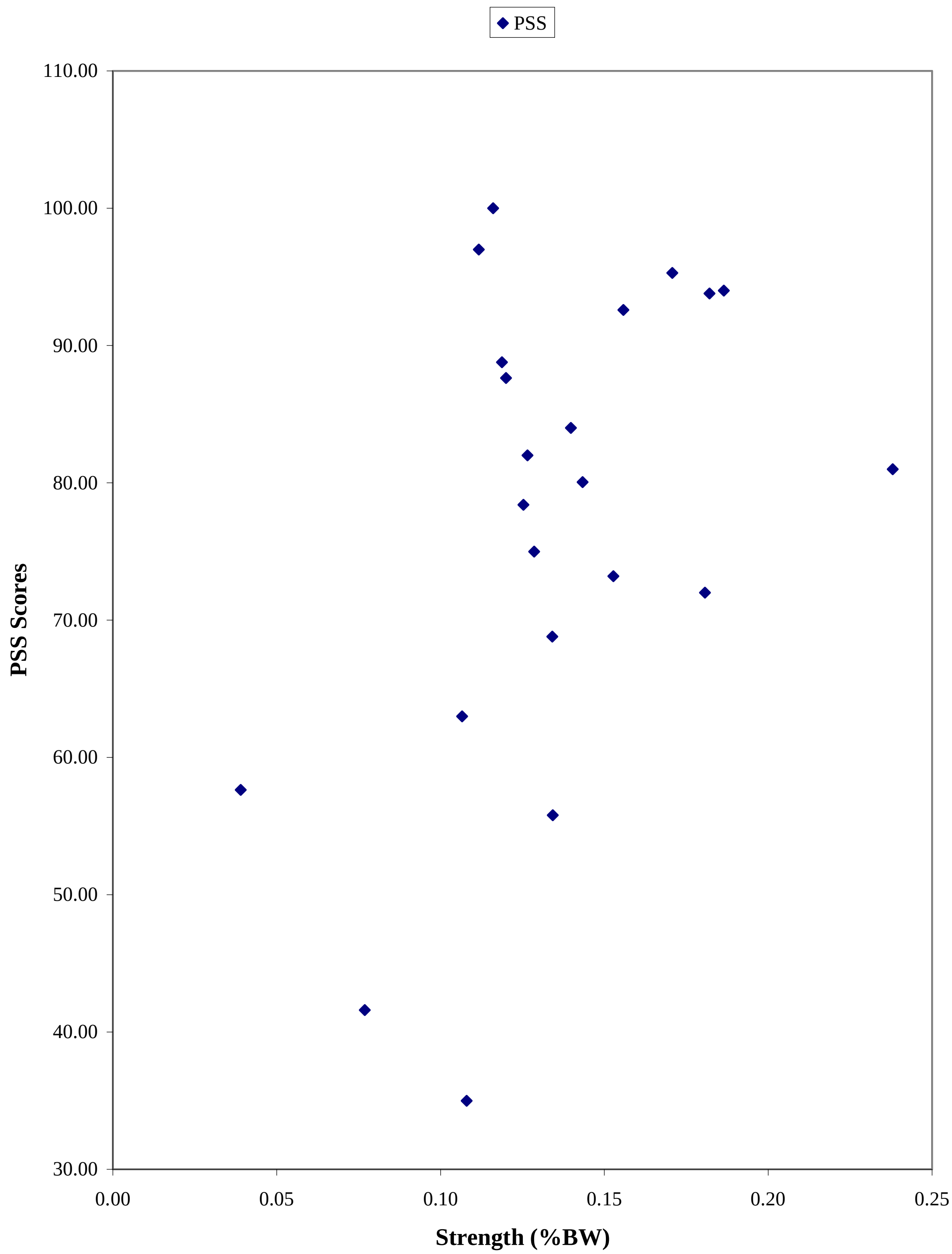


Figure 56. Scatterplot for correlation between the PSS and internal rotation strength

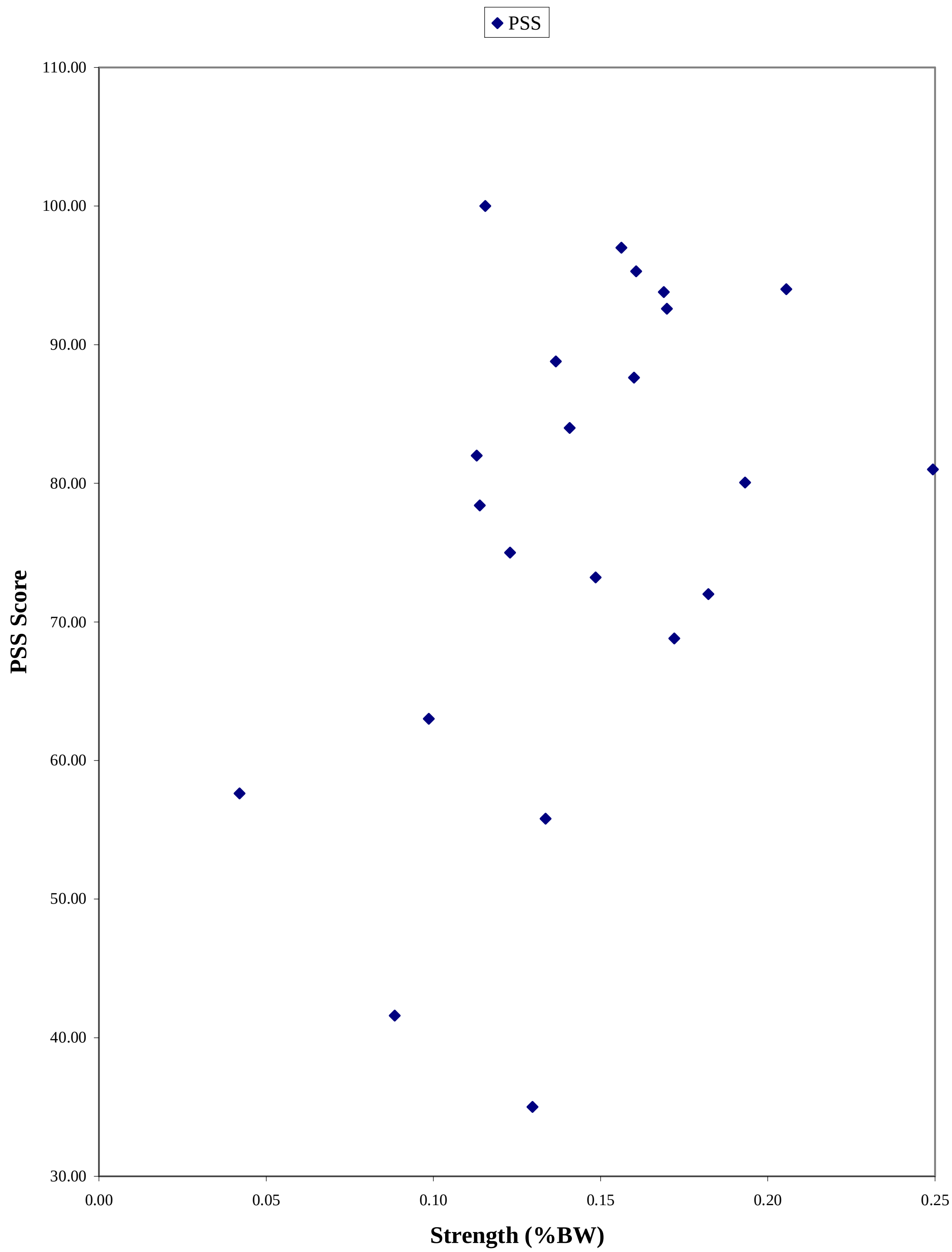


Figure 57. Scatterplot for correlation between the PSS and scaption strength

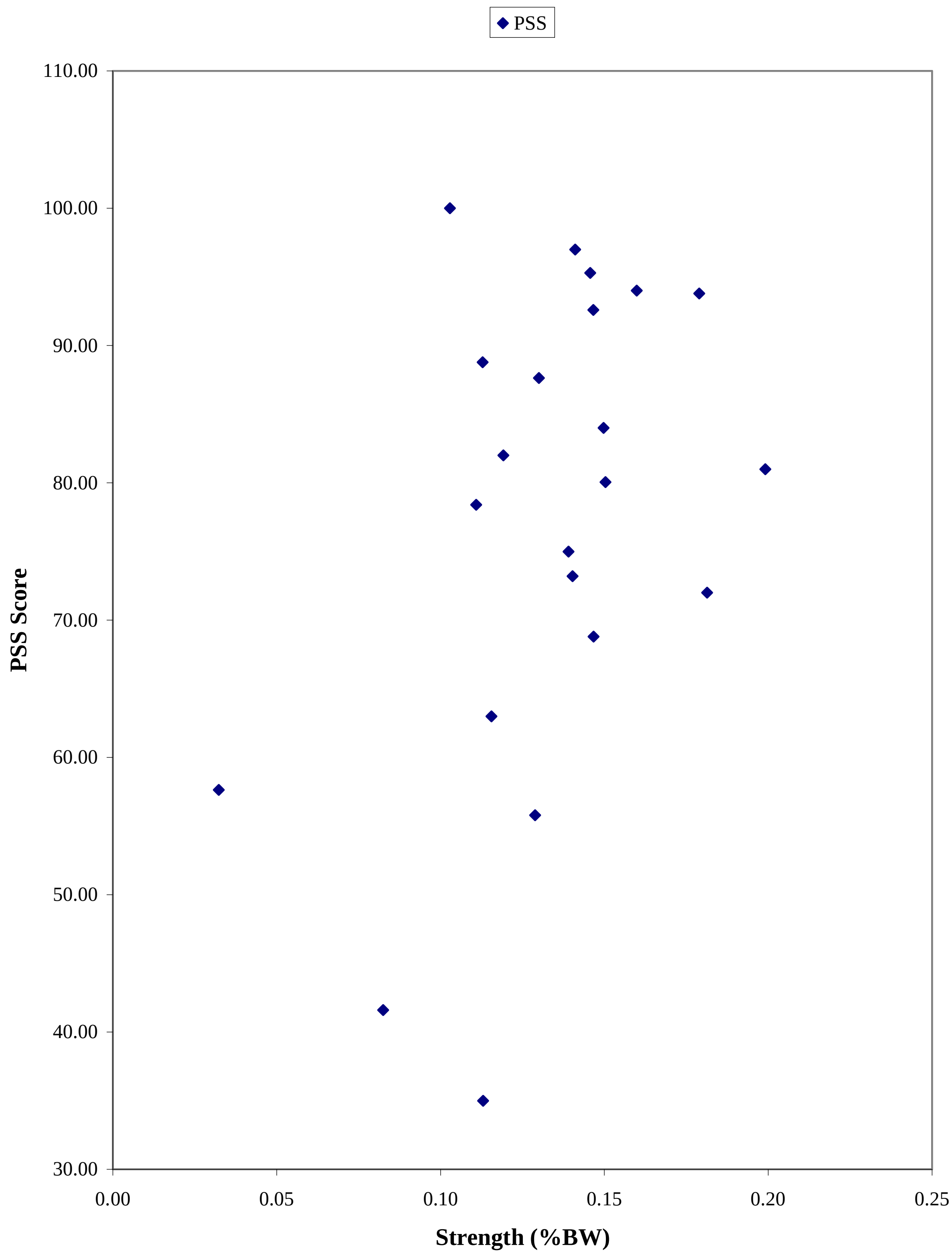


Figure 58. Scatterplot for correlation between the PSS and adduction strength

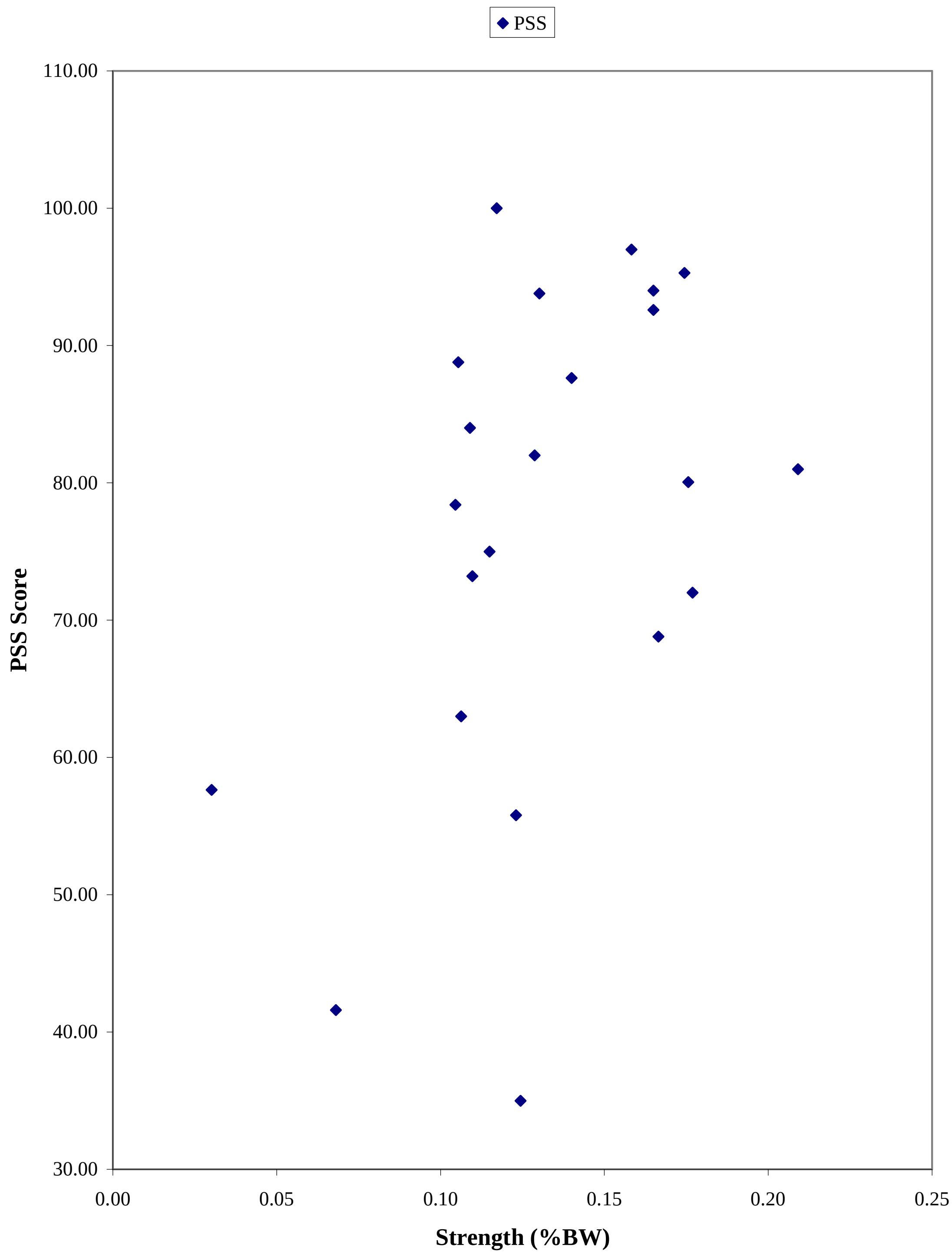


Figure 59. Scatterplot for correlation between the PSS and cervical left side bending

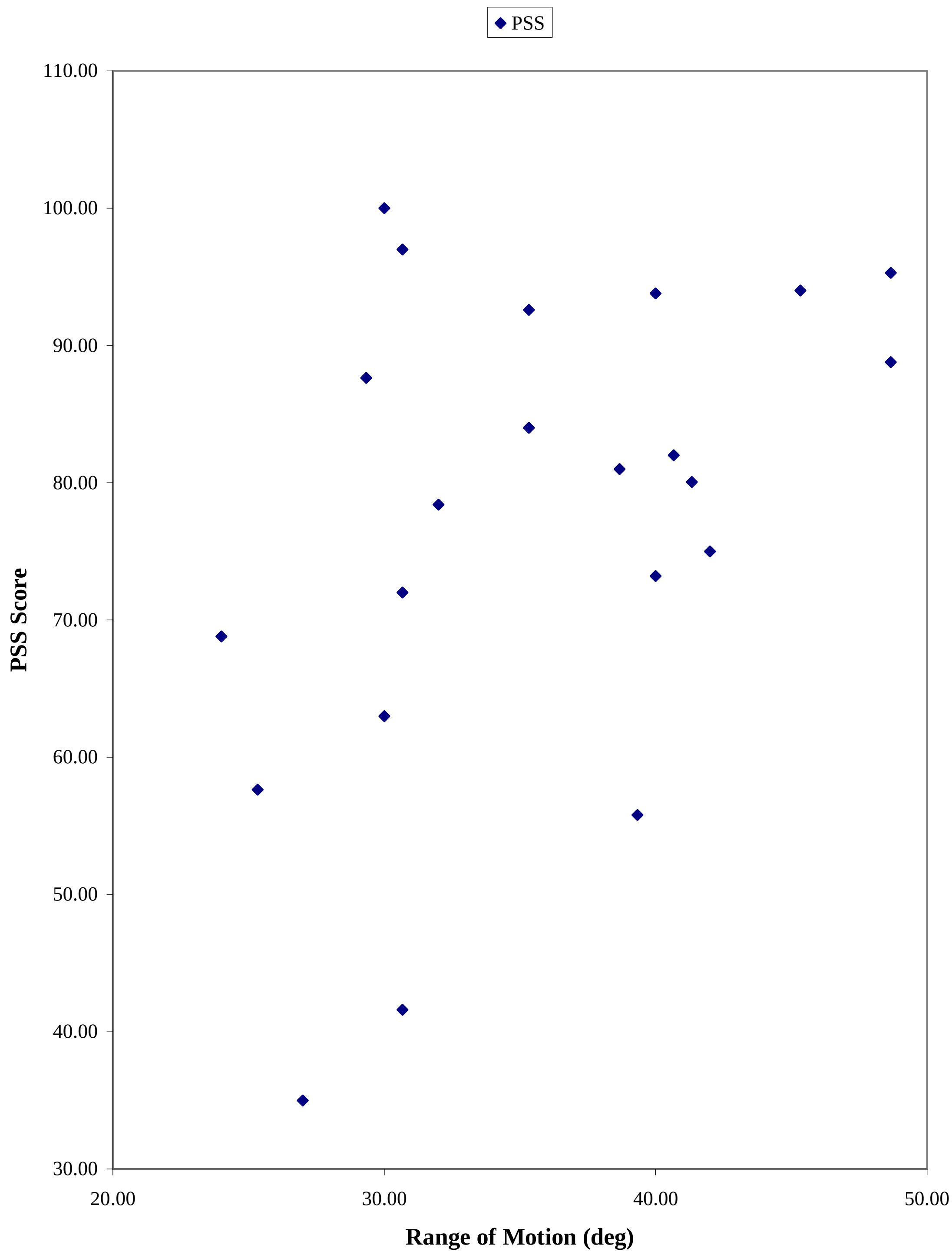


Figure 60. Scatterplot for correlation between the PSS and cervical left rotation

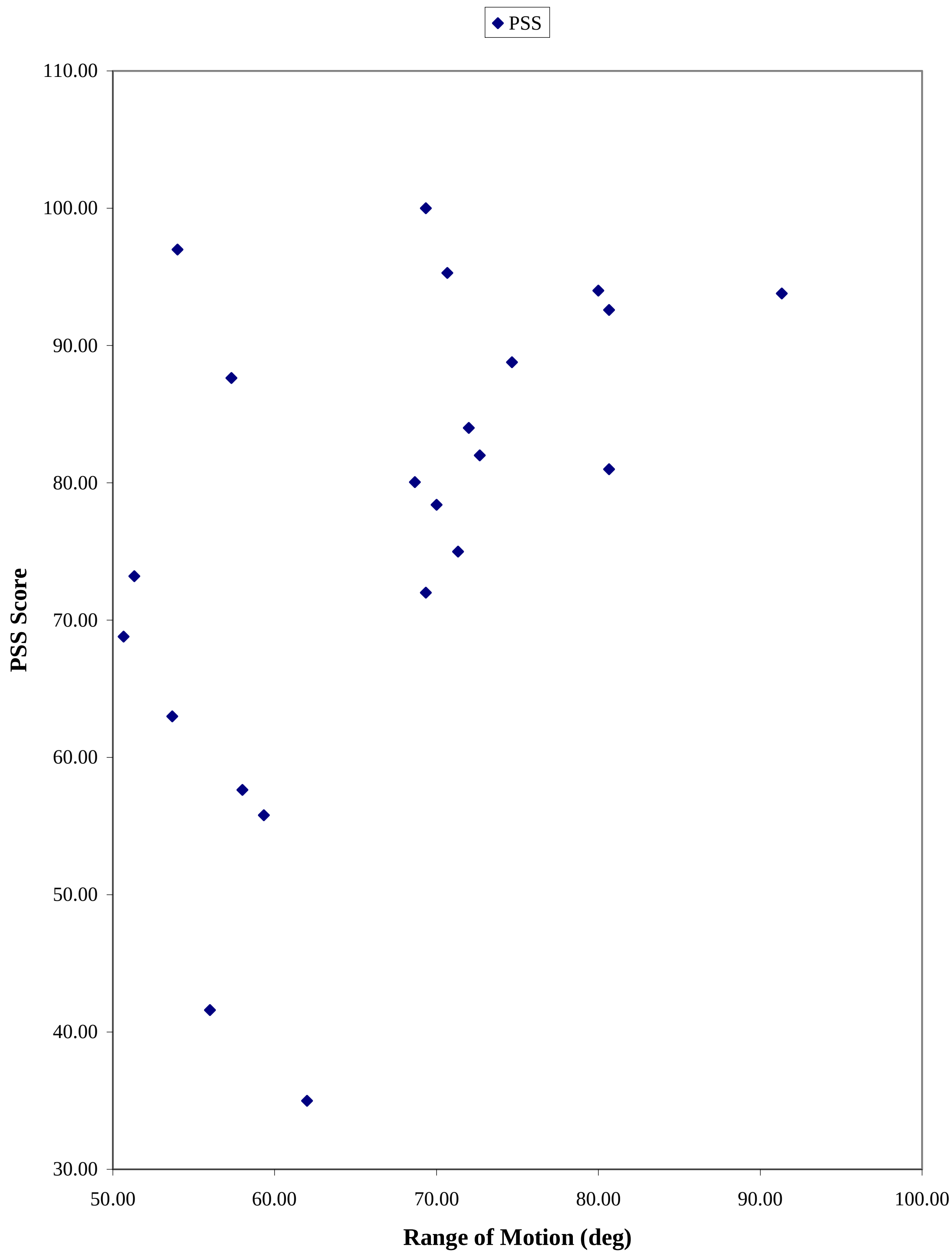
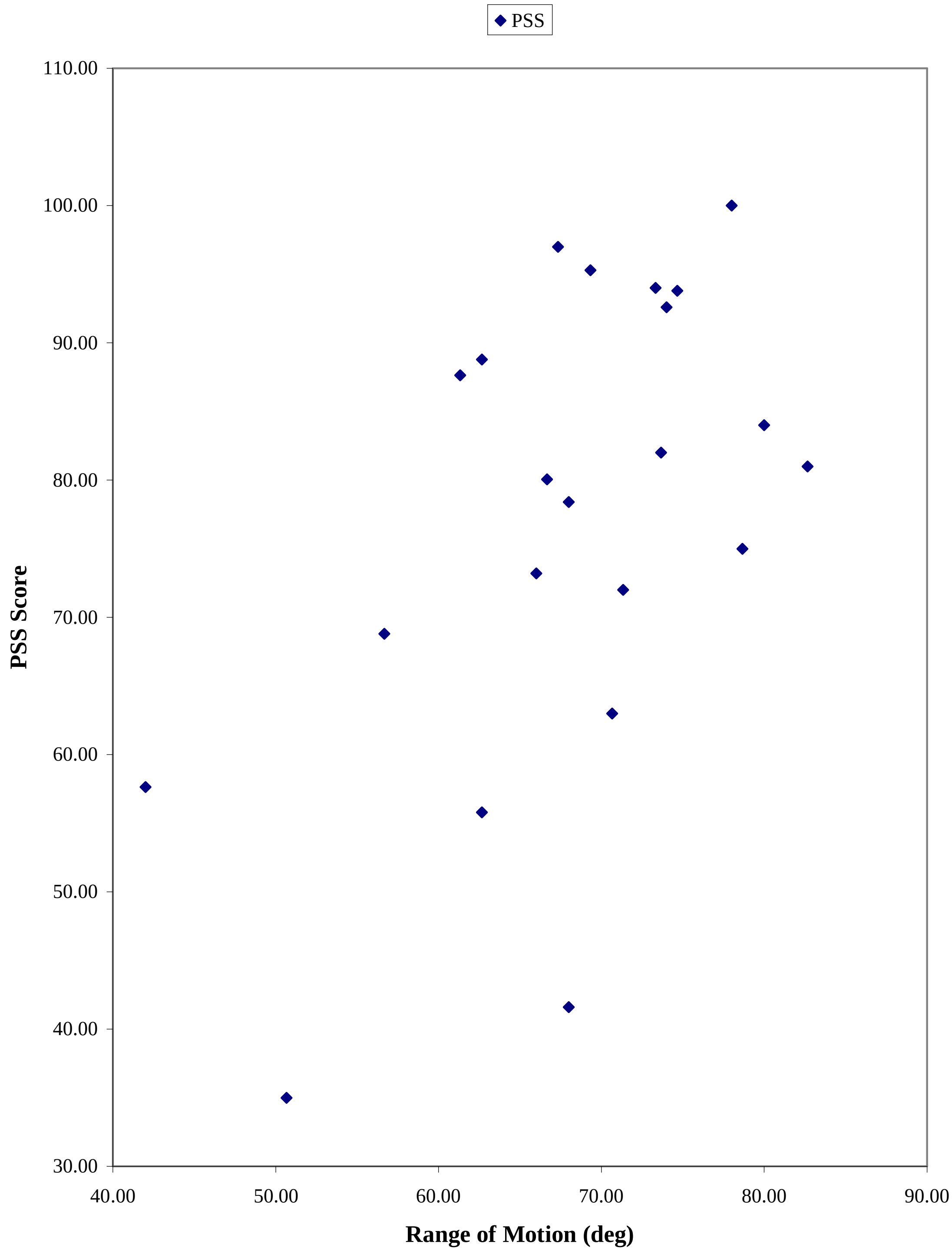


Figure 61. Scatterplot for correlation between the PSS and cervical right rotation



Appendix I:

Functional Questionnaire 1 - DASH

DISABILITIES OF THE ARM, SHOULDER AND HAND

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 10 lbs).	1	2	3	4	5
12. Change a lightbulb overhead.	1	2	3	4	5
13. Wash or blow dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover sweater.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g., cardplaying, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

Functional Questionnaire 1 – DASH (continued)

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
22. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? *(circle number)*	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? *(circle number)*	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(circle number)*

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(circle number)*	1	2	3	4	5

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. *(circle number)*	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE = $\left[\left(\frac{\text{sum of n responses}}{n}\right) - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may not be calculated if there are greater than 3 missing items.

Appendix II:

Functional Questionnaire 2, Part 1, PSS

The Penn Shoulder Score, Part 1: Pain and Satisfaction Subscales

Please circle the number closest to your level of pain or satisfaction	Office Use Only
Pain at rest with your arm by your side: 0 1 2 3 4 5 6 7 8 9 10 No pain — Worst pain possible	______ (10 – # circled)
Pain with normal activities (eating, dressing, bathing): 0 1 2 3 4 5 6 7 8 9 10 No pain — Worst pain possible	______ (10 – # circled) (Score 0 if not applicable)
Pain with strenuous activities (reaching, lifting, pushing, pulling, throwing): 0 1 2 3 4 5 6 7 8 9 10 No pain — Worst pain possible	______ (10 – # circled) (Score 0 if not applicable)
Pain score:	=____/30
How satisfied are you with the current level of function of your shoulder? 0 1 2 3 4 5 6 7 8 9 10 Not satisfied — Very satisfied	____/10 (# circled)

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Functional Questionnaire 2, Part 2, PSS

The Penn Shoulder Score: Function Subscale

Please circle the number that best describes the level of difficulty you might have performing each activity	No difficulty	Some difficulty	Much difficulty	Can't do at all	Did not do before injury
1. Reach the small of your back to tuck in your shirt with your hand	3	2	1	0	X
2. Wash the middle of your back/hook bra	3	2	1	0	X
3. Perform necessary toileting activities	3	2	1	0	X
4. Wash the back of opposite shoulder	3	2	1	0	X
5. Comb hair	3	2	1	0	X
6. Place hand behind head with elbow held straight out to the side	3	2	1	0	X
7. Dress self (including put on coat and pull shirt off overhead	3	2	1	0	X
8. Sleep on affected side	3	2	1	0	X
9. Open a door with affected arm	3	2	1	0	X
10. Carry a bag of groceries with affected arm	3	2	1	0	X
11. Carry a briefcase/small suitcase with affected arm	3	2	1	0	X
12. Place a soup can (1-2 lb) on a shelf at shoulder level without bending elbow	3	2	1	0	X
13. Place a one gallon container (8-10 lb) on a shelf at shoulder level without bending elbow	3	2	1	0	X
14. Reach a shelf above your head without bending your elbow	3	2	1	0	X
15. Place a soup can (1-2 lb) on a shelf overhead without bending your elbow	3	2	1	0	X
16. Place a one gallon container (8-10 lb) on a shelf overhead without bending your elbow	3	2	1	0	X
17. Perform usual sport/hobby	3	2	1	0	X
18. Perform household chores (cleaning, laundry, cooking)	3	2	1	0	X
19. Throw overhand/swim/overhead racquet sports (circle all that apply to you)	3	2	1	0	X
20. Work full-time at your regular job	3	2	1	0	X

SCORING
Total of columns = ____ (a)
Number of Xs × 3 = ____(b), 60 – ____(b) = ____ (c) (if no Xs are circled, function score = total of columns)
Function Score = ____(a) ÷ ____(c) = ____ × 60 ____/60

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