CHRONIC PAIN AND DISABILITY ONE YEAR AFTER BREAST CANCER SURGERY (BCS): EVALUATING THE PSYCHOMETRIC PROPERTIES OF THE DISABILITIES OF THE ARM, SHOULDER, AND HAND (DASH) QUESTIONNAIRE

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ABSTRACT

The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire is increasingly used to assess upper-extremity disability following breast cancer surgery, despite limited psychometric evaluation in this population. This study evaluated the psychometric properties of the DASH in 133 women one-year following BCS. Item-level analyses identified substantial ceiling effects, non-normal distributions, and limited sensitivity for several items. Confirmatory factor analyses demonstrated poor fit with previously proposed DASH structures. Exploratory factor analysis identified a clinically meaningful four-factor solution reflecting gross motor function, fine motor function, shoulder range of motion, and sensory and motor symptoms. Several poorly performing items demonstrated high missingness, ceiling effects, and failed factor loadings, supporting item removal. These findings informed development of the 28-item Disabilities of the Arm, Shoulder and Hand-Breast Cancer Surgery Questionnaire (DASH-BCS), which demonstrated strong internal consistency and evidence of convergent and divergent validity.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ALND	Axillary Lymph Node Dissection
ASA	American Society of Anesthesiologists
BCS	Breast Cancer Surgery
BPI	Brief Pain Inventory
BPS	Biopsychosocial
CBCSP	Chronic Breast Cancer Surgery Pain
CAM	Confusion Assessment Method
CCI	Charlson Comorbidity Index
CES-D	Center for Epidemiologic Studies – Depression Scale
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
COSMIN	Consensus-based Standards for the Selection of Health Measurement Instruments
CPAQ	Chronic Pain Acceptance Questionnaire
DASH	Disabilities of the Arm, Shoulder, and Hand
DASH-BCS	Disabilities of the Arm, Shoulder, and Hand – Breast Cancer Surgery
DASH-30	30 Item – Disabilities of the Arm, Shoulder, and Hand
DASH-32	32 Item – Disabilities of the Arm, Shoulder, and Hand
R-DAS	Dyadic Adjustment Scale
EFA	Exploratory Factor Analysis
ESAS	Edmonton Symptom Assessment System
ECR	Experiences in Close Relationships Inventory
FACIT-Sp-12	Functional Assessment of Chronic Illness Therapy – Spiritual Wellbeing 12
ICF	International Classification of Functioning, Disability, and Health
IES-R	Impact of Event Scale – Revised
IRT	Item Response Theory
KMS	Kansas Marital Satisfaction Scale
KPI	Karnofsky Performance Index
MCAR	Missing Completely at Random
MOS-SS	Medical Outcomes Study Social Support Survey
MPI	Multidimensional Pain Inventory Caregiver Responses Scale
MSH	Mount Sinai Hospital
PASS	Pain Anxiety Symptoms Scale Short-Form
PAQ-R	Pain Attitudes Questionnaire Revised

PCS	Pain Catastrophizing Scale
PHQ	Pain History Questionnaire
QuickDASH	Short-Form Disabilities of the Arm, Shoulder, and Hand
RA	Research Assistant
RMSEA	Root Mean Square Error of Approximation
SAT	Satisfaction with Pain Control
SF-12	Medical Outcome Study Short-Form 12
SF-12 MCS	Mental Health Component Score
SF-12 PCS	Physical Health Component Score
SF-MPQ	Short Form McGill Pain Questionnaire
SF-NPQ	Neuropathic Pain Questionnaire-Short Form
SLND	Sentinel Lymph Node Dissection
SOMC	Short Orientation-Memory-Concentration Test
SRMR	Standardized Root Mean Square Residual
STAI	State-Trait Anxiety Inventory
TLI	Tucker–Lewis Index
UHN	University Health Network
WHO	World Health Organization

INTRODUCTION

Approximately 1 in 8 women will be diagnosed with breast cancer in their lifetime[1,2]. Surgery is the most common treatment for this type of cancer[2]. Acute pain is expected post-operatively[3,4] and usually resolves after a few weeks[4]. However, over half of women continue to experience pain for an extended period of time after breast cancer surgery (BCS)[5,6], becoming chronic in nature. Predictors of chronic pain after BCS include higher intensity acute postoperative pain, younger age, emotional distress, and more invasive surgery type[3,6–8]. Chronic pain experienced post-BCS may limit participation in activities of daily living and reduce quality of life[9,10]. In addition to chronic pain, over half of the women experience physical impairments such as arm and shoulder pain, limited range of motion, lymphedema, and reduced grip strength, lasting up to two years after BCS[11]. Despite this, disability following BCS remains underdiagnosed, undertreated[12] and understudied, with long-term follow up rare. Due to the biopsychosocial nature of predictors of chronic pain and disability after BCS, the biopsychosocial model of health may offer a valuable approach to further assess these predictors for women undergoing BCS.

The Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH)[13] is a 30-item self-report measure that is becoming increasingly popular to assess upper extremity disability in this population[14]. Although it has been validated for patients experiencing postoperative, acute, and chronic shoulder pain and dysfunction not related to BCS[14,15], it has not yet been extensively validated for women with breast cancer, specifically post-BCS[16,17]. In the current study, the DASH was psychometrically evaluated for use among women who undergo BCS. This research will determine the appropriateness of a widely used disability measure which is essential to

future studies in this population. In addition, it will enhance our knowledge of disability in women who undergo BCS.

Breast Cancer Surgery

In 2026, approximately 32,400 women in Canada will be diagnosed with breast cancer, and 89% of these women will survive for at least five years[1]. About 83% of women diagnosed will be over 50 years old[18]. Surgery is the most common treatment received by women with breast cancer[2]. In Ontario, approximately 87% of women diagnosed with breast cancer undergo BCS[2], either lumpectomy or mastectomy. A lumpectomy removes a small portion of breast tissue, including the tumor and some surrounding tissue[19]. In a mastectomy, all the breast tissue is removed unilaterally (one breast) or bilaterally (both breasts)[20]. Depending on the type of mastectomy, the nipple, areola, as well as varying portions of the axillary lymph nodes and chest wall could be removed[20]. To remove axillary lymph nodes, an axillary lymph node dissection (ALND) can be performed independently or alongside a lumpectomy or mastectomy[21]. In an ALND, lymph nodes are removed from the underarm area to check for or remove cancerous cells[21]. In the current study, women were scheduled for unilateral or bilateral modified radical mastectomy (entire removal of the breast including tissue, skin, nipple, and areola with ALND) or lumpectomy with ALND. The inclusion of women undergoing both surgical procedures allowed us to investigate a broader range of upper-extremity outcomes following BCS[22].

Pain Following BCS

Pain is a negative sensory and emotional experience in response to actual or potential tissue damage[23]. The individual experience of pain varies based on biological, social, and

psychological factors[24]. Following BCS, acute pain is relatively common due to the invasive nature of the procedure and can be expected to last several days to several weeks[4]. Common symptoms include pain, reduced strength, lymphedema, and limited range of motion[4,25]. Lymphedema is the build-up of lymph fluid in the body, which results in swelling and discomfort[26]. Over half of women report severe acute postoperative pain after BCS[25]. Up to 60% of women continue to experience pain for an extended period of time after BCS[5,6], becoming chronic in nature. Chronic breast cancer surgery pain (CBCSP) is typically defined as persistent pain three months after BCS[6]. Jung et al[27] describe CBCSP as being nociceptive (injury to a ligament or muscle), neuropathic (injury to the nervous system), or a combination of nociceptive and neuropathic with neuropathic pain most common[27]. CBCSP is typically experienced near the area of surgery, such as in the breast, chest, arm, or armpit[28]. It has been associated with poorer quality of life, functional impairment, and psychosocial distress[7,9].

Disability Following BCS

Disability is defined as any physical or mental impairments that may impact ability to perform daily activities and participate in society[29]. Two years after BCS, over half of women report ongoing impairments including arm and shoulder pain, limited range of motion, reduced grip strength, and lymphedema [11]. Hack et al[30] use the term chronic 'arm morbidity' to refer to functional disability post-BCS. About 75% of women who experience chronic pain after BCS report the pain either slightly or moderately affects their everyday lives[31], limiting participation in activities of daily living and reducing quality of life[9,10]. As such, it meets the criteria for a disability. Given the high rate of survival and the predominance of surgical treatment [4], many women are living with chronic BCS-related pain and disability. Yet, the long-term impact of

disability and predictors of disability after BCS remains understudied[11,12], highlighting the need for psychometrically sound measures that can accurately capture upper-extremity disability in this population.

Models of Pain

Previous models of pain, such as the specificity theory of pain, proposed a direct one-to-one relationship between injuries and pain, where pain responses were sent from receptors on the skin, to the spinal cord, then to a pain centre in the brain[32]. This theory failed to account for pain variability and the role of psychosocial factors[32]. Following this, the gate control theory, proposed in 1965[33], began to consider the psychological influences on individual pain experience. Specifically, the gate control theory suggested that the spinal cord had a 'gate' that would either block or allow signals from the periphery to be carried to the brain[32]. This suggested that pain was not only influenced by peripheral sensory input, but also by the brain[33]. The brain plays a complex, selective role in the gate-control system based on past and current experiences[33]. For example, psychological factors such as emotions could influence whether pain signals are inhibited or facilitated[34]. The gate control theory provided an early framework for understanding why individuals with similar physical injuries may experience substantially different levels of pain than others, and helped establish the importance of psychological processes in pain perception[33].

The biopsychosocial (BPS) model of pain recognizes the reciprocal interaction between biological, psychological, and social factors on individual health[35]. Such factors can include age, depression, and socioeconomic status. The BPS model has progressed from previous models on pain and builds off the Gate Control Theory by further emphasizing the individual experience of

pain as a result of the dynamic interaction between biological, psychological, and social factors[35]. The BPS model of pain is now the most widely accepted model to describe the variability of pain[35].

Recent literature supports the biopsychosocial nature of cancer pain[7,36,37] as well as chronic pain[35]. Many predictors of these types of pain are biological, psychological, and social factors[7,31,35]. Various studies have taken a BPS approach to BCS pain specifically. These studies have found that for BCS specifically, factors in the BPS domain play a significant role in long-term pain-related disability in women following BCS, such as age, surgery type, and depression[38–40]. Therefore, a BPS approach is needed to enhance the literature in the field, while most accurately describing chronic pain after BCS.

Models of Disability

The biomedical model of disability views disability in terms of the impairment that it causes an individual[41]. Specifically, it views disability as something that is caused by the health condition or disease of the individual and that requires medical care[42]. Although this model is widely used, the labelling of disabled individuals based on their bodily function can lead to isolation[41,43] and can create negative perceptions regarding disability[44].

Alternatively, the social model of disability views disability as a socially created phenomenon[45]. It distinguishes between a physical impairment versus a disability, suggesting that a disability occurs when an individual with an impairment encounters social or environmental barriers that restrict them from participating in society[46]. The social model understands that disability is not at the individual level, but instead needs societal level action as well as environmental changes for individuals with impairments to be able to participate in

society[41,45]. Limitations to the social model include the lack of differentiation between individuals with disabilities and failing to account that an impairment is an aspect of an individual's lived experience[47]. The biomedical and social disability models are not frequently used as a framework to explain the phenomenon of cancer pain and upper-extremity disability.

More recently, the World Health Organization (WHO) developed a BPS model of disability that is currently more widely accepted[48]. The International Classification of Functioning, Disability, and Health (ICF) views disability as a multidimensional construct influenced by the interaction between impairments in bodily functions, limitations in activities, participation in society, and environmental factors[49]. This framework is particularly relevant to the current study due to the literature supporting the BPS nature of BCS pain and upper-extremity disability[7,39,50]. For the purposes of this study specifically, upper-extremity disability is defined as limitations in upper-extremity functioning that may involve physical symptoms and impairments, difficulty performing daily activities, and restrictions in participation of activities following BCS. Furthermore, as the current study will focus on a range of biopsychosocial factors, the BPS model of pain and disability will be adopted.

Factors Associated with Disability and Pain Following BCS

Acute Pain Post-Operatively

Several studies have found that more intense acute postoperative BCS pain increases the risk of developing chronic pain[3,6]. Specifically, women who experience moderate to severe acute pain after BCS are at greater risk than those who experience mild acute pain of developing chronic pain[8]. Several factors have been associated with a higher intensity of acute pain post-BCS, such as younger age, longer duration of surgery, more invasive surgery such as ALND,

preoperative anxiety, and being unmarried[8,51]. Katz et al[51] measured biopsychosocial factors 2, 10, and 30 days post-BCS. They found younger age, being unmarried, and preoperative anxiety predicted acute pain in their sample of 114 women[51]. Unfortunately, this study did not look at outcomes beyond 30 days[51]. Wang et al[6] conducted a systematic review and found high-quality evidence suggesting that greater acute pain post-BCS is associated with developing chronic pain over two months after surgery. Although the relationship between acute pain and chronic pain after BCS is well established, there is a lack of long-term follow-up, with little to no research on the relationship between acute pain and long-term disability directly.

Surgery Type

Some studies have found that more invasive surgeries can increase the risk and intensity of both acute and chronic pain after BCS[7,51]. Specifically, ALND has been associated with a higher risk of developing CBSCP[6]. In their systematic review, Wang et al[6] found high-quality evidence supporting this relationship. Sagen et al[52] found that women who underwent ALND had worse outcomes than women who underwent Sentinel Lymph Node Dissection (SLND) in terms of lymphedema, grip strength, shoulder mobility, pain intensity during shoulder abduction, and BMI 2.5 years after BCS[52]. SLND is a minimally invasive removal of cancerous cells, where lymph nodes are removed in a more specific area compared to ALND[53]. BCS that is accompanied by ALND may double the chance of developing CBSCP[54]. Initial evidence has suggested that sentinel lymph node biopsy may reduce the risk of CBCSP[55]. In the current study, all of the participants underwent an ALND. This study will provide important knowledge regarding chronic pain and disability following ALND.

Chronic Pain

Women who experience chronic pain after BCS are more likely to have a decreased health-related quality of life, which includes biological as well as psychosocial symptoms[7]. Chronic pain following BCS has been associated with high levels of physical disability[31]. Specifically, Tasmuth et al[31] found that out of 569 women who underwent a modified radical mastectomy with axillary evacuation or breast resection with axillary evacuation, half developed chronic pain that impacted their life on a daily basis, resulting in disability. Chronic pain and disability are highly related, as chronic pain can be a symptom of disability[56,57]. For example, Steven et al[58] found that in a study of 95 women after BCS, 20% reported chronic pain. For some of these women, their pain interfered with their everyday activities[58]. Specifically, some reported having to reduce to part-time work, while others could not work at all and received disability benefits[58]. Given the relationship between chronic pain and physical disability following BCS, it is important that measures used to assess upper-extremity disability adequately capture the functional consequences experienced by this population.

Age

Recently, it has been found that age may be a predictor of the type of surgery received, with older patients being more likely to have a more invasive surgery as well as ALND[59]. Another study found that younger women tend to have more aggressive treatments[60]. Definitions of "younger" and "older" women vary across studies[61].

Younger age may be associated with both acute and chronic pain after BCS[6,7]. Miaskowski et al[62] classified three groups of persistent pain after breast cancer surgery, consisting of no pain, mild pain, and moderate pain. They found that compared to the no pain

group, women in the moderate pain group were younger[62]. Younger women consistently have been found to have an increased risk than older women of psychological distress after being diagnosed with breast cancer[60,63–65]. This includes anxiety, depression, and pain catastrophizing[60,63,64]. Pain catastrophizing can be defined as ruminating about pain or over exaggerating the threat of pain[66] and can influence pain outcomes negatively[67,68]. However, the age-related differences between psychological symptoms and BCS remain unclear.

Similarly, the relationship between age, pain and upper-extremity disability are not well established. Overall quality of life may be poorer in older than younger patients after breast cancer [69]. Specifically, Park et al[69] found significant age-related differences in factors such as physical well-being and social well-being. In another study, Avis et al[70] found that compared to older women, younger women had a significant risk for poor quality of life several years after breast cancer diagnosis.

Older women are more likely to become disabled than younger women after the age of 40[71]. Among women treated for breast cancer, older age and the presence of comorbidities have been associated with greater declines in physical functioning following treatment[72]. However, the influence of specific treatment types on these age-related differences remains unclear[72], and age-related differences in upper-extremity disability specifically following breast cancer surgery remain understudied.

Psychological and Psychosocial Factors

The relationship between psychological symptoms and breast cancer surgery pain remains unclear. Some studies have found that preoperative anxiety is a predictor of acute pain[51]. Katz et al[51] found that preoperative anxiety independently contributed to acute pain from 2 to 30

days post-BCS. However, other studies have found that preoperative emotional functioning did not predict the intensity of chronic pain after BCS[7]. Poleschuk et al[7] found that in a sample of 114 women, psychological well-being measures did not predict development or intensity of chronic pain post-BCS. Follow-ups were conducted 2 days, 10 days, 1, 3, 7, and 12 months after surgery[7]. The role psychological factors may play in the development of upper-extremity disability remains unclear in the literature.

Additionally, psychosocial factors such as attachment styles and spiritual wellbeing may also play a role in BCS-related outcomes[73,74]. Attachment style refers to the patterns of thoughts, feelings, and behaviours within interpersonal relationships[75]. Attachment anxiety, defined as heightened fears of rejection and concerns regarding the availability of close others[75], has been associated with poorer quality of life and unmet supportive care needs among women with breast cancer[73]. Attachment avoidance, defined by discomfort with closeness and dependence on others[75], has also been associated with psychological distress following breast cancer surgery[73]. Although these relationships have been identified, the exact nature of these relationships remains unclear. Importantly, for this study, attachment anxiety, attachment avoidance, and spiritual well-being represent psychosocial constructs that are theoretically distinct from physical upper-extremity function[73,74] and were included to assess relationships between upper extremity disability and broader psychosocial factors.

Measuring Upper-Extremity Disability

Upper-extremity disability can be assessed using both objective clinical measures and patient-reported outcome measures (PROM). Objective assessments, including shoulder range of motion, grip strength, and physical performance testing, provide valuable information regarding

specific impairments following breast cancer surgery [76]. However, these measures do not necessarily provide the entire picture. While objective measures can provide an idea of a patient's anatomy, PROMs allow for a understanding of how a patient functions on biopsychosocial and multidimensional levels [76]. For example, women with similar shoulder range of motion may report substantially different levels of functional limitation because of pain, fatigue, sensory disturbances, compensatory movement strategies, or differences in activity demands[14,30,77].

PROMs complement objective assessments by capturing the patient's perception of symptoms and functional ability during everyday activities[78]. Consequently, PROMs have become an essential component of breast cancer rehabilitation research and clinical practice because they provide information that cannot be obtained through impairment-based measures alone[78]. However, the usefulness of any PROM depends on its psychometric quality. A questionnaire must demonstrate adequate reliability and validity within the population in which it is intended to be used before scores can be interpreted with confidence[79,80].

Psychometric Evaluation of Patient-Reported Outcome Measures (PROM)

Psychometric evaluation examines the measurement properties of an instrument, such as a PROM, to determine whether it reliably and validly measures the construct it is intended to assess[80]. In addition to reliability and validity, item-level analysis can be conducted to assess how individual items perform in a specific population, such as the distribution of responses and the presence of floor or ceiling effects. Floor effects occur when a large portion of the sample selects the worst possible response on the scale item[81], and ceiling effects occur when most of the sample selects the best possible response on the scale item[81].

Reliability refers to the degree to which a measure produces consistent and reproducible scores[80]. One aspect of reliability is internal consistency, which reflects the degree to which items on a scale are related to one another[80]. Cronbach's alpha is a commonly used measure of internal consistency in the literature, where higher values indicate greater levels of interrelatedness of items on a questionnaire[79,82].

Validity refers to the extent to which a measure accurately measures the construct it is intended to measure[80]. Validity encompasses several related components, all of which assess different aspects of validity. Face validity is the extent to which items in a measure subjectively appear to measure the construct that they are intended to[80]. For example, a measure intended to assess upper-extremity disability following BCS should include items that are relevant to the functional difficulties experienced by women in this population. Structural validity refers to the degree to which the scores of a measurement instrument adequately reflect the uni- or multi-dimensional nature of the construct being measured[80]. That is, it examines whether the items reflect a single underlying construct or multiple distinct dimensions of a construct[83]. Structural validity is most often evaluated using techniques such as confirmatory and exploratory factor analysis[84]. Construct validity examines whether scores demonstrate expected relationships with other measures based on theoretically derived hypotheses. This includes convergent validity, in which scores are expected to correlate with measures assessing similar or related constructs, and divergent validity, in which weaker relationships are expected with measures assessing theoretically distinct constructs[80]. Together, these measurement properties provide evidence regarding whether an instrument produces reliable and meaningful scores for its intended population and purpose[79,80].

Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH)

Development of the DASH

The DASH is a 30-item PROM questionnaire that is commonly used to assess upper extremity disability through a self-reported 5-point Likert scale[13]. The questionnaire was released in 1996 as a joint collaboration between the American Academy of Orthopedic Surgeons, the Council of Musculoskeleta1 Specialty Societies, and the Institute for Work and Health[13,85]. The DASH was developed to describe and assess change over time in individuals with one or more upper extremity disorders[15]. The conceptual framework in the development of this measure includes two main concepts; functional status and symptomatology[85]. The functional status concept includes a physical, social, and psychological dimension with subcomponents such as daily activities, family care, and self-image[15,85]. Symptoms refers to components such as pain, weakness, stiffness, and tingling/numbness[15,85]. The original development of the DASH assumed that all 30 items measured a single underlying construct of upper-extremity disability, making it unidimensional in nature[15,85].

There also exists a short-form version of the DASH, known as the QuickDASH[86]. It has 11-items and measures the same concepts as the full 30-item DASH measure. For the current study, only the full-length DASH was used.

DASH Scoring

The DASH provides a formula to calculate a final score ranging from 0 to 100. Higher scores indicate greater levels of disability, however, there are currently no cut-off scores for what constitutes as "disabled"[13]. MacLean et al[87] proposed a general guideline where a score lower than 25 indicates no disability, 25-75 indicates some disability, and above 75 indicates extremely

disabled. Medeiros da Luz et al[88] have adopted the same classification. Williams[89] suggests that a score less than 30 is an indication of no disability. Some research is not concerned with the overall score, but instead the clinically meaningful difference in change between scores over time[90] or difference in scores between sample populations[91]. To date, there is no gold standard for interpreting DASH scores.

DASH Development: Psychometric Evaluation

Upon development of the DASH, it was validated for patients with postoperative, acute, and chronic shoulder pain and dysfunction due to an upper limb disorder[15]. Beaton et al[15] found that in a sample of 200 patients with wrist, hand, and shoulder problems, the DASH was able to demonstrate construct validity, test-retest reliability, and responsiveness. It was able to discriminate between groups such as those who were working with a disability and those who were not[15]. The test-retest score was 0.96 over 3-5 days, reflecting good test-retest reliability[15]. The DASH displayed good responsiveness to reflect change over time, before and after treatment[15]. There were no factor analysis conducted[15]. To test construct validity, the DASH was correlated with other measures of upper limb functioning that were expected to be highly related[15]. Although the DASH has been validated for a general population with upper limb dysfunction, these findings cannot be applied confidently to the BCS population. In addition to assessing psychometric properties, questionnaires need to be validated for each population separately to assess the measures' effectiveness in the intended population[92].

Current DASH Validity and Reliability Studies

Since the initial development of the DASH in 1996[85], there have been several studies assessing its psychometric properties. These studies have reported mixed findings in regard to the DASH's validity and reliability. While some have reported good reliability, responsiveness, and construct validity in populations including individuals with rheumatoid arthritis, shoulder disorders, hand injuries, and other upper-extremity musculoskeletal conditions[93,94], other studies have questioned the unidimensional structure that was previously proposed[95,96]. Several investigations have identified multidimensional factor structures, with most proposed solutions suggesting three factors[95–97]. However, some have also suggested a potential four-factor model, with further investigation needed[98]. Although these studies consistently suggest that the DASH may measure multiple related domains of upper-extremity disability rather than a single construct, the proposed factor structures have differed across studies and clinical populations. Most psychometric evaluations of the DASH have been conducted in orthopedic or musculoskeletal populations, including individuals with shoulder disorders, fractures, tendon injuries, and arthritis[94–96]. Other investigations have reported acceptable fit of the original one-factor structure, particularly among individuals with rheumatoid arthritis[94]. These findings suggest that the dimensionality of the DASH remains unclear and may vary according to the population in which it is used.

DASH and BCS

The DASH is becoming increasingly popular in studies of BCS-related impairment[14]. MacLean et al[87] analyzed the relationship between arm morbidity and disability 6-12 months after BCS. Harrington et al[14] conducted a cross-sectional study to observe the relationship of

upper extremity strength and range of motion (ROM) to disability after BCS. Both of these studies found DASH scores were significantly correlated with decreased functional arm strength and ROM[77,87]. However, as the DASH has not yet been validated for BCS specifically[16,88] , interpretation of these findings is limited.

Little is known about how the questionnaire performs psychometrically among women following BCS, despite its widespread use within breast cancer rehabilitation research. Existing validation studies of the DASH in breast cancer populations have generally focused on internal consistency, test-retest reliability, and convergent validity of the DASH or QuickDASH[99–101], while structural validity, item performance, and dimensionality have received limited attention.

Most studies have assumed that the original DASH structure is transferable across populations[77]. However, it is possible that upper-extremity disability following BCS may be organized differently than in the orthopedic and musculoskeletal populations in which the DASH was originally developed. According to the Consensus-based Standards for the Selection of Health Measurement Instruments (COSMIN), psychometric properties should be evaluated within the population in which an instrument is intended to be used, rather than assuming that evidence from one clinical population is transferable to another[79,80]. Women following breast cancer surgery experience a unique combination of pain, shoulder mobility limitations, sensory disturbances, treatment-related fatigue, and lymphedema that differs from the impairments typically observed in orthopedic populations[11]. These differences may influence how questionnaire items are interpreted and how well the original DASH structure reflects upper-extremity disability in this population. Furthermore, a thorough psychometric evaluation of the DASH in women following breast cancer surgery is warranted to determine whether the instrument can demonstrate validity and reliability in this population.

Modification of the DASH for the Current Study

For the current study, the original 30-item DASH (DASH-30) has been modified with the addition of two items: (14. a) "Touch your back on the same side as your surgery;" and (14. b) "Touch your back on the opposite side as your surgery". These items were added to maximize the face validity for the study population based on clinical experience[102]. These items were included to capture functional movements relevant to activities such as fastening or removing a bra, which require behind-the-back reach and components of shoulder internal rotation[103], and may not be fully represented by the original DASH-30 items. The items were composed and edited to consensus by the research team, creating a 32-item DASH (DASH-32).

Rationale for the Current Study

Many women experience pain and upper-extremity disability following BCS[30], which can interfere with daily activities and impact quality of life[7]. Measures that are both valid and reliable are essential to accurately assess and understand BCS-related upper-extremity disability[80]. However, there are currently mixed findings regarding the DASH's psychometric properties, and it has not yet been extensively evaluated for the BCS population[85,86,95,97,98,101]. As the DASH is increasingly administered in BCS populations, it is critical to ensure it is appropriate for use[14]. Given this, the current study extensively assessed the psychometric properties of the DASH-30 and DASH-32 for BCS one-year after surgery, an important step in addressing the present gap in our knowledge about the DASH and enabling interpretation of existing research and enhancing the quality of future research into BCS-related disability.

OBJECTIVES

1) Evaluate the psychometric properties of the DASH-32 for women with breast cancer.
    a. Analyze item-level psychometric properties of the DASH-32.
    b. Assess internal consistency reliability of the DASH-32 scores.
    c. Evaluate the DASH-32 for construct validity.
2) Develop validated DASH-BCS
    a. Assess internal consistency reliability and convergent and divergent validity.

METHODS

Study Design and Setting

A longitudinal study collected measures of pain, physical function, well-being, and psychosocial factors pre-operatively and post-operatively for two years following BCS (Canadian Cancer Society Research Institute Grant no. 18367). The current study performed a sub-analysis of the data collected from the larger BCS study. Ethics approval was obtained from York University (#07-0553), Mount Sinai Hospital (MSH), and the University Health Network (UHN).

Sample, Inclusion and Exclusion Criteria

The sample consisted of 300 women scheduled for unilateral or bilateral modified radical mastectomy or lumpectomy with ALND who were recruited from UHN (Princess Margaret Cancer Centre and Toronto General Hospital), and MSH.

Inclusion Criteria

Participants were ≥ 18 years old, able to read and write English, and had an American Society of Anesthesiologists (ASA) Physical Status Classification System Class 1 to 3 (ASA Class 1=normal healthy patient; ASA Class 2=patient with mild systemic disease; ASA Class 3=patient with severe systemic disease; American Society of Anesthesiologists, 2020).

Exclusion Criteria

Participants were excluded from the study if they had: significant CNS, respiratory, cardiac, hepatic, renal or endocrine dysfunction and/or any significant sequelae; contraindications to opioids, acetaminophen or Tylenol 3; documented DSM-IV Axis I disorder

or cognitive dysfunction; documented substance abuse or dependence within 1 year; pregnancy or breastfeeding within 6 months or use of exogenous hormones in regularly menstruating women (e.g., oral contraceptives or hormone replacement therapy) within 3 months; immunization within 30 days; blood donation within 60 days; acute or infectious illness, allergic reactions, herbal supplements, physical injuries or dental work within 2 weeks.

Procedure

Acronyms are used to describe all measures administered as part of the larger BCS study. A complete list of measures and corresponding abbreviations is provided in the List of Abbreviations (pages vii-viii). Measures included in the current study are described in further detail in the following section.

Pre-Admission Assessment

Participants were recruited one week before scheduled surgery and informed consent was obtained. Eligibility was recorded for each patient based on the inclusion and exclusion criteria. A research assistant (RA) administered the SOMC to eligible participants. The SOMC is a brief test that measures cognitive impairment (>10 errors indicate cognitive impairment)[104]. If the patient's score was indicative of cognitive impairment, they were withdrawn from the study. For the remaining participants, demographic information was collected and the PHQ, SF-MPQ, SF-NPQ, NRS-R, NRS-M and ESAS were administered. The RA completed a physical examination protocol (i.e. BMI, blood samples, bilateral range of motion, bilateral grip strength) and completed the CCI and KPI for the participant. The BPI, SF-12, STAI, PASS, PCS, CES-D were given to participants to take home and return on the date of their scheduled surgery.

Day of Surgery

If any participants did not complete the pre-admission questionnaires, they were withdrawn from the study. The remaining participants completed the SF-MPQ, NRS-R, NRS-M, STAI-S, and ESAS. Analgesic use within the last 24 hours was recorded prior to surgery. The CAM was administered by the RA 6 hours and 24 hours after surgery. Participants whose CAM score indicated delirium were withdrawn from the study.

Post-Operative Follow-Up

Follow-ups occurred at 1 week ± 1 day, 6 weeks ± 2 weeks, 3 months ± 2 weeks, 6 months ± 2 weeks, 1 year ± 3 months and 2 years ± 3 months after surgery. This analysis will primarily be concerned with the 1-year follow-up assessment. Participants were contacted by phone or e-mail to schedule the follow-ups. Depending on the participants' preference, follow-ups were conducted at UHN, in their home, or over the phone. The RA began each assessment with the SOMC, and participants with >10 errors were withdrawn. Eligible participants completed the NRS-R, NRS-M, ESAS and SAT with the RA. The RA completed the CCI and recorded information about arm function, wound healing, additional surgeries, analgesic use, and sensations other than pain (i.e. numbness). Participants were provided with a questionnaire package to complete at home and return by mail. The package consisted of the DASH, SF-MPQ, NRS-R, NRS-M, SAT, BPI, SF-NPQ, ESAS, SF-12, PASS, STAI-S, PCS, CES-D, FACIT-Sp-12, PAQ-R, IES-R, MOS-SS, ECR, KMS, R-DAS, CPAQ, and the MPI.

Primary Outcome Measure

For this study, only a subset of the measures at one-year post-BCS were used. These measures have well-established relationships to disability and functional impairment in the literature and were used to assess the psychometric properties of the DASH. Demographic data were collected at the pre-operative assessment. All other data were collected at the assessment corresponding to one-year postoperatively.

Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH)

The DASH is 30-item questionnaire that measures participants' physical functioning and symptoms related to the upper limbs (Appendix 1). Participants rate their ability to carry out certain movements or tasks on a scale from 1-5, where 1= "no difficulty", and 5= "unable". The DASH has two optional sections, the "work module" and the "sports/performing arts module". These sections contain an additional 4 items targeted towards disability impacting work performance and musical instrument and sport performance, respectively. The optional modules were not used in the current study. The score is calculated based on the sum of responses, which equates to a final score out of 100. Higher scores indicate greater levels of disability. It has been validated for participants with postoperative, acute, and chronic shoulder pain and dysfunction[14,15]. The proposed study employs the DASH-32 which has two additional items specific to disability often reported by women following BCS, 14a "Touch your back on the same side as your surgery") and 14b ("Touch your back on the opposite side as your surgery"). The DASH-30 scoring formula is based on the mean item response and accounts for the number of items included, allowing the DASH-32 to retain a standardized score ranging from 0 to 100[13].

Secondary Outcome Measures

Cognitive Functioning Measures

Short Orientation-Memory-Concentration Test (SOMC)

The SOMC [105] is a 6-item cognitive status measure that takes less than 5 minutes to complete. It has demonstrated good levels of validity and reliability across the lifespan [105] and the ability to detect difference in cognitive performance over time [104]. The SOMC was administered at the pre- and post-operative assessments, and any patients who indicated cognitive impairment were withdrawn from the study.

Confusion Assessment Method (CAM)

The CAM [106] is a brief questionnaire that is used to identify delirium (an acute disturbance in attention, awareness, and cognition that can develop in response to a medical condition or surgery[106]) in users by rating observable behaviours. It has demonstrated adequate levels of validity and reliability in a general population [107]. Any patients who developed delirium were withdrawn from the study 24-hours after surgery.

Pain Measures

Pain intensity at rest (NRS-R) and with movement (NRS-M)

The NRS is an 11-point numerical rating scale (NRS) where participants are asked to report their present pain intensity at rest (NRS-R) and with movement (NRS-M) on a horizontal line numbered from 0 = “no pain” to 10 = “worst possible pain”. For the NRS-R participants were asked to report their pain at rest, whereas for the NRS-M participants were asked to sit up

and take two maximal breaths before reporting their pain. The NRS-R and NRS-M have demonstrated good reliability and validity in both cancer and surgical populations[108,109]. For the current study, the NRS-R was used instead of the NRS-M because it is more frequently used in the literature[110] and can allow for more standardized measurement[110,111].

Brief Pain Inventory (BPI)

The BPI[112] measures the impact of pain on desired activities through 11 items. The BPI produces two separate subscale scores – pain severity and pain interference. For pain severity, items assess pain at its worst, least, average, and current intensity using a numeric rating scale (NRS) from 0 to 10, where 0= "no pain" and 10= "pain as bad as you can imagine". For pain interference, it assesses the extent to which pain interferes with general activity, mood, walking ability, normal work, relationships with others, sleep, and enjoyment of life, where 0= "does not interfere" and 10= "completely interferes". The BPI has been validated for participants with cancer-related pain [113], and specifically for the breast cancer surgery population[114].

Psychological Measures

Functional Assessment of Chronic Illness Therapy – Spiritual Wellbeing 12 (FACIT-Sp-12)

FACIT-Sp-12[74] is a 12-item scale which measures spiritual wellbeing. It measures two domains of spirituality: meaning, peace, and comfort; and the role of faith in illness. The total score ranges from 0-48, with higher scores indicating greater spirituality. The FACIT-Sp-12 has shown good psychometric properties in individuals with cancer[74].

Social Measures

Experiences in Close Relationships Inventory (ECR)

The ECR[115] is a 36-item questionnaire measuring attachment style in close relationships. It consists of two subscales of attachment types: anxiety and avoidance. Participants are asked to respond to questions on a 7-point Likert scale, where 1= "strongly disagree" 7= "strongly agree"[75]. The ECR has good reliability in both chronic cancer and non-malignant pain[115,116].

Physical Functioning Measures

Medical Outcome Study Short-Form 12 (SF-12)

The SF-12[117] is a 12-item questionnaire that assesses health-related quality of life through physical and mental health domains. It produces two scores: the Physical Health Component Score (SF-12 PCS) and the Mental Health Component Score (SF-12 MCS). The SF-12 has demonstrated reliability and validity in participants with breast cancer[117].

Arm Function Measures

Edema, Range of Motion, and Grip Strength

A standardized physical assessment protocol was followed by the RA to measure range of motion, grip strength, and edema on both arms. To assess edema, upper arm and forearm circumference was measured. A measuring tape was placed 10 cm proximal to the olecranon and 15 cm proximal to the processus styloideus ulnae[118]. A goniometer and hand-held hydraulic dynamometer were used to measure bilateral shoulder range of motion (ROM) and bilateral grip strength, respectively.

For ROM, the goniometer measured the range of ‘Right Forward’, ‘Right Side’, and ‘Right Behind’ as labelled in the protocol. The goniometer was placed on the rotator cuff. The participant was instructed to position one of their arms along the vertical body, and then either as far forward, to the side, or behind them, depending on which angle was being measured[119]. This process was repeated on the other arm. For the present study, the three ROM measurements were averaged to create a composite ROM score for each arm[120]. Scores were then classified as ipsilateral or contralateral according to the side of surgery. For grip strength, the participant was asked to squeeze the dynamometer in one hand, then the other hand. This process was repeated three times on each hand. For the current study, an average of the three grip strength tests was created.

DATA ANALYSIS

Descriptive statistics (mean, median, and standard deviation) were calculated for all variables. Continuous variables were checked for normal distribution using histograms. For categorical variables, frequency distributions were calculated. For non-normally distributed variables, medians and interquartile range were calculated prior to transformation. Little's Missing Completely at Random (MCAR) test was used to assess if data were missing completely at random, missing at random, or not missing at random[121]. Data were checked for outliers using boxplots.

Psychometric analyses were conducted sequentially, with subsequent analyses informed by the results of preceding tests. To test Objective 1a, assessment began at the item level. For item-level analyses of the DASH-32, missing responses were retained and not imputed, as patterns of missingness were considered informative[122]. The psychometric properties of the DASH-32 were evaluated by first conducting an item response analysis to assess the distribution of responses across all items. By calculating the percentage of responses in each of the five Likert response categories for each item, this identified any potential floor (defined as greater than 15% of the sample selecting the worst possible response on the scale item[81]) or ceiling effects (defined as greater than 15% of the sample selecting the best possible response on the scale item[81]). For Objective 1b, Cronbach's alpha was calculated to measure internal consistency for all items. Generally, a score of 0.7 to 0.9 indicates acceptable levels of internal consistency[123].

To test Objective 1c, construct validity was measured by conducting a confirmatory factor analysis (CFA) based on one-factor and three-factor models reported in the

literature[13,15,85,95,96] of the DASH-30. The two additional items of the DASH-32 were not included in confirmatory factor analyses, as no a priori factor structure for these items has been established. Missing data were subjected to multiple imputation strategies at the item level for the DASH psychometric analyses. Cases with less than 5% missing responses were imputed employing the Expectation Maximization multiple imputation method to preserve the item covariance structure and reduce unnecessary case loss, consistent with recommendations for multivariate and factor analytic procedures[124,125]. A CFA measurement model was run. Fit indices (e.g., chi-square, degrees of freedom, CFI, TLI, RMSEA, SRMR) were used as an indicator of goodness of fit for the models. Specifically, model fit was first assessed using the chi-square to degrees-of-freedom ratio (χ^2/df), where values below 2 indicate good fit and values below 3 indicate acceptable fit. Comparative Fit Index (CFI) and Tucker–Lewis Index (TLI); for both indices, values ≥ .95 were considered indicative of good model fit, while values ≥ .90 were interpreted as acceptable. For Root Mean Square Error of Approximation (RMSEA), values ≤ .05 reflecting close fit and values ≤ .08 representing acceptable fit. Finally, the Standardized Root Mean Square Residual (SRMR) was examined, where values ≤ .05 were considered excellent, and values ≤ .08 were deemed acceptable.

As these CFA models demonstrated inadequate fit, an exploratory factor analysis (EFA) was conducted to identify a factor structure better suited to the present sample[95]. The two added items (items 14a and 14b) were included in the analysis. The resulting factor solution informed the refinement of the DASH-32 into the DASH-BCS.

To test Objective 2, the four proposed DASH-BCS subscales were then evaluated for internal consistency and for convergent and divergent validity. To test the convergent and divergent validity of the DASH-BCS, Pearson's correlation coefficient was calculated between

variables of interest. Demographic data and data other than the DASH items were not imputed and were subject to listwise deletion in subsequent analyses. This conservative approach was chosen to avoid introducing model-based assumptions into criterion variables and to ensure that observed associations reflected directly measured data rather than imputed estimates, consistent with best practices in measurement validation and missing data analysis[83,126]. For convergent validity, the SF-12 PCS subscale, BPI severity and interference subscales, and arm function measures were used[127]. R values of 0.3 to 0.7 were considered to demonstrate moderate correlations[128]. For divergent validity, the FACIT-Sp-12, ECR Anxiety, ECR Avoidance, and SF-12 MCS questionnaires were used[127]. R values less than 0.2 were considered weak correlations, evidence of divergent validity[128]. All analyses were conducted using R version 2025.05.1+513 and SPSS v. 28.0.1.1.

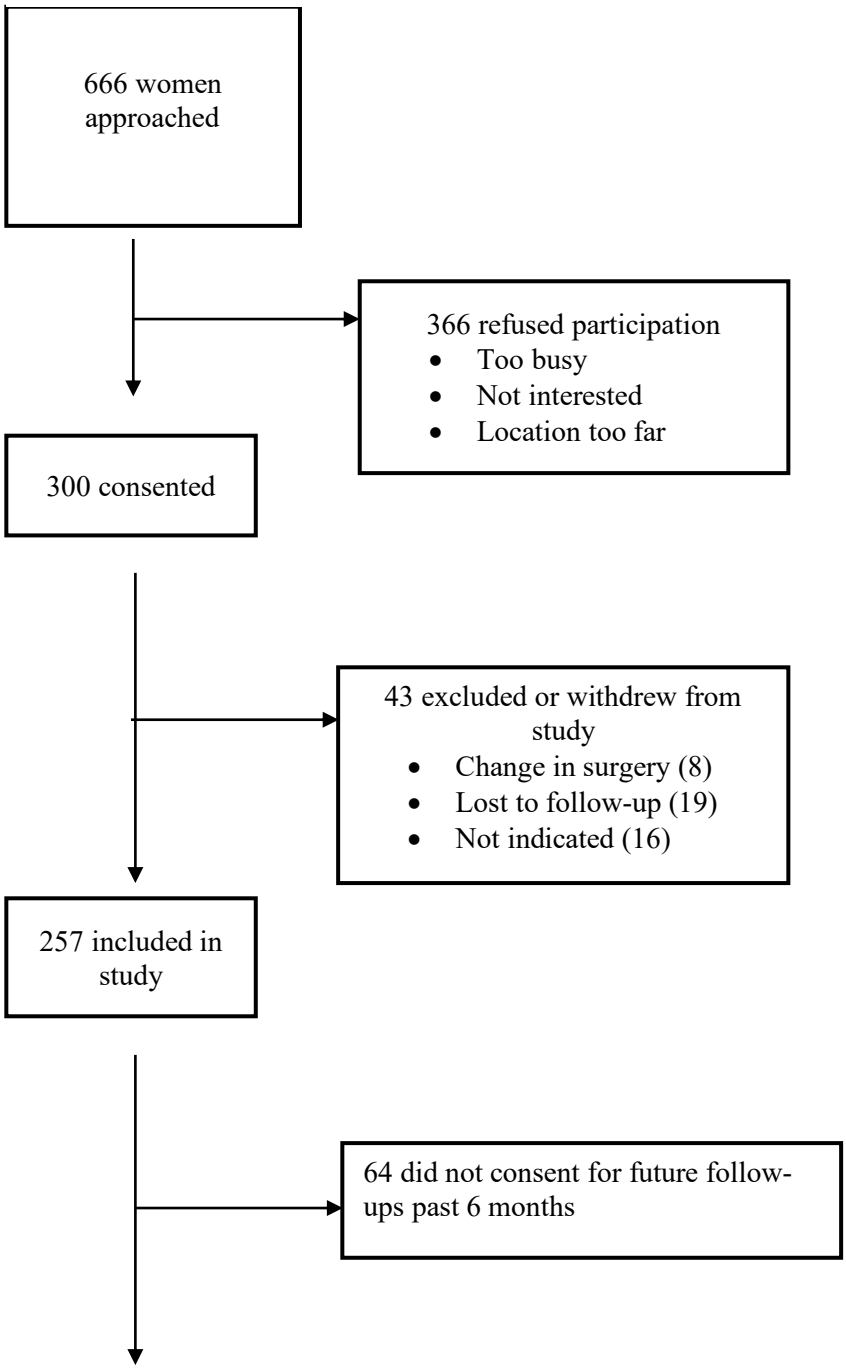
RESULTS

Participant Characteristics

Of the 300 women who consented to participate in the study, 133 (44.3%) were included in the present analysis. Figure 1 displays a flow chart of included participants. Table 1 shows descriptive statistics of the sample population. The mean age of participants was 53.86 years (SD = 11.09), and the mean body mass index (BMI) was 25.84 kg/m² (SD = 4.69). Most participants were partnered (71.4%, n = 95), identified as White (82.8%, n = 110), and reported having children (77.4%, n = 103), with two children being the most common (39.1%, n = 52). Regarding living arrangements, most participants lived with a partner (73.6%, n = 98). Most of the women underwent a lumpectomy (45.9%, n = 61), mastectomy (30.8%, n = 41), or bilateral mastectomy (21.1%, n = 28).

At one-year post surgery, nearly half of participants reported experiencing pain on most days in the last three months (42.9%, n = 57). Pain at rest was reported by 41.4% (n = 55) of participants, with an average score of 1.2 out of 10 on the NRS-R. Most did not undergo other surgeries related to breast cancer (84.2%, n = 112) and had not received breast reconstruction (82.0%, n = 109). Chemotherapy was received by 36.1% (n = 48), radiation by 60.9% (n = 81), and hormone therapy by 66.2% (n = 88). Just over 16% (n = 22) reported being diagnosed with lymphedema. Mean ipsilateral and contralateral arm function range of motion scores were 124 degrees (SD = 17.7) and 129 degrees (SD = 15.1), respectively, while mean grip strength was 26.4 kg (SD = 6.5) on the ipsilateral side and 26.8 kg (SD = 5.8) on the contralateral side.

Figure 1. CONSORT Diagram of Participants



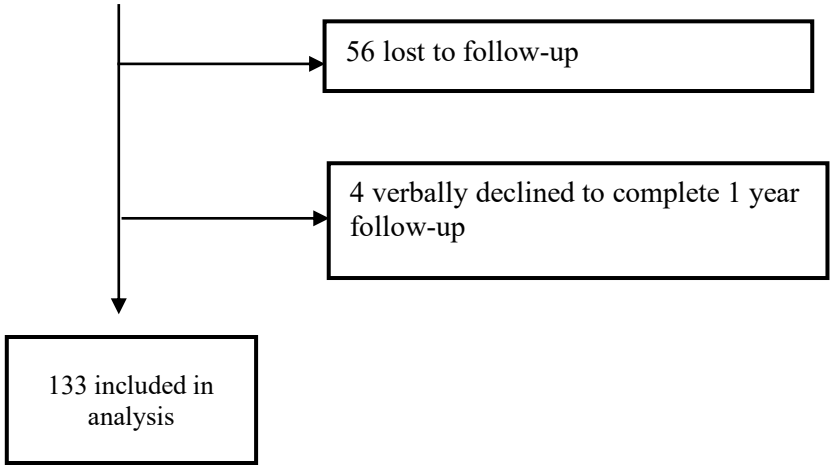


Table 1. Participant Characteristics (n=133)

	n (%) or Mean (SD)	Range	n
Demographic			
Age (years)	53.86 (11.09)		133
Marital status			
Partnered (married/common-law)	95 (71.4)		
Not partnered	37 (27.8)		
Missing	1 (0.8)		
Ethnicity			
White	110 (82.8)		
Non-White	18 (13.5)		
Missing	5 (3.8)		
Have children			
Yes	103 (77.4)		
No	30 (22.6)		
Number of children			
None	30 (22.6)		
One to two	74 (55.6)		
Three or more	29 (21.8)		

	n (%) or Mean (SD)	Range	n
Living arrangement			
With partner (with or without children)	98 (73.6)		
Alone	21 (15.8)		
Other	14 (10.5)		
Working at 1-year post-surgery			
Yes	72 (54.1)		
No	61 (45.9)		
Physical			
Body mass index (kg/m²)	25.84 (4.69)		133
Ipsilateral range of motion (degrees) reported at 1-year	124.0 (17.7)	60-211.67	87
Contralateral range of motion (degrees) reported at 1-year	129.0 (15.1)	102.33-206.67	87
Ipsilateral grip strength (kg) reported at 1-year	26.4 (6.5)	6.33-44.67	86
Contralateral grip strength (kg) reported at 1-year	26.8 (5.8)	12.7-46	87
Medical			
Surgery type			
Lumpectomy	61 (45.9)		
Mastectomy	41 (30.8)		
Bilateral lumpectomy	2 (1.5)		
Bilateral mastectomy	28 (21.1)		
Mastectomy and lumpectomy	1 (0.8)		
Cancer-related treatment reported at 1-year*			
Chemotherapy	48 (36.1)		
Radiation	81 (60.9)		
Hormone therapy	88 (66.2)		
Breast reconstruction reported at 1-year			
Yes	21 (15.8)		
No	109 (82.0)		
Missing	3 (2.3)		
Diagnosed with lymphedema at 1-year			
Yes	22 (16.5)		
No	111 (83.5)		

	n (%) or Mean (SD)	Range	n
Pain			
Pain at rest (NRS-R) at 1-year			
Yes	55 (41.4)		
No	74 (55.6)		
Missing	4 (3.0)		
Average pain intensity (NRS-R) at 1-year	1.2 (1.97)	0-10	129

[a] Values are presented as n (%) for categorical variables and mean (SD) for continuous variables.
[b] Not partnered includes single, separated, divorced, and widowed participants.
[c] Variables marked with an asterisk (*) indicate that categories are not mutually exclusive; participants could report more than one cancer-related treatment.

Item Analysis

Table 2 displays each DASH-32 item with number of missing responses, mean, mode, standard deviation, skewness, kurtosis, and range. Range values indicated that most items covered the full possible scoring span, supporting adequate response spread despite the skewness. However, item-level descriptive statistics for the DASH-32 indicated that mean scores for individual items ranged from 1.13 to 2.10, with most items clustering toward the lower end of the response scale, suggesting possible ceiling effects. Standard deviations ranged from 0.41 to 1.15, indicating limited variability for some items and greater response spread for others. Skewness values were generally positive, indicating that responses were skewed toward lower scores (less difficulty), and several items (e.g., Items 2, 16, 17, 20) exhibited high skewness (>3), suggesting a strong ceiling effect[129]. Kurtosis values ranged widely, with some items displaying pronounced positive kurtosis, suggesting peaked distributions and limited variability in responses. Item 21 “Sexual activities” had the largest number of missing responses (n=12) followed by item 18 “Recreational activities in which you take some force or impact through

your arm, shoulder or hand (e.g., golf, hammering, tennis etc.)" (n=4) and item 19 "Recreational activities in which you move your arm freely (e.g., playing Frisbee, badminton etc.)" (n=4).

Items 14a ("Touch your back on the same side as your surgery") and 14b ("Touch your back on the opposite side as your surgery") were added to the DASH-32 for this study to enhance face validity for women who had undergone breast cancer surgery. Descriptively, items 14a and 14b behaved similarly to the original DASH-30 items. Both items demonstrated low mean scores ($M = 1.46$, $SD = 0.81$ and $M = 1.40$, $SD = 0.77$, respectively), suggesting potential ceiling effects consistent with the broader item set. Missing responses were minimal, and skewness and kurtosis values were within acceptable ranges, indicating adequate distributional properties.

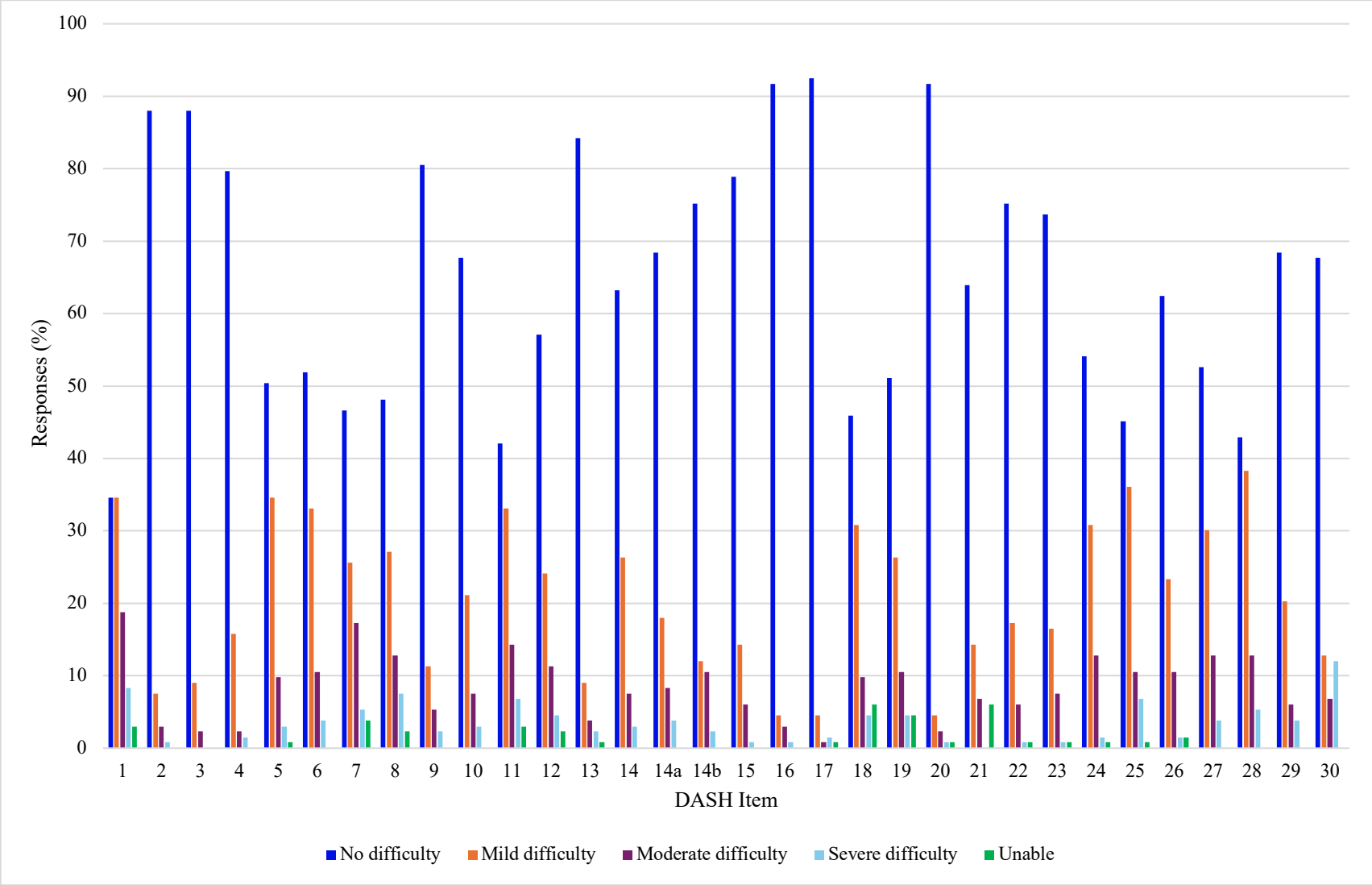
Table 2. Descriptive Statistics of DASH-32 Items (n=133)

Item number	n Missing	Mean	Mode	Std. Deviation	Variance	Skewness	Kurtosis	Range
1	1	2.1	1	1.07	1.14	0.83	0.06	4
2	1	1.16	1	0.49	0.24	3.48	12.82	3
3	1	1.14	1	0.41	0.16	3.12	9.61	2
4	1	1.25	1	0.57	0.33	2.7	8.15	3
5	2	1.67	1	0.84	0.7	1.33	1.79	4
6	1	1.66	1	0.82	0.67	1.13	0.66	3
7	1	1.94	1	1.10	1.22	1.07	0.43	4
8	3	1.86	1	1.06	1.13	1.15	0.53	4
9	1	1.29	1	0.67	0.45	2.51	5.86	3
10	1	1.45	1	0.77	0.59	1.71	2.31	3
11	1	1.94	1	1.06	1.12	1.09	0.60	4
12	1	1.7	1	1	0.99	1.49	1.70	4
13	0	1.26	1	0.71	0.5	3.12	10.11	4
14	0	1.50	1	0.76	0.56	1.53	1.86	3
14a	2	1.46	1	0.81	0.65	1.72	2.13	3
14b	0	1.40	1	0.77	0.59	1.82	2.26	3
15	0	1.29	1	0.61	0.37	2.19	4.31	3
16	0	1.13	1	0.47	0.22	4.05	17	3
17	0	1.14	1	0.56	0.32	5	26.78	4
18	4	1.91	1	1.15	1.32	1.38	1.2	4
19	4	1.81	1	1.10	1.22	1.44	1.44	4
20	0	1.14	1	0.55	0.31	4.72	24.76	4
21	12	1.57	1	1.09	1.2	2.17	3.98	4
22	0	1.35	1	0.7	0.49	2.41	6.8	4
23	0	1.37	1	0.72	0.52	2.24	5.57	4
24	0	1.64	1	0.82	0.67	1.26	1.51	4
25	1	1.81	1	0.93	0.87	1.13	0.76	4
26	1	1.55	1	0.86	0.74	1.74	3.16	4
27	1	1.67	1	0.84	0.71	1.07	0.32	3
28	1	1.80	1	0.86	0.74	0.91	0.17	3
29	1	1.46	1	0.79	0.63	1.79	2.52	3
30	1	1.63	1	1.05	1.11	1.43	0.54	3

Floor and Ceiling Effects

The item-level response distributions were examined by calculating the percentage of responses in each of the five Likert response categories for each item, to assess whether responses clustered at the lowest or highest response options. Figure 2 displays the percentage of selected responses for each DASH-32 item. Analysis of ceiling effects revealed that several items demonstrated a high proportion of participants selecting the "No difficulty" response, indicating potential limitations in capturing variability at the higher end of functional ability. In particular, items 2, 3, 16, 17, and 20 showed especially pronounced ceiling effects, with over 88% of respondents reporting no difficulty. Multiple other items, including Items 9, 13, 15, 22, and 23, also displayed elevated ceiling effects, with over 73% of responses in the highest functioning category.

Figure 2. DASH-32 Response Distributions



Internal Reliability of the DASH

The original DASH-30 demonstrated excellent reliability (α = 0.963), and the DASH-32 version showed similarly high internal consistency (α = 0.965). This demonstrates that the addition of items of 14a and 14b to the DASH-32 is not problematic when compared to the DASH-30 items.

Confirmatory Factor Analysis

A confirmatory factor analysis was conducted on the DASH-30 to evaluate the fit of both a one-factor and three-factor model based on existing literature[15,85,95,96]. Table 3 shows the fit indices of both models. Of the one and three-factor models tested, both demonstrated poor fit based on established thresholds for goodness-of-fit indices. For the one factor model, the chi-square statistic was 1167.22 with 405 degrees of freedom. The Comparative Fit Index (CFI) was 0.69, and the Tucker-Lewis Index (TLI) was 0.67, both falling well below the acceptable cutoff of 0.90. The Root Mean Square Error of Approximation (RMSEA) was 0.14, and the Standardized Root Mean Square Residual (SRMR) was 0.09, both indicating inadequate model fit. For the three-factor model, the chi-square value was 1061.70 with 402 degrees of freedom. The CFI was 0.73 and TLI 0.70. The RMSEA was 0.11 and SRMR 0.09. The fit measures of the three-factor model demonstrated poor fit.

Table 3. CFA Goodness of Fit Models

Model	Chi-square value	Degrees of freedom	CFI	TLI	RMSEA	SRMR
1 factor model	1167.22	405	0.69	0.67	0.14	0.09
3 factor model	1061.70	402	0.73	0.70	0.11	0.09

Exploratory Factor Analysis

As the confirmatory factor analyses did not demonstrate adequate model fit, exploratory factor analysis (EFA) was conducted to identify an underlying factor structure for the DASH-32 that was better suited to the present sample. All 32 items were included. Prior to factor extraction, parallel analysis was performed to guide factor retention[130]. Parallel analysis compares eigenvalues obtained from the observed data with eigenvalues generated from simulated random data to determine the number of factors that should be retained[130]. Results of the parallel analysis supported a four-factor solution. Given that previous DASH research has reported three-factor structures, a three-factor EFA was also estimated to allow direct comparison with existing literature [95]. All EFAs were conducted using minimum residual extraction with oblimin rotation, allowing factors to correlate[84,131].

Three-Factor Model

The three-factor solution demonstrated poor interpretability and limited construct clarity. As shown in Table 4, several items loaded strongly onto Factor 1, including items 6–15 and 18–19. Factor 2 included items 2, 3, 16, 17, and 24–30. Factor 3 was weakly defined, with a clear loading observed only for item 5 and cross-loadings on item 6, indicating inadequate factor differentiation. Additionally, seven items failed to load meaningfully onto any factor (Table 4). The presence of multiple non-loading items and cross-loadings suggested poor model coherence and limited conceptual interpretability[84]. As a result, the three-factor model was deemed inadequate and was not retained.

Table 4. EFA Three-Factor Model

DASH-32 item	Factor 1	Factor 2	Factor 3
1. Open a tight or new jar			
2. Write		0.79	
3. Turn a key		0.55	
4. Prepare a meal			
5. Push open a heavy door			0.43
6. Place an object on a shelf above your head	0.57		0.42
7. Do heavy household chores (e.g., wash walls, wash floors)	0.8		
8. Garden or do yard work	0.76		
9. Make a bed	0.83		
10. Carry a shopping bag or briefcase	0.58		
11. Carry a heavy object (over 10lbs)	0.59		
12. Change a lightbulb overhead	0.89		
13. Wash or blow dry your hair	0.6		
14. Wash your back	0.53		
14a. Touch your back on the same side as your surgery	0.55		
14b. Touch your back on the opposite side as your surgery	0.54		
15. Put on a pullover sweater	0.59		
16. Use a knife to cut food		0.77	
17. Recreational activities which require little effort (e.g., card playing, knitting etc.)		0.7	
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis etc.)	0.84		
19. Recreational activities in which you move your arm freely (e.g., playing Frisbee, badminton etc.)	0.91		
20. Manage transportation needs (getting from one place to another)			
21. Sexual activities			
22. During the past week to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbors or groups?			
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?			
24. Arm, shoulder or hand pain		0.67	
25. Arm, shoulder or hand pain when you performed any specific activity		0.71	

26. Tingling (pins and needles) in your arm, shoulder or hand		0.7	
27. Weakness in your arm, shoulder or hand		0.73	
28. Stiffness in your arm, shoulder or hand		0.76	
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? (circle number)		0.51	
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem		0.41	

[a] Items presented in bold did not load onto any factor or demonstrated cross-loadings in the exploratory factor analysis.

Four-Factor Model

Consistent with the results of the parallel analysis, a four-factor solution demonstrated substantially improved interpretability and conceptual clarity. Table 5 presents the pattern of factor loadings for the four-factor model. DASH-32 items were more evenly dispersed across the factors than in the previous three-factor solution. There were no cross-loadings observed in the four-factor model. Items 20 (“Manage transportation needs”), 21 (“Sexual activities”), 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?”) and 30 (“I feel less capable, less confident or less useful”) did not load significantly onto any factor, suggesting limited contribution to the underlying constructs measured by the DASH-32 in this population. Based on the results of the parallel analysis, the absence of cross-loadings, and the improved conceptual coherence of the factor structure, the four-factor model was selected as the best-fitting and most interpretable solution for subsequent analyses.

Table 5. EFA Four-Factor Model

4 Factor Model				
Dash-32 Item	Factor 1	Factor 2	Factor 3	Factor 4
1. Open a tight or new jar	0.45			
2. Write		0.91		
3. Turn a key		0.61		
4. Prepare a meal		0.42		
5. Push open a heavy door	0.51			
6. Place an object on a shelf above your head	0.58			
7. Do heavy household chores (e.g., wash walls, wash floors)	0.92			
8. Garden or do yard work	0.88			
9. Make a bed	0.76			
10. Carry a shopping bag or briefcase	0.58			
11. Carry a heavy object (over 10lbs)	0.72			
12. Change a lightbulb overhead	0.76			
13. Wash or blow dry your hair			0.45	
14. Wash your back			0.64	
14a. Touch your back on the same side as your surgery			0.88	
14b. Touch your back on the opposite side as your surgery			0.67	
15. Put on a pullover sweater			0.67	
16. Use a knife to cut food		0.74		
17. Recreational activities which require little effort (e.g., card playing, knitting etc.)		0.78		
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis etc.)	0.79			
19. Recreational activities in which you move your arm freely (e.g., playing Frisbee, badminton etc.)	0.8			
20. Manage transportation needs (getting from one place to another)				
21. Sexual activities				
22. During the past week to what extent has your arm, shoulder or hand problem interfered with your	0.4			

normal social activities with family, friends, neighbors or groups?				
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?				
24. Arm, shoulder or hand pain				0.52
25. Arm, shoulder or hand pain when you performed any specific activity				0.56
26. Tingling (pins and needles) in your arm, shoulder or hand				0.66
27. Weakness in your arm, shoulder or hand				0.64
28. Stiffness in your arm, shoulder or hand				0.73
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? (circle number)				0.47
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem				

[a] Items presented in bold did not load onto any factor.

Summary of Findings

Table 6 flags DASH-32 items which indicate problematic psychometric aspects, identified at all stages of analysis. The present findings identify several DASH-32 items that may pose substantial measurement limitations including non-normal response distributions, high number of missing data, pronounced ceiling effects, and non-loading in the EFA. Items 2, 3, 16, 17, 20, and 21 were flagged for both non-normal distribution and ceiling effects greater than 80%, suggesting limited ability to capture variability among participants with higher functional status. Additionally, items 8, 18, 19, and 21 demonstrated notable missing responses, which may indicate issues with item clarity or relevance for respondents. A substantial number of items

(e.g., items 1, 4–7, 10–12, 14–15, 22, 24–29) showed moderate ceiling effects between 40–80%, further contributing to reduced sensitivity in detecting functional limitations in less impaired individuals.

Importantly, the EFA results provided convergent evidence regarding item performance. Items 20 (Manage transportation needs), 21 (Sexual activities), 23 (Work or regular daily activities), and 30 (Perceived capability/usefulness) failed to load onto any factor, indicating that these items do not contribute meaningfully to the latent constructs assessed by the DASH-32 in this BCS sample. Taken together, findings from item-level analyses, ceiling and missingness evaluation, and factor analysis results support the removal of items 20, 21, 23, and 30 from the DASH-32.A revised 28-item measure, the Disabilities of the Arm, Shoulder and Hand Questionnaire-Breast Cancer Surgery (DASH-BCS) is proposed, consisting of items that demonstrated adequate psychometric performance and coherent factor structure in the present sample.

Table 6. Flagged Items

DASH Item	Missing items (n >3)	Non-normal distribution	Ceiling effects (40-80%)	Ceiling effects (> 80%)	No factor loadings on 4-factor model (EFA)
1			X		
2		X		X	
3		X		X	
4			X		
5			X		
6			X		
7			X		
8	X		X		
9				X	
10			X		
11			X		
12			X		
13				X	
14			X		
14a			X		
14b			X		
15			X		
16		X		X	
17		X		X	
18	X		X		
19	X		X		
20		X		X	X
21	X		X		X
22			X		
23			X		X
24			X		
25			X		
26			X		
27			X		
28			X		
29			X		
30			X		X

DASH-BCS Subscales: Labelling

Following identification of the four-factor solution as the best-fitting model, each factor was examined to determine an appropriate and conceptually meaningful label. To ensure the labels accurately reflected the content and intent of the grouped items, the research team independently reviewed the new factors and corresponding items to identify common themes within each factor and to develop preliminary factor labels. Importantly, this team represented expertise in psychometrics, pain assessment, cancer pain, survivorship, palliative care, psychology, biomechanics, and kinesiology. Following this, the team met as a group, and through collaborative discussion, reached consensus on the factor labels[132]. The four DASH-BCS subscales were labelled as Factor 1: Gross Motor Function; Factor 2: Fine Motor Function; Factor 3: Shoulder Range of Motion; and Factor 4: Sensory and Motor Symptoms, reflecting the distinct dimensions of upper limb function and symptom experience captured by the questionnaire. Table 7 shows the items grouped into their respective subscales.

Table 7. Proposed DASH-BCS Subscales

Factor 1: Gross Motor Function	**Factor 2: Fine Motor Function**	**Factor 3: Shoulder Range of Motion**	**Factor 4: Sensory and Motor Symptoms**	**Items that did not load onto any factor**
1. Open a tight or new jar	2. Write	13. Wash or blow dry your hair	24. Arm, shoulder, or hand pain	20. Manage transportation needs (getting from one place to another)
5. Push open a heavy door	3. Turn a key	14. Wash your back	25. Arm, shoulder or hand pain when you performed any specific activity	21. Sexual activities
6. Place an object on a shelf above your head	4. Prepare a meal	14a. Touch your back on the same side as your surgery	26. Tingling (pins and needles) in your arm, shoulder or hand	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?
7. Do heavy household chores (e.g. wash walls, wash floors)	16. Use a knife to cut food	14b. Touch your back on the opposite side as your surgery	27. Weakness in your arm, shoulder or hand	30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem
8.Garden or do yard work	17. Recreational activities which require little effort (e.g. card playing, knitting etc.)	15. Put on a pullover sweater	28. Stiffness in your arm, shoulder or hand	
9. Make a bed			29. During the past week, how much difficulty	

			have you had sleeping because of the pain in your arm, shoulder or hand?	
10. Carry a shopping bag or briefcase				
11. Carry a heavy object (over 10 lbs)				
12. Change a lightbulb overhead				
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g. golf, hammering, tennis etc.)				
19. Recreational activities in which you move your arm freely (e.g. playing Frisbee, badminton etc.)				
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?				

DASH-BCS Subscales: Scoring

Based on the results of the exploratory factor analysis and the subsequent labeling of the four factors, new subscale scores were derived for the DASH-BCS. Each subscale score was

calculated as a loading-weighted composite, where each item response was multiplied by its corresponding factor loading and the resulting values were averaged across items within each subscale. This approach ensured that items with stronger associations with the underlying factor contributed proportionally more to the subscale score, while maintaining comparability across subscales with differing numbers of items[133].

For example, the *Shoulder Range of Motion* subscale (Factor 3), which includes items 13, 14, 14a, and 14b with standardized factor loadings of 0.45, 0.64, 0.88, and 0.67, respectively, was calculated by multiplying each participant's item response by the corresponding factor loading and then calculating an average by dividing by the number of items in the subscale. For the example of the Shoulder ROM subscale, the score was calculated as:

$$Shoulder\ ROM = \frac{(x_{13}\ X\ 0.45) + (x_{14}\ X\ 0.64) + (x_{14a}\ X\ 0.88) + (x_{14b}\ X\ 0.67)}{n}$$

Where x_i represents the participant's response to the item and n represents the number of items in the subscale.

This procedure was repeated for all four subscales: Gross Motor Function, Fine Motor Function, Shoulder Range of Motion, and Sensory and Motor Symptoms. For the scope of the current study, subscale scores were calculated using the imputed dataset employed for the factor analyses, with imputed values used in place of missing item responses[134].

Table 8 includes descriptive statistics for the derived subscales. The DASH-BCS mean values were similar to the DASH-32 score distribution in this sample. All subscales were positively skewed, suggesting that most participants reported relatively low levels of disability one year following breast cancer surgery.

Table 8. Descriptive Statistics of DASH-BCS Subscales

DASH-BCS Subscale	n	minimum	maximum	mean	std. deviation	skew
Gross motor	133	0.68	3.06	1.17	0.52	1.43
Fine motor	133	0.69	2.71	0.81	0.29	3.77
Shoulder ROM	133	0.65	2.62	0.90	0.40	2.2
Sensory and Motor Symptoms	133	0.6	2.48	0.99	0.42	1.51

Internal Reliability of Proposed DASH-BCS Subscales

For the four identified factors, three had excellent internal consistency: Factor 1 – Gross Motor ($\alpha = 0.95$), Factor 3 – Shoulder Range of Motion ($\alpha = 0.9$), and Factor 4 – Sensory Motor Symptoms ($\alpha = 0.9$), and 1 had internal consistency approaching excellent: Factor 2 – Fine Motor ($\alpha = 0.88$). These findings indicate that the proposed factors of the DASH-BCS possess strong internal reliability, suggesting that the items within each scale measure the same constructs.

Convergent and Divergent Validity

Table 9 presents correlations between the DASH-BCS subscales and variables of interest. Convergent validity was evaluated using predefined criteria, whereby correlation coefficients between $r = 0.3$ and $r = 0.7$ were considered indicative of moderate to strong correlations, reflecting evidence of convergent validity[128].

Across the four DASH-BCS subscales, moderate to strong correlations were observed with theoretically related pain and physical functioning constructs. All subscales demonstrated moderate to strong positive correlations with BPI pain severity ($r = 0.42$ to 0.69, $p < .001$) and BPI pain interference ($r = 0.52$ to 0.68, $p < .001$), consistent with expectations that greater upper-

extremity disability would be associated with higher pain severity and interference. Similarly, the DASH-BCS subscales showed moderate to strong negative correlations with the SF-12 Physical Component Summary score ($r = -0.40$ to -0.73, $p < .001$), indicating that higher levels of upper-limb disability were associated with poorer physical health status. Nonsignificant and weak correlations were observed between the DASH-BCS subscales and objective measures of upper-extremity function, including ipsilateral and contralateral shoulder range of motion ($r = -0.28$ to -0.06) and grip strength ($r = -0.27$ to 0). Significant but weak associations were observed between the Gross Motor subscale and ipsilateral shoulder range of motion ($r = -0.28$, $p = 0.01$) and between the Sensory Motor Symptoms subscale and ipsilateral shoulder range of motion ($r = -0.21$, $p = 0.01$). The weak correlations between the DASH-BCS subscales and objective measures of upper-extremity function did not meet the predefined criteria for convergent validity (between $r = 0.3$ and $r = 0.7$[128]).

Divergent validity was assessed using constructs theoretically unrelated to upper-extremity function, including the FACIT-Sp-12, ECR Anxiety, ECR Avoidance, and SF-12 Mental Component Summary (MCS). Consistent with expectations, correlations between the DASH-BCS subscales and these measures were generally small in magnitude. Correlation coefficients less than $r = 0.2$ were interpreted as weak correlations, providing evidence of divergent validity[128]. Correlations with ECR Anxiety ($r = -0.01$ to 0.05) consistently met the criterion for divergent validity. Correlations with ECR Avoidance ($r = 0.07$ to 0.13) and FACIT-Sp-12 ($r = -0.23$ to -0.09) were small, with several meeting or approaching the predefined divergence threshold. Similarly, correlations with the SF-12 Mental Component Summary score ($r = -0.33$ to -0.15) were weaker than those observed for pain and physical functioning constructs.

Table 9. Convergent and Divergent Validity of DASH-BCS

	BPI Severity	BPI Int	SF-12 PCS	SF-12 MCS	Facit Sp 12	ECR Avoidance	ECR Anxiety	Ipsilateral ROM	Contralateral ROM	Ipsilateral grip	Contralateral grip
Gross Motor	**0.64****	**0.68****	**-0.73****	**-0.19**	**-0.14**	**0.08**	**0.02**	-0.28**	-0.17	-0.27**	-0.2
p-value	<.001	<.001	<.001	0.05	0.106	0.367	0.836	0.009	0.12	0.01	0.07
n	133	133	111	111	130	130	130	87	87	86	87
Fine Motor	**0.62****	**0.64****	**-0.4****	**-0.26****	**-0.2***	**0.07**	**0.05**	-0.15	-0.07	-0.12	-0.1
p-value	<.001	<.001	<.001	0.006	0.025	0.412	0.609	0.17	0.5	0.29	0.37
n	133	133	111	111	130	130	130	87	87	86	87
Shoulder ROM	**0.42****	**0.52****	**-0.56****	**-0.15**	**-0.09**	**0.08**	**-0.01**	-0.15	-0.06	-0.01	0
p-value	<.001	<.001	<.001	0.113	0.31	0.398	0.948	0.17	0.56	0.96	0.97
n	133	133	111	111	130	130	130	87	87	86	87
Sensory Motor	**0.69****	**0.67****	**-0.46****	-0.33**	-0.23**	0.13	**0.01**	-0.21**	-0.08	-0.08	-0.02
p-value	<.001	<.001	<.001	<.001	0.009	0.139	0.93	0.05	0.45	0.48	0.85
n	133	133	111	111	130	130	130	87	87	86	87

[a] Items presented in bold indicate items that met the convergent and divergent cutoffs.

DASH-BCS Subscales and Pain

To explore the relationship between upper limb function and pain, weighted subscale scores on the four new DASH-BCS domains were compared between participants reporting pain and those not reporting pain. Pain groups were defined using the NRS-R, which measures pain intensity at rest. For the current study, the NRS was treated as a dichotomous variable where woman were categorized as either in pain (NRS-R≥1) or not in pain (NRS-R=0)[135]. Approximately 43% (n=55) of women were still experiencing pain at rest one year after their surgery, and 57% (n=74) were not. Independent samples t-tests were conducted to examine differences in weighted DASH-BCS subscale scores between participants reporting pain and those reporting no pain. No statistically significant differences were observed between the pain groups across any of the four subscales (Table 10).

Table 10. Analysis of DASH-BCS and Pain

Weighted subscale scores by pain group	Group	n	t-score (p-value)	mean	std. deviation
Gross Motor	no pain	74	-0.59 (0.55)	1.1517	0.525
	pain	55		1.2071	0.523
Fine Motor	no pain	74	0.54(0.59)	0.8214	0.336
	pain	55		0.7947	0.229
Shoulder ROM	no pain	74	0.2(0.84)	0.9121	0.388
	pain	55		0.8973	0.433
Sensory and Motor Symptoms	no pain	74	0.82(0.42)	1.019	0.451
	pain	55		0.9594	0.373

DISCUSSION

This study developed the Disabilities of the Arm, Shoulder, and Hand-Breast Cancer Surgery (DASH-BCS) questionnaire, the first revised version of the DASH-30 specifically refined and psychometrically evaluated for women following breast cancer surgery (BCS). Two additional items were initially added to the DASH-30 to improve face validity for this population (DASH-32). Although the DASH-30 and DASH-32 demonstrated excellent internal consistency, multiple psychometric limitations were identified that may reduce their utility in BCS populations. Item-level analyses demonstrated substantial skewness, kurtosis, and ceiling effects across several items, indicating there may be limited sensitivity to subtle or residual impairments one year following surgery. In addition, confirmatory factor analyses (CFA) demonstrated poor fit for previously proposed DASH structures, suggesting that the underlying construct of upper-extremity disability in this population may differ from that represented in the original DASH-30. In response to these limitations, exploratory factor analysis (EFA) identified a clinically meaningful and psychometrically robust four-factor structure. Several poorly performing items were subsequently removed, resulting in the refined 28-item DASH-BCS with four conceptually distinct subscales. Taken together, these findings suggest that while the DASH-30 contains relevant content, it may not optimally capture upper-extremity disability following BCS. The DASH-BCS provides a more psychometrically appropriate and clinically interpretable assessment of disability in this population.

Psychometric Evaluation Criteria

A key consideration in evaluating any patient-reported outcome measure is the extent to which it demonstrates strong measurement properties within the target population. A well-performing scale should exhibit adequate content validity, ensuring that items are relevant and representative of the construct of interest; structural validity, such that the underlying factor structure accurately reflects the dimensionality of the construct; and reliability, indicating internal consistency among items measuring the same domain [80,129]. In addition, the scale should demonstrate good measurement sensitivity, including minimal floor or ceiling effects, to allow for discrimination across varying levels of impairment[83,129]. Lastly, it should demonstrate appropriate construct validity, including expected relationships with related and unrelated variables, and be interpretable in a clinically meaningful way[82,132]. The item analysis allowed assessment of content validity and sensitivity, Cronbach's alpha tested for reliability, factor analysis evaluated the structural validity, and correlations between other variables tested for convergent and divergent validity – all key components in understanding the DASH-32's psychometric performance in BCS.

Content Validity and Sensitivity

The items in the DASH-30 and DASH-32 demonstrated substantial clustering toward the lowest response options of the 5-point Likert scale, with mean item scores concentrated near the "no difficulty" end of the scale, indicating ceiling effects. High positive skewness and kurtosis values were observed for several items, particularly those assessing low-demand functional tasks such as writing (item 2), turning a key (item 3), using a knife (item 16), engaging in light recreational activities (item 17), and managing transportation (item 20). This interpretation aligns

with prior research indicating that generic upper-extremity measures may demonstrate reduced sensitivity in cancer survivorship and higher-functioning populations[14,15] and supports the need for population-specific refinement of upper-extremity outcome measures.

Interestingly, there have been mixed findings across other validation studies of the DASH-30, with some finding ceiling effects[98] and others not finding ceiling effects[136]. Forget et al[98] found that there were ceiling effects in individuals with Dupuytren's contracture, a musculoskeletal hand condition, at pre-op, 3 months, 6 months, and 12 months post-op. On the other hand, Wang et al[136] observed no ceiling effects when comparing DASH-30 scores in 2724 participants with orthopedic shoulder impairments from outpatient physiotherapy clinics. The literature in the field may suggest that the DASH-30 may vary across clinical populations, emphasizing the importance of thorough psychometric evaluation.

In the present study, it is possible that by one-year post-BCS, the DASH-32 scores reflect true recovery. On the other hand, despite the high proportion of participants reporting no difficulty on many DASH-32 items, over half of the women reported experiencing pain one year following surgery (NRS-R). Given that the majority of the DASH-32 items measure physical functioning disability[85], and that pain and functional disability are typically moderately to strongly associated[15,77,137], the existence of ongoing pain and high function suggests that the DASH-32 may not fully capture the nature of pain-related disability in this population. Several explanations may account for this pattern. First, many DASH items assess relatively low-demand activities that most women may have resumed by one-year post-surgery[85]. Second, the DASH primarily assesses whether a task can be completed, but does not capture how the activity is performed, including pain during movement, compensatory movement strategies, fatigue, or activity avoidance, all of which have been documented in women following breast cancer

surgery[138,139]. For example, by asking a participant to rate their ability to push open a heavy door on a scale from 1 to 5, their response does not necessarily tell us if they are in pain doing this or if they are opening the door in a different way than before. Participants may be reporting "no difficulty" despite ongoing symptoms or altered movement patterns.

Breast cancer-related upper-extremity impairment is most commonly characterized by limitations in shoulder mobility, overhead reaching, behind-the-back movements, sustained or repetitive arm activity, and by pain or sensory disturbances[77,137]. In contrast, many of the original DASH-30 items demonstrating the greatest skewness and kurtosis primarily involve fine motor or low-load activities requiring minimal shoulder range of motion, strength, or sustained upper-extremity use, including writing (item 2), turning a key (item 3), using a knife (item 16), and light recreational activities (item 17). As a result, many participants may have been able to perform these tasks without difficulty despite experiencing ongoing impairments in more shoulder-intensive activities.

Reliability

Internal consistency for both the original DASH-30, DASH-32, and DASH-BCS was excellent, and the proposed four subscales also demonstrated strong internal reliability. These alpha values exceed commonly cited thresholds for acceptable internal consistency (approximately .70–.90[123]) and are comparable to those reported in many DASH-30 validation studies in musculoskeletal populations, such as carpal tunnel syndrome[15,93]. There have also been breast cancer-specific DASH-30 and QuickDASH validation studies, which both found the questionnaire to demonstrate reliability[100,101]. In this context, it is possible that the excellent internal consistency may reflect highly interrelated items, but not necessarily that the scale is

optimally discriminating across the full range of function. Cronbach's alpha reflects the extent to which items measure a common underlying construct, indicating how well items "hang together" as a set rather than evaluating the performance of individual items[82]. While high alpha values support internal reliability, values approaching or exceeding .95 may indicate item redundancy rather than optimal measurement precision, particularly when coupled with ceiling effects[129,132]. This suggests that while items are highly interrelated, they may not provide sufficient discrimination across the full range of functional ability.

Structural Validity and Interpretability

This study's construct validity findings provide evidence that the original DASH-30 one-factor structure may not adequately represent upper-extremity disability in women one-year following BCS and that a four-factor model may be more appropriate. These findings challenge the DASH-30's developers' suggestion that the measure was unidimensional for upper musculoskeletal conditions[15,85]. Importantly, the proposed unidimensionality was based largely on correlations between the DASH-30 and related and unrelated constructs, without direct evaluation of the underlying factor structure[85,140]. More recently, Prodinger et al[94] reported acceptable fit of the original one-factor model in 337 individuals with rheumatoid arthritis, suggesting that a unidimensional structure may be appropriate in some clinical populations. LeBlanc et al[101] reported a one-factor structure for the QuickDASH in a group of 150 postmenopausal women with stage I to III hormone receptor positive breast cancer. Although these studies found a one factor model, the generalizability from the musculoskeletal to the breast cancer population cannot be assumed nor can psychometric properties of the shortened version of the DASH be assumed to be the same in other versions.

In contrast, several psychometric studies have suggested that the DASH may be multidimensional rather than unidimensional [95–97]. Similar to the current study, these authors found that the original one-factor structure did not adequately represent the data. However, unlike the current findings, they proposed that a three-factor model was most appropriate. For example, Lehman et al [96] identified factors representing gross motor function, fine motor function, and symptoms, while Franchignoni et al[95] identified factors representing manual functioning, shoulder range of motion, and symptoms and consequences. These domains encompass similar constructs to those identified in the present study, including gross motor function, fine motor function, shoulder range of motion, and sensory and motor symptoms. One important distinction, however, is that these studies were conducted in heterogeneous musculoskeletal populations, including individuals with conditions such as elbow tendinitis and wrist fractures[95,96], rather than women following BCS. When these previously proposed three-factor structures were tested in the current sample using confirmatory factor analysis, all fit indices suggested poor fit. This further supports our suggestion that factor structures derived from musculoskeletal populations may not generalize well to women following breast cancer surgery.

The current study found not only that the one-factor and three-factor models demonstrated poor fit, but also that a four-factor model best represented the data. Interestingly, Forget et al[98] also identified a four-factor structure in individuals with Dupuytren's contracture. The subscales found by Forget et al[98] were not given labels, and do not appear to include similar items to the current study. Despite identifying the same number of factors, the authors concluded that the DASH did not demonstrate adequate validity for use in that population due to substantial ceiling effects and poor model fit, and recommended further revision of the questionnaire[98].

In the current study, several deleted items - including item 20 ("Managing transportation needs"), item 21 ("Sexual activities"), item 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?"), and item 30 ("I feel less capable, less confident or less useful because of my arm, shoulder or hand problem") - demonstrated substantial ceiling effects, high missingness, and/or failed to load meaningfully onto any factor. Similarly, previous psychometric evaluations of the DASH-30 have found that items 20 and 21 in particular do not fit within the proposed factor structure[95,96]. This overlap regarding misfit of items 20 and 21 in particular support the present findings and removal from the questionnaire.

To our knowledge, the present study is the first to specifically evaluate the factor structure of the DASH-30 in women one year following breast cancer surgery. While previous studies have demonstrated that the DASH may be multidimensional[95–98,136], the current findings extend this literature by suggesting that factor structures derived from musculoskeletal populations may not adequately fit women following breast cancer surgery. This may be because the combination of characteristics many women experience after BCS such as pain, lymphedema, restricted ROM[4,25] may differ from that experienced in certain musculoskeletal conditions. These findings reinforce the importance of evaluating structural validity within the specific population in which an outcome measure is intended to be used[79,80], rather than assuming that psychometric properties established in one population are transferable to another.

DASH-BCS Subscales

In contrast to the original DASH-30 structure, the four-factor solution identified through exploratory factor analysis demonstrated substantially improved interpretability and conceptual

coherence with the experiences of women following breast cancer surgery. The four resulting DASH-BCS subscales represent distinct but related domains of upper-extremity morbidity following breast cancer surgery.

The Gross Motor Function subscale encompasses activities requiring coordinated movement of the shoulder, elbow, wrist, and hand to perform larger functional tasks. These activities involve force generation, lifting, carrying, overhead reaching, and object manipulation through the coordinated action of multiple upper-extremity muscle groups[141]. Examples include opening a heavy door, carrying objects, and placing an object on a shelf above head level. Biomechanical studies have demonstrated that muscles including the deltoid, pectoralis major, rotator cuff, and biceps play important roles in generating force and coordinating functional upper-extremity movement during everyday activities[142]. These activities are particularly relevant following BCS, as impairments in shoulder strength, lifting ability, overhead function, and altered movement patterns have been consistently reported among survivors[77,137]. Similar gross motor domains have also been identified in previous psychometric evaluations of the DASH[96], suggesting that larger functional movements represent an important component of upper-extremity disability across multiple clinical populations.

In contrast, the Fine Motor Function subscale captures activities requiring more precise and coordinated hand and finger movements, including writing, turning a key, and using a knife to cut food. These activities rely less on force production and more on dexterity, coordination, and object manipulation[143]. Although fine motor impairments are less frequently discussed than shoulder dysfunction within the breast cancer literature, persistent pain, weakness, and sensory disturbances may influence hand function and performance of more precise upper-extremity tasks[77,137]. The emergence of a distinct fine motor domain is also consistent with previous DASH

factor analysis studies[96]. However, because relatively few studies have specifically examined fine motor function following breast cancer surgery, additional research is needed to determine whether this represents a unique domain of disability or reflects the influence of broader upper-extremity impairments on fine motor activities.

The Shoulder Range of Motion subscale encompasses activities requiring coordinated glenohumeral and scapulothoracic movement through shoulder flexion, abduction, internal rotation, and external rotation[141]. These activities include washing or blow-drying hair, washing the back, and the two newly added DASH-BCS items assessing the ability to touch the back on the ipsilateral and contralateral side of surgery. Successful performance of these activities requires adequate shoulder mobility and coordinated movement of the shoulder complex[141]. Following breast cancer surgery, shoulder range of motion is commonly limited because of post-surgical scarring, pain, soft tissue restrictions, radiation-related fibrosis, and protective movement patterns that develop during recovery[137,138]. Recent biomechanical research has demonstrated that breast cancer surgery alters muscle function and movement biomechanics, contributing to persistent functional limitations during upper-extremity movement[142]. Although Franchignoni et al[95] also identified a shoulder range of motion domain in a musculoskeletal population, the emergence of this factor in the present study suggests that shoulder mobility may represent an especially important dimension of disability following breast cancer surgery, where movement restrictions are among the most frequently reported long-term treatment-related impairments[77].

Finally, the Sensory and Motor Symptoms subscale includes items assessing pain, tingling, numbness, weakness, and stiffness. For BCS specifically, these type of symptoms may occur because of treatment-related mechanisms, such as peripheral nerves that were damaged

during surgery[144]. Unlike the other three subscales, which primarily capture activity performance, this domain reflects symptom burden that may influence movement quality, confidence during upper-extremity use, and participation in daily activities. Persistent pain and sensory disturbances following breast cancer treatment have been associated with reduced upper-extremity function, altered movement strategies, and reduced quality of life[77,137,145]. Similar symptom domains have also emerged in previous DASH factor analytic studies[95,96], suggesting that symptom burden represents an important but distinct aspect of upper-extremity disability.

The loading-weighted scoring approach used to calculate the DASH-BCS subscale scores should also be considered when interpreting the present findings. The weights applied to individual items were derived from factor loadings obtained in the current sample and may therefore be sample-specific. Subsequent studies may produce different factor loadings and corresponding item weights[146]. As such, the current scoring formulas should be considered preliminary until replicated or standardized across multiple independent breast cancer surgery populations. Future research should determine whether the factor structure and item loadings remain stable across samples and over repeated assessments and whether loading-weighted scoring provides meaningful advantages over simpler unweighted approaches[146].

Convergent and Divergent Validity

Convergent validity was supported by the moderate to strong correlations observed between all DASH-BCS subscales and measures of pain severity, pain interference, and physical health status. Similar relationships have been reported for the original DASH-30, where higher levels of upper-extremity disability are consistently associated with greater pain and poorer physical functioning in both musculoskeletal and breast cancer populations[77,140]. The strongest

correlations were observed for the Gross Motor Function and Sensory and Motor Symptoms subscales, which may reflect the extent to which shoulder pain, mobility limitations, stiffness, and sensory disturbances contribute to difficulty performing larger functional tasks following breast cancer surgery[137,138]. This pattern also supports the proposed four-factor structure, as the subscales most strongly associated with pain represent domains that are commonly reported as persistent impairments following breast cancer treatment[10,77].

Objective measures of upper-extremity function demonstrated weaker relationships with the DASH-BCS subscales than the patient-reported measures, which was an unexpected finding. Interestingly, most convergent and divergent DASH literature use only self-report measures to test convergent and divergent validity[140,147–149]. One potential explanation is that objective measures of arm functioning may not adequately represent the perceived level of disability of an individual[150]. However, of the few studies that used objective measures, there are generally moderate relationships observed. Fayad et al[151] in their validation of the French version of the DASH, used both self-report measures of pain and disability as well as objective measures of strength and ROM in 150 women with a variety of shoulder conditions such as frozen shoulder or dislocation[151]. They found strong correlations between DASH scores and self-reported measures of pain and disability[151]. However, they found only moderate correlations between DASH scores and objective measures of ROM[151]. Lee et al[152] found moderate correlations between the Chinese version of the DASH and grip strength measures among 334 participants with a broad range of upper-extremity disorders, such as fracturs, finger injuries, and amputations. As neither study included people who had undergone BCS specifically, future research is needed to further investigate the relationship between the DASH and objective arm function measures in the BCS population.

Divergent validity was generally supported through weak or non-significant relationships with constructs less directly related to upper-extremity disability, including attachment avoidance, attachment anxiety, and spiritual well-being. Some statistically significant associations with the SF-12 mental health component were observed; however, these correlations were consistently weaker than those observed with physical health and pain-related variables. Similar findings have been reported for the original DASH-30, which demonstrates stronger relationships with measures of physical functioning and pain than with measures of mental or emotional wellbeing[15,147,149,152].

DASH-BCS Subscales and Pain Status

Previous research using the original DASH-30 has consistently demonstrated moderate to strong associations between upper-extremity disability and pain in both musculoskeletal and breast cancer populations[15,77]. Pain is widely recognized as an important contributor to functional limitations following breast cancer treatment and has been associated with reduced shoulder mobility, activity restrictions, and poorer quality of life[77,137]. However, much of this work has relied on total DASH-30 scores, making it difficult to determine whether pain influences all domains of upper-extremity function equally.

In the current study, no significant differences were observed across any of the four DASH-BCS subscales between participants with and without pain at rest. This was unexpected, given the established relationship between pain and upper-extremity disability following breast cancer surgery[31,39,58,87]. One possible explanation could be statistical. When creating groups based on the presence or absence of pain, there may be a reduced statistical power to detect meaningful differences between groups[153].

Additionally, the dichotomous classification of pain used in this analysis, which distinguished only between the presence and absence of pain at rest and did not account for pain severity, interference, frequency, or pain experienced during movement. This study found moderate to strong correlations observed between the DASH-BCS subscales and continuous measures of BPI pain severity and interference, suggesting that the severity and functional impact of pain may be more closely related to upper-extremity disability than the presence of pain at rest alone. These findings are consistent with previous literature suggesting that pain interference may be more closely related to disability than pain intensity alone[77,137]. While pain intensity reflects symptom severity, pain interference captures the extent to which symptoms disrupt daily activities and participation[112]. Pain at rest was selected in the current study because it is more widely reported in the literature and movement-evoked pain measurement can lack standardization across studies[110,111]. Future research should examine whether more detailed assessments of pain severity, interference, and movement-evoked pain demonstrate stronger relationships with specific domains of upper-extremity disability following breast cancer surgery.

Recommendations for Revision of the Current DASH-30

Independent of the proposed DASH-BCS, several broader revisions to the DASH-30 may improve measurement performance in breast cancer populations. First, the current response format does not allow respondents to indicate that they do not engage in an activity for reasons unrelated to upper-extremity function. Introducing an explicit “I do not engage in this activity” option, paired with carefully defined scoring rules, may help distinguish true absence of difficulty from activity non-participation[154]. This modification could improve interpretation of missing responses and provide additional information regarding item relevance, although further

research would be needed to determine whether such a change improves overall measurement performance. Similar modifications have been proposed in other patient-reported outcome measures to address activity irrelevance and strengthen content validity[129,155].

Beyond activity relevance, the broader response structure of the DASH-30 may also warrant reconsideration. The current five-point ordinal response scale assumes that respondents can reliably distinguish between categories such as “mild difficulty,” “moderate difficulty,” and “severe difficulty”[156,157]. However, questionnaire research has demonstrated that respondents do not always interpret adjacent response categories consistently, particularly when functional limitations are subtle or fluctuate over time[156,157]. In populations with relatively low levels of disability, limited differentiation between response categories may contribute to clustering of responses at the lower end of the scale, potentially reducing sensitivity to subtle impairment[158]. This possibility is consistent with the substantial ceiling effects observed in the present study. Future research should therefore examine the functioning of the DASH response categories using methods such as Rasch modelling[159] or Item Response Theory (IRT)[160] to determine whether all five response options provide meaningful distinctions between levels of difficulty.

Consideration should be given to capturing how activities are performed, rather than solely whether they can be completed. The current DASH-30 may not fully account for important aspects of disability such as pain during movement, compensatory strategies, or fatigue, all of which are common following breast cancer surgery[138,139]. For example, a participant may report no difficulty placing an object on a shelf above head level despite experiencing pain, requiring greater effort, or compensating through trunk movement to complete the task. Because the response options focus primarily on whether the activity can be completed, these additional dimensions of disability may not be fully captured. As a result,

participants may report “no difficulty” even when the task requires compensatory movement patterns, pacing, or causes substantial discomfort[138,139]. Expanding the response framework to reflect these dimensions may improve the scale’s ability to capture subtle but clinically meaningful impairments. Similar recommendations have been made within contemporary patient-reported outcome measure development, which increasingly emphasizes the assessment of symptoms, activity adaptation, and participation restrictions in addition to task completion alone[79,155]. Future research could evaluate more targeted approaches to decrease patient burden, such as adding a small number of supplementary items assessing pain during movement, compensatory strategies, fatigue, or effort across upper-extremity activities.

The linguistic demands and interpretability of questionnaire items may also influence response patterns. Research on patient-reported outcome measure development emphasizes that items and response categories should be easily interpretable, conceptually distinct, and relevant to the lived experiences of the target population[79,156,161]. The present findings suggest that some DASH-30 items and response categories may not fully align with how women conceptualize upper-extremity disability one year following breast cancer surgery. Future refinement efforts should therefore evaluate not only item content, but also response category functioning, wording clarity, and the extent to which the scale captures symptom burden and activity adaptation in addition to simple task completion[79]. This could include cognitive interviewing methods to examine how respondents interpret items and response options, testing alternative response formats, or incorporating questions that explicitly assess pain during activity, compensatory movement strategies, or activity modification[156].

Implications for Models of Disability

The findings of the current study can be considered within the context of models of disability. The biomedical model views disability primarily as a consequence of disease or bodily impairment[46]. However, in the current study, objective measures of upper-extremity impairment, including shoulder range of motion and grip strength, demonstrated generally weak or nonsignificant correlations with the DASH-BCS subscales. In contrast, stronger relationships were observed between self-reported upper-extremity disability and pain severity, pain interference, and perceived physical health. These findings could suggest that objective physical impairment alone may not fully explain an individual's experience of functional limitation following BCS and therefore challenge a strictly biomedical understanding of disability.

The findings of the current study align more closely with the social model of disability that recognize a distinction between bodily impairment and the lived experience of disability[46]. For example, women with similar levels of shoulder range of motion or grip strength may report different levels of functional limitation. Although this study did not directly investigate environmental or societal barriers, the weak relationships between objective measures of upper-extremity impairment and self-reported disability highlight the importance of considering disability as more than a direct consequence of a physical dysfunction alone.

The identification of four distinct DASH-BCS subscales suggests that upper-extremity disability following BCS may be multidimensional, involving distinct but related aspects of gross motor function, fine motor function, shoulder range of motion, and sensory and motor symptoms. These findings aligns closely with the ICF model of disability as well as with research suggesting the biopsychosocial nature of cancer pain[36,38–40,162] and further contributes to the understanding of post-BCS upper-extremity disability. These findings support a more

comprehensive understanding of disability following BCS that considers both physical impairment and the individual's perceived experience of functional impairment.

Strengths of the Current Study

A key strength of this study is the comprehensive psychometric evaluation of the DASH within a group of people undergoing breast cancer surgery, a group for whom the underlying measurement properties of the instrument have received relatively limited investigation. Although previous studies have reported that the DASH and QuickDASH demonstrate acceptable reliability and validity in breast cancer populations[99–101], these investigations primarily focused on internal consistency, test-retest reliability, and convergent validity rather than evaluating the underlying factor structure. Consequently, relatively little is known about whether the latent construct measured by the DASH-30 is represented similarly in women following breast cancer surgery. The study employed a multi-method psychometric approach, incorporating item-level analyses, internal consistency reliability, multiple forms of validity assessment, and both confirmatory and exploratory factor analytic techniques. Evaluating the measure across multiple psychometric domains provided a more comprehensive understanding of DASH performance.

Another strength is the use of a well-characterized sample of women one-year following breast cancer surgery. While much of the breast cancer rehabilitation literature has focused on acute treatment effects and early recovery, fewer studies have examined upper-extremity disability during longer-term survivorship[77,137]. Evaluating the DASH at this time point provided a unique opportunity to assess whether the measure is sensitive to the subtle but persistent impairments that may remain after initial recovery and treatment completion. Previous research

has demonstrated that pain, reduced shoulder mobility, weakness, sensory disturbances, and activity limitations can persist months to years following breast cancer treatment despite substantial overall recovery[77,138,145]. This population-specific focus therefore allowed for direct evaluation of whether the DASH adequately captures the residual patterns of upper-extremity morbidity experienced during breast cancer survivorship.

Importantly, the study extended beyond identifying psychometric limitations by generating and evaluating a refined measure. The analytic approach enabled identification of specific problematic items, supported evidence-based recommendations for revision of the DASH-30, and resulted in the development of the DASH-BCS. Finally, the interdisciplinary process used to interpret and label the emergent factors strengthened the clinical relevance and interpretability of the proposed subscales.

Limitations

Several limitations should be considered when interpreting these findings. First, although the sample size was sufficient for exploratory factor analysis[163], replication in larger and more diverse samples is needed to confirm the stability and generalizability of the proposed four-factor structure in people following BCS. Secondly, the participants were predominantly White, which may limit generalizability to more diverse people with breast cancer. Future validation studies should evaluate the performance of the DASH-BCS across broader demographic and clinical groups.

Thirdly, the present psychometric evaluation was conducted using data collected one year following breast cancer surgery. The present findings may not fully generalize to earlier or later phases of recovery, where the nature and severity of upper-extremity disability may differ.

Although the parent study has data at two years post-BCS, investigating factorial stability was beyond the scope of the current study. Additional research is needed to evaluate the responsiveness of the DASH-BCS over time.

Lastly, some psychometric approaches, including Item Response Theory (IRT) and Rasch modeling, could not be meaningfully applied because of the substantial ceiling effects and limited variability observed across questionnaire items[158]. While this restricted the range of psychometric analyses that could be performed, these response patterns also provided important evidence regarding the measurement limitations of the original DASH-30 in this population and helped inform the development of the DASH-BCS. Larger studies should implement Rasch modeling in order to further investigate the psychometric properties of the DASH-30.

Implications

Clinically, the refined four-subscale DASH-BCS provides more precise information than a single total score by distinguishing between domains that could respond differently to rehabilitation (e.g., shoulder range of motion versus sensory symptoms). In research contexts, the four-factor structure can support more targeted hypothesis testing and may improve the interpretability of upper-extremity outcomes in BCS studies. At the same time, the observed ceiling effects indicate that the DASH may be less useful for detecting subtle limitations among higher-functioning individuals at one-year post-surgery, underscoring the value of refinement or supplementation with more sensitive items.

Future Research Directions

Several avenues for future research follow directly from the present findings and offer opportunities to further refine and validate the DASH-BCS for use with people with breast cancer. First, the proposed four-factor structure should be evaluated using confirmatory factor analysis in independent groups of people, ideally across multiple time points such as early post-treatment, one year, and longer-term follow-up. This would allow for assessment of structural stability and potential changes in factor relevance across the recovery trajectory. Longitudinal studies are also needed to evaluate responsiveness to change, which is particularly important for assessing rehabilitation outcomes and monitoring long-term effects.

Second, further refinement of DASH-BCS items remains an important area of future investigation. Items demonstrating persistent ceiling effects, high skewness, or weak factor loadings may benefit from revision or replacement[129]. In particular, items that were frequently skipped or failed to load onto any factor (e.g., transportation needs, sexual activity, and perceived capability) warrant further evaluation regarding their relevance, clarity, and conceptual alignment with upper-extremity disability. A promising qualitative approach to guide this process is the use of think-aloud cognitive interviewing methods[156,161], in which participants verbalize their thought processes while completing the DASH-BCS. Think-aloud methods have been shown to identify sources of measurement error, including ambiguous wording, mismatches between item intent and respondent interpretation, and difficulties selecting response options[156,161]. In the context of patient-reported outcome measure development, cognitive interviewing is also considered an important method for evaluating content validity and ensuring that items are relevant, comprehensive, and comprehensible to the target population[79]. Among people who have had breast cancer surgery, this approach could help determine whether ceiling

effects reflect true absence of difficulty or whether participants perceive certain items as irrelevant, outdated, or insufficiently specific to their experiences.

Additional psychometric evaluation using IRT and Rasch modeling may further support refinement of the DASH-BCS. These approaches can provide detailed information regarding item discrimination and difficulty across the functional continuum and may help identify which items are most informative for women with varying levels of impairment[164,165]. Such analyses may ultimately support development of a shorter and more sensitive version of the DASH-BCS. However, the substantial ceiling effects observed in the present study limited response variability, suggesting that additional item refinement may be necessary before these methods can be effectively implemented[158,164].

Finally, future research should focus on developing standardized scoring procedures for handling missing item responses within the DASH-BCS. Given the elevated missingness observed for certain items, particularly those reflecting potentially less applicable activities, clear guidelines for managing incomplete responses will be necessary. Future research should evaluate the impact of different missing-data strategies, including imputation, and alternative scoring approaches[166], on subscale reliability and validity. Ultimately, the development and validation of a standardized approach to handling missing responses will be necessary to support the accurate interpretation, clinical utility, and broader implementation of the DASH-BCS.

CONCLUSION

In conclusion, the DASH-30 and DASH-32 demonstrated important psychometric limitations when used to assess disability in women one year following breast cancer surgery. Substantial ceiling effects, non-normal item distributions, and poor fit of previously proposed

factor structures indicate limitations in sensitivity, content validity, and structural validity within this population. These findings suggest that the original DASH structure does not adequately capture the multidimensional nature of upper-extremity disability following BCS.

In response to these limitations, a refined four-factor structure emerged that better reflects clinically meaningful domains of impairment, including gross motor function, fine motor function, shoulder range of motion, and sensory and motor symptoms. The resulting DASH-BCS demonstrated strong reliability, improved interpretability, and evidence of construct validity. Collectively, these findings support the DASH-BCS as a more psychometrically appropriate and clinically meaningful measure of upper-extremity disability in women following breast cancer surgery. With additional validation and potential item/response-option refinement, the proposed DASH-BCS subscales may improve the assessment of upper-extremity outcomes and support use in this population.

APPENDICES

Appendix 1. Disabilities of the Arm, Shoulder, and Hand Questionnaire

THE DASH

INSTRUCTIONS

This questionnaire asks about your symptoms as well as your ability to perform certain activities. Please answer *every question*, based on your condition in the last week, by circling the appropriate number. If you did not have the opportunity to perform an activity in the past week, please make your *best estimate* on which response would be the most accurate. It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.

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 light bulb overhead	**1**	**2**	**3**	**4**	**5**

	No Difficulty	**Mild Difficulty**	**Moderate Difficulty**	**Severe Difficulty**	**Unable**
13. Wash or blow dry your hair	**1**	**2**	**3**	**4**	**5**
14. Wash your back	**1**	**2**	**3**	**4**	**5**
14.a) Touch your back on the same side as your surgery	**1**	**2**	**3**	**4**	**5**
14.b) Touch your back on the opposite side as your surgery	**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., card playing, 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**

	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, neighbors or groups? (circle number)	**1**	**2**	**3**	**4**	**5**

	Not Limited At All	Slightly Limited	Moderately Limited	Very Limited	Extremely
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**

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

	None	Mild	Moderate	Severe	Extreme
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 or Disagree	Agree	Strongly Agree
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem	**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 <u>not</u> be calculated if there are greater than 3 missing items.

WORK MODULE (OPTIONAL)

The following questions ask about the impact of your arm, shoulder or hand problem on your ability to work (including homemaking if that is your main work role).

Please indicate what your job/work is:_____

I do not work. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty:

	No Difficulty	Mild Difficulty	Moderate Difficulty	Severe Difficulty	Unable
1. using your usual technique for your work?	**1**	**2**	**3**	**4**	**5**
2. doing your work because of arm, shoulder or hand pain?	**1**	**2**	**3**	**4**	**5**
3. doing your work as well as you would like?	**1**	**2**	**3**	**4**	**5**
4. spending your usual amount of time doing your work?	**1**	**2**	**3**	**4**	**5**

SPORTS/PERFORMING ARTS MODULE (OPTIONAL)

The following questions relate to the impact of your arm, shoulder or hand problem on playing *your musical instrument or sport or both*. If you play more than one sport or instrument (or play both), please answer with respect to that activity which is most important to you.

Please indicate the sport or instrument which is most important to you:_____

I do play a sport or an instrument. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty:

	No Difficulty	Mild Difficulty	Moderate Difficulty	Severe Difficulty	Unable
5. using your usual technique for playing your sport or instrument?	**1**	**2**	**3**	**4**	**5**
6. playing your musical instrument or sport because of arm, shoulder or hand pain?	**1**	**2**	**3**	**4**	**5**
7. playing your musical instrument or sport as well as you would like?	**1**	**2**	**3**	**4**	**5**
8. spending your usual amount of time practicing or playing your instrument or sport?	**1**	**2**	**3**	**4**	**5**

SCORING THE OPTIONAL MODULES: Add up assigned values for each response; divide by 4 (the number of items); subtract 1; multiply by 25.

An optional module score may <u>not</u> be calculated if there are any missing items

Appendix 2. Distribution of Participant Responses Across DASH-32 Response Categories

			Response category (%)				
Item	n	n (%) missing	No difficulty	Mild difficulty	Moderate difficulty	Severe difficulty	Unable
1	132	1 (0.8)	34.6	34.6	18.8	8.3	3
2	132	1 (0.8)	88	7.5	3	0.8	0
3	132	1 (0.8)	88	9	2.3	0	0
4	132	1 (0.8)	79.7	15.8	2.3	1.5	0
5	131	2 (1.5)	50.4	34.6	9.8	3	0.8
6	132	1 (0.8)	51.9	33.1	10.5	3.8	0
7	132	1 (0.8)	46.6	25.6	17.3	5.3	3.8
8	130	3 (2.3)	48.1	27.1	12.8	7.5	2.3
9	132	1 (0.8)	80.5	11.3	5.3	2.3	0
10	132	1 (0.8)	67.7	21.1	7.5	3	0
11	132	1 (0.8)	42.1	33.1	14.3	6.8	3
12	132	1 (0.8)	57.1	24.1	11.3	4.5	2.3
13	133	0 (0)	84.2	9	3.8	2.3	0.8
14	133	0 (0)	63.2	26.3	7.5	3	0
14a	131	2 (1.5)	68.4	18	8.3	3.8	0
14b	133	0 (0)	75.2	12	10.5	2.3	0
15	133	0 (0)	78.9	14.3	6	0.8	0
16	133	0 (0)	91.7	4.5	3	0.8	0
17	133	0 (0)	92.5	4.5	0.8	1.5	0.8
18	129	4 (3)	45.9	30.8	9.8	4.5	6
19	129	4 (3)	51.1	26.3	10.5	4.5	4.5
20	133	0 (0)	91.7	4.5	2.3	0.8	0.8
21	121	12 (9)	63.9	14.3	6.8	0	6
22	133	0 (0)	75.2	17.3	6	0.8	0.8
23	133	0 (0)	73.7	16.5	7.5	0.8	0.8
24	133	0 (0)	54.1	30.8	12.8	1.5	0.8
25	132	1 (0.8)	45.1	36.1	10.5	6.8	0.8
26	132	1 (0.8)	62.4	23.3	10.5	1.5	1.5
27	132	1 (0.8)	52.6	30.1	12.8	3.8	0
28	132	1 (0.8)	42.9	38.3	12.8	5.3	0
29	132	1 (0.8)	68.4	20.3	6	3.8	0
30	132	1 (0.8)	67.7	12.8	6.8	12	0

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