Predicting Breast Cancer-Related Lymphedema Using Self-Reported Symptoms

Jane M. Armer ▼ M. Elise Radina ▼ Davina Porock ▼ Scott D. Culbertson

► **Objectives:** This study aimed to determine the accuracy of using self-reported signs and symptoms to identify the presence of lymphedema as well as the usefulness of identifying clinically measurable lymphedema on the basis of certain symptoms elicited by the Lymphedema Breast Cancer Questionnaire (LBCQ).

► **Methods:** This analysis used logistic regression to identify symptoms predictive of differences between symptom experiences of participants belonging to two distinct groups (study A): those with known post-breast cancer lymphedema ($n = 40$) and those in a control group of women with no history of breast cancer or lymphedema ($n = 40$). Symptoms in this model of best fit were used to examine their relation to limb circumferences of breast cancer survivors in a second independent data set (study B; $n = 103$) in which a diagnosis of known lymphedema was not previously determined using symptom experiences.

► **Results:** The presence of lymphedema was predicted by three symptoms comprising a model of best fit for study A ($c = .952$): "heaviness in past year," "swelling now," and "numbness in past year." Using this model, prediction of absolute maximal circumferential limb difference (i.e., ≥ 2 cm) in study B showed that "heaviness in the past year" ($p = .0279$) and "swelling now" ($p = .0007$) were predictive. "Numbness in the past year" was not predictive. However, those with lesser limb differences reported this symptom more often.

► **Conclusions:** The findings suggest that changes in sensations may be indicators of early lymphedema or other treatment-related sequelae that must be assessed carefully at each follow-up visit and over time. A combination of symptom assessment and limb volume measurement may provide the best clinical assessment data for identifying changes associated with post-breast cancer lymphedema.

► **Key Words:** breast neoplasms · diagnosis · lymphedema · symptoms

Secondary lymphedema is a chronic aftereffect of breast cancer treatment. With the increasing number of women surviving treatment (American Cancer Society, 2003), there is a growing population of women at risk for the development of this complication. In the Western world, breast cancer and its treatment are the leading causes of secondary lymphedema (hereafter referred to as lymphedema).

Although the potential impact of lymphedema is extensive, it is largely unrecognized and underdiagnosed. This is partly because the historical focus has largely been on acute treatment, lack of uniformity in diagnostic criteria, and the complexities in valid and reliable limb measurement (Armer, Heppner, & Mallinckrodt, 2002). Because clinical assessment of lymphedema with regard to changes in arm volume appears to lack optimal accuracy for sufficient diagnosis of lymphedema, other assessment options should be considered. Self-reported signs and symptoms over time may be most revealing of subjective limb changes indicating a need for further lymphedema assessment and follow-up management (Kosir et al., 2001). Thus, sensation changes (e.g., limb heaviness, swelling, change in fit of garments, redness, and tenderness) and functional changes (e.g., reduced range of motion) also must be assessed in addition to anthropometric measurements.

To date, no research has explicitly investigated the relation between the symptoms women experience as early indicators and limb volume changes. Early indicators allow for early intervention with acute lymphedema that can be

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reversible, reducing the risk of chronic lymphedema development (Petrek, Pressman, & Smith, 2000; Rockson, 1998). Furthermore, early intervention is associated with better overall outcomes (Petrek et al., 2000). Thus, the purpose of this study was to test the predictive and discriminatory validity of using symptom experiences related to limb volume change secondary to post-breast cancer lymphedema to determine the presence of clinically measurable lymphedema.

Literature Review

In the United States, breast cancer develops in more than 200,000 women annually (American Cancer Society, 2003). Worldwide, this number exceeds 1 million women (Ferlay, Bray, Pisani, & Parkin, 2001). More than 2 million women living with breast cancer in the United States, accounting for nearly 30% of all cancer survivors, are at risk for the development of lymphedema throughout their lifetimes (Bumpers, Best, Norman, & Weaver, 2002).

Lymphedema occurs as both acute and chronic conditions in which persistent swelling associated with an abnormal accumulation of protein-rich fluid is experienced in the affected area (Casley-Smith, 1992; Mortimer, 1998). For breast cancer survivors, this can be the arm, breast, or chest wall on the side of the body where treatment for breast cancer occurred.

The impact of unmanaged and unresolved lymphedema on quality of life among women surviving breast cancer encompasses interpersonal and family relationships, functional abilities, occupational roles, self-image, and self-esteem (Mirolo et al., 1995; Passik & McDonald, 1998; Petrek & Heelan, 1998; Tobin, Lacey, Meyer, & Mortimer, 1993). Treatment for chronic lymphedema, such as compression bandaging (overnight only for routine long-term maintenance or 23 hours a day during intensive treatment) has a further impact on activities of daily living and caring for self and family (Radina & Armer, 2001). Significant health-related complications of unmanaged lymphedema include cellulitis, lymphadenitis, open wounds, and potentially life-threatening septicemia and angiosarcoma (Humble, 1995; Mortimer, 1998; Petrek & Heelan, 1998). In addition to the risk of infection associated with cellulitis and lymphangitis, which often result from the protein-rich stagnant lymph fluid, the swelling associated with post-breast cancer lymphedema frequently causes discomfort and disability (Hull, 1998).

Incidence and Prevalence
A factor inhibiting the recognition of lymphedema with regard to prevalence and the extent of its impact on lives is the apparent underdiagnosis and underrecognition of the condition by healthcare providers. Estimates for the incidence of post-breast cancer lymphedema range from 6% to 30% (Petrek & Heelan, 1998) and from 6% to 62.5% (Passik & MacDonald, 1998). Longitudinal studies that follow women for longer periods generally have found that the length of time since breast cancer surgery is associated with a higher incidence of lymphedema (Petrek & Heelan, 1998). This broad range of findings may be attributed to recent breakthroughs in breast cancer treatment including

progress in breast conservation and therapeutic combinations leading to increased survivorship (Meek, 1998; Tobin et al., 1993), inconsistent criteria for defining lymphedema, small samples, retrospective rather than prospective analyses, and difficulties, particularly with reliability, in assessing lymphedema (Armer et al., 2002).

After reviewing the lymphedema literature, Petrek and Heelan (1998) noted that the scanty evaluation of lymphedema may be attributed to several factors including a history of relative neglect of women's health and the traditional view that quality of life is less important than the eradication of cancer and detection of recurrence. Typically, lymphedema has not been considered a "life-threatening" complication. It may emerge while other more acute and distressing symptoms demand attention, thus contributing to underrecognition. Only recently has there been serious attention to survivorship and quality-of-life issues.

Diagnosis
Diagnosis of lymphedema has been problematic, although various methods have been used to measure the swollen arm (Petrek & Heelan, 1998). Three measurement techniques currently in use include: (a) circumferences, using a tape measure to assess limb girth at certain intervals; (b) water displacement, using a volumeter—the "gold standard" of limb volume estimation; and c) perometry, using infrared laser technology to estimate volume and graph shape (Petlund, 1991). The lack of standard measurement protocols, reliability and validity studies, and a uniform definition contributes to the dilemma of accurate measurement and limits the diagnosis of lymphedema (Petrek et al., 2000; Rockson, Miller et al., 1998). Circumferential measurement at selected points (every 2 to 10 cm, or at one to five anatomic points) is the most commonly used anthropometric assessment in the clinical setting, although it is hampered by problems with intra- and interrater reliability. Water displacement, the "gold standard" of limb volume estimation, is inappropriate for routine use in the clinical setting. Estimation of limb volume by infrared perometry using equipment marketed for custom fitting of compression garments is now in research trials (Armer, 2001).

Perhaps the most common criterion for lymphedema diagnosis has been a difference of 2 cm or more in arm circumference at a corresponding point (or 200 ml of difference in limb volume if water displacement is used) between affected and nonaffected limbs (Meek, 1998). These measurement criteria are dichotomous, without specification as to severity. They overlook latent-stage disease when early intervention may be most effective in reversing swelling.

In a recent prevalence study, Armer and Whitman (2002) found the women (39%) ($n = 103$) returning for breast cancer follow-up evaluation (mean time since diagnosis, 36 months) had 2 cm of difference or more in circumference at one or more points between the affected and nonaffected limbs. However, among the 99 medical records reviewed, only a few (21%) showed a medical diagnosis of lymphedema. Furthermore, additional women (40%) ($n = 103$) had limb differences at one or more

points of 1 cm or more but less than 2 cm, a difference that some consider indicative of latent lymphedema (Meek, 1998).

Armer and Whitman's (2002) findings emphasize two important points. First, the limbs of patients with breast cancer are not measured routinely in the clinical setting during acute treatment or routine follow-up evaluation. Thorough assessment requires objective measures of inspection, palpation, and volume estimation (by circumferences, water displacement, or perometry), as compared with evaluation of the nonaffected limb. Second, when limb measurements are performed, most often a one-time comparison of circumferences between limbs is performed for those not known to be equal in size or shape before treatment (Armer et al., 2002). Although comparison with the nonaffected limb is critical, the optimal assessment would involve an evaluation of both limbs over time. Limb volume changes compared over time and with the contralateral limb provide the most complete objective assessment data for lymphedema diagnosis and treatment decisions.

Secondary lymphedema is a chronic aftereffect of breast cancer treatment

Another key measurement issue stems from the common lack of a preoperative limb volume baseline for postoperative comparison. Recent findings show that healthy limbs may not be symmetrical (Armer, 2000). A finding (≥2 cm or 200 ml difference) between the preoperative baseline of the affected limb and the postoperative measurement of the same limb would better support the diagnosis of lymphedema. Optimally, lymphedema clinical assessments should begin preoperatively with assessment of both the bilateral limb volume and the symptom experience, and should continue with each follow-up visit.

Symptoms

Sensation changes may be the earliest indicator of increasing interstitial pressure changes associated with lymphedema, even before observable changes or measurable volume changes (Kosir et al., 2001). The breast cancer survivor may be the first to notice that a ring, watch, or favorite sleeve may no longer fit as before, or that a sensation has changed. As the fluid increases, the arm may become visibly swollen and may feel heavy, with an observable or measurable increase in arm size.

In a recent cross-sectional descriptive study, breast cancer survivors with a difference of 2 cm or more between limb circumferences reported more symptoms currently and in the past year (Armer & Whitman, 2002). Numbness, tightness, and heaviness were experienced at the time of the interviews by approximately one fourth (23%) to one half (55%) of all women. Limb tenderness, limb swelling, and aching were reportedly experienced over the preceding year by one third (34%) to two fifths (42%) of all women. Symptoms experienced most commonly among women with lymphedema were swelling (63%), heaviness (60%), tenderness (45%), and numbness (38%).

Other symptoms associated with post-breast cancer lymphedema include fatigue, pain and other sensation changes, and limitations in arm range of motion. First, individuals with lymphedema may experience a level of fatigue that is moderately severe and moderately disruptive to daily living (Armer & Porock, 2002). The fatigue may be associated with lingering effects of radiation or chemotherapy, but also may be an early cue of a change in health status (e.g., cellulitis).

Second, differentiation of posttreatment pain etiology using functional and sensation changes may be difficult because there are a variety of other possible explanations for these changes. For example, pain may be related to nerve damage during surgery, as in the case of postmastectomy pain syndrome (Carpenter et al., 1998; Kwekkeboom, 1996; Stevens, Dibble, & Miaskowski, 1995; Wallace, Wallace, Lee, & Dobke, 1996). The stretching of skin and interstitial tissue to accommodate the buildup of lymph fluid as well as the pressure of increased lymph fluid on nerve endings also may cause discomfort and/or pain. Posttreatment sensation changes may be related to the surgical incision or to nerve injury during axillary lymph node dissection. Sensations include phantom breast sensations, numbness, hyperesthesias, and "pins and needles" sensations (Stevens et al., 1995). Dysesthesia, defined as unpleasant abnormal sensation, may be described as a cutting or burning pain.

Third, early postoperative range of motion changes in the ipsilateral arm and shoulder may result from tissue manipulation and positioning during surgery (Ernst, Voogd, Balder, Klinkenbijl, & Roukema, 2002; Gerber et al., 1992; Hack, Cohen, Katz, Robson, & Goss, 1999; Sugden, Rezvani, Harrison, & Hughes, 1998). Later, range of motion changes may result from scar tissue and fibrosis related to surgery or radiation therapy. Swelling and fibrosis from lymphedema also may cause range of motion restrictions in the shoulder, elbow, wrist, and fingers (Humble, 1995).

Considering the lack of consistent lymphedema diagnosis and awareness, this study contends that assessment of signs and symptoms experienced by women is a useful method for alerting practitioners to the need for anthropometric assessment and possibly early intervention. Thus, the authors' main focus is to test the predictive and discriminatory validity of using symptom experiences (related to limb volume change secondary to breast cancer treatment) to determine the presence of clinically measurable lymphedema.

Theoretical Framework

The current examination of lymphedema was guided by a biobehavioral model of cancer, stress, and disease progression proposed by Anderson, Kiecolt-Glaser, and Glaser (1994), and emerging models of stress and coping (Hola-

FIGURE 1. Structural model of post-breast cancer lymphedema providing the theoretical framework for investigation of two indicators of limb volume changes secondary to treatment: self-reported symptoms and volume estimates by circumferences (Armer et al., 2002).
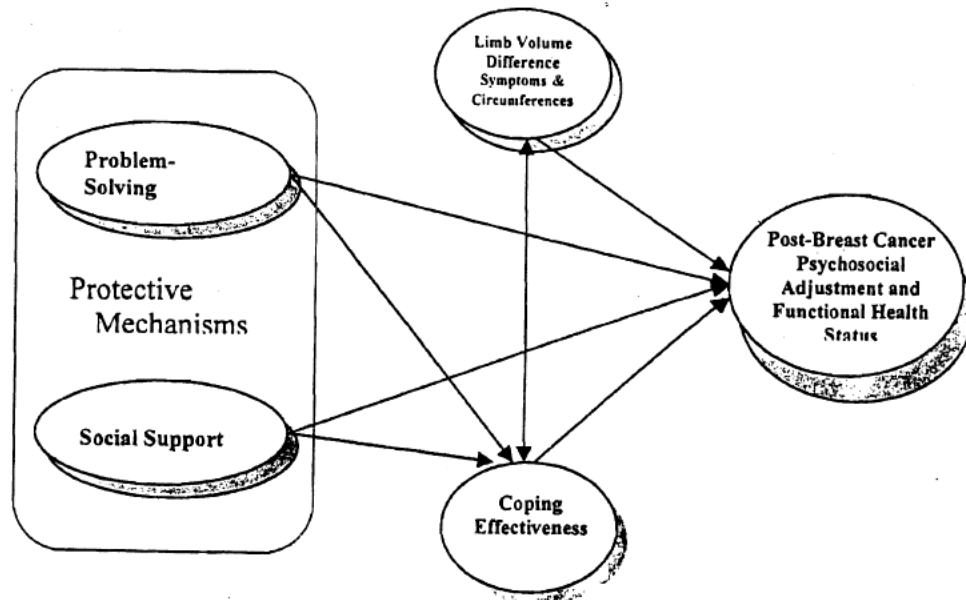
han, Moos, & Schaefer, 1996). Stressors substantially affect an individual's psychological and physiologic well-being (Lazarus & Folkman, 1984). Growing empirical evidence supports the key roles that psychosocial factors play in adaptive responses to stress (Zeidner & Endler, 1996). In particular, problem solving and social support can be viewed as protective mechanisms that reduce the risk resulting from life crises and transitions (Holahan et al., 1996; Mrazek & Haggerty, 1994).

On the basis of these foundations, a framework was developed to guide the current study of lymphedema (Armer et al., 2002). First, problem solving and social support are conceptualized as potential protective mechanisms that could reduce the progression of lymphedema (Figure 1). Lymphedema is conceptualized as consisting of both objective and subjective indicators, specifically limb volume difference, associated signs and symptoms, and coping effectiveness (Figure 1). Likewise, because very little is known about coping with lymphedema, the study examined coping through measurement of lymphedema coping efficacy. Objective (e.g., circumferential measurement) and subjective (e.g., symptom evaluation) assessments describe different dimensions of lymphedema that may further understanding of not only the physical aspects of lymphedema, but also the cognitive and affective components related to coping with this disease. Finally, the right side of Figure 1 depicts dimensions of post-breast cancer treatment psychosocial adjustment, specifically psychosocial distress, quality of life, adjustment to chronic illness, and functional health status.

On the basis of this framework (Figure 1), the purpose of the reported study was to determine the predictive and discriminant validity of using lymphedema-related symptoms (subjective assessment) to predict the outcome of measurable lymphedema (objective assessment) and to discriminate between those with and those without lym-

phedema. Specifically, the research questions were as follows:

1. Can the Lymphedema and Breast Cancer Questionnaire (LBCQ) tool differentiate between women with known post-breast cancer lymphedema and healthy women? That is, do self-reported breast cancer lymphedema-related symptoms as elicited by the LBCQ differentiate group membership (between lymphedema and non-lymphedema) among healthy women and breast cancer survivors with known lymphedema?

2. Do LBCQ symptoms, identified as predictors of group membership in the regression model of best fit in one sample, contribute to the identification of participants with maximal limb circumferences of 2 cm or more in a second independent sample, as compared with those who have a maximum limb difference of less than 2 cm?

Methods

Upon receipt of approval from the university's institutional review board, data collection for both studies took place at a Midwestern university-affiliated cancer center. Trained oncology research nurses and graduate nursing research assistants administered both the circumferential measurements and the face-to-face interview with the LBCQ tool. Once collected, all the data were transcribed into a computer database for data management and analysis.

Instrumentation

The LBCQ is a structured interview tool designed to assess indicators of lymphedema, their frequency, and symptom management strategies (Armer & Whitman, 2002). The theoretical foundation that guided the development of the LBCQ arose from early qualitative work based on Leven-
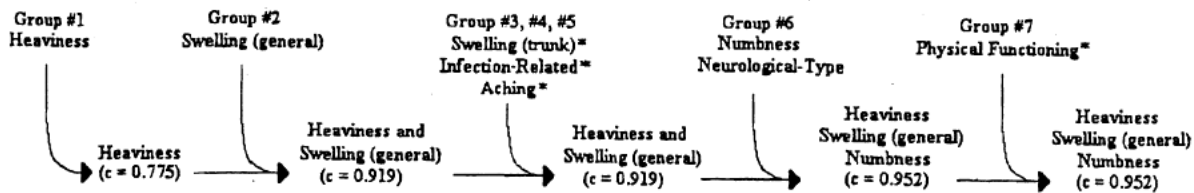
Group #1 Heaviness	Group #2 Swelling (general)	Group #3, #4, #5 Swelling (trunk)* Infection-Related* Aching*	Group #6 Numbness Neurological-Type	Group #7 Physical Functioning*
Heaviness $(c = 0.775)$	Heaviness and Swelling (general) $(c = 0.919)$	Heaviness and Swelling (general) $(c = 0.919)$	Heaviness Swelling (general) Numbness $(c = 0.952)$	Heaviness Swelling (general) Numbness $(c = 0.952)$

FIGURE 2. Blocks of symptom clusters theoretically ordered on the basis of current literature and clinical observation. Variables making a significant contribution at each step were retained. Asterisk indicates no change from previous step when block variable was stepped in.

thal's Common Sense Model (Leventhal, Meyer, & Nerenz, 1980). The symptom experience of 25 women with diagnosed lymphedema was explored through individual interviews and participant observations of lymphedema support groups (Armer, 1999; Radina, Armer, Culbertson, & Dusold, in press). Thematic analysis of these data and critical review of the published literature produced a list of 28 symptoms associated with lymphedema that formed the basis of the LBCQ.

The LBCQ elicits responses regarding 19 symptoms occurring currently or in the past year. For example, the participant is asked, "Have you had a change in how your sleeve fits?" to which the person responds with "yes" or "no" answers regarding whether the sign or symptom is currently present ("now or in the past month") or has been present at any point in the past year. Scores for total current symptoms and total symptoms in the past year are calculated, resulting in a maximum total symptom score of 38. The LBCQ concludes with demographic items, an assessment of treatment history, and open-ended questions about treatment, disease course, and symptom management.

The LBCQ has demonstrated face and content validity. It was reviewed and revised by expert oncologic advanced practice nurses for clarity, simplicity of format, and complete coverage of the symptom domain. In addition, expert patient educators reviewed the LBCQ for clarity, format, and education level. Revisions were made, and the tool was pilot tested with eight women who had breast cancer lymphedema, leading to further refinement, with minor changes in the ordering of items.

The reliability of the LBCQ was evaluated using Kuder-Richardson-20 and the test-retest method. The Kuder-Richardson-20 shows an acceptable measure of internal consistency ($r = .785$) for all 19 items. Test-retest reliability was evaluated using a sample of healthy women without breast cancer or lymphedema ($n = 35$) and allowing a 2-hour test-retest interval. The findings show a high degree of reliability for the LBCQ ($r = .98$).

Studies and Sample Characteristics

The data presented in this report are derived from two studies in which similar protocols guided data collection by the research team. Both studies used the LBCQ symptom assessment tool and collected bilateral circumferential limb data with the arm supported in the horizontal position.

Study A

This study assessed the intra- and intermethod and the test-retest reliability of three methods for assessing limb vol-

ume (water displacement, circumferences, and perometry), as well as the symptoms associated with limb swelling. Thus, a control group of healthy women without breast cancer or lymphedema and a group with known post-breast cancer lymphedema were subject to the same data collection procedures twice during a 4-hour interval for comparison purposes.

The participants were recruited using convenience sampling. The women with lymphedema were recruited through flyers distributed in local clinics, through local lymphedema and breast cancer support groups, and by snowball sampling. Healthy women were recruited through flyers and snowball sampling. These procedures included the completion of the LBCQ via face-to-face interviews and measurement of both limbs using circumferential measurements, water displacement, and perometry in a laboratory setting. Symptom data from time 1 were used to predict group membership (lymphedema vs. nonlymphedema).

Study B

This study attempted to document the prevalence of breast cancer lymphedema among women treated for breast cancer, describe the symptom experience and self-care management of lymphedema, and compare the LBCQ and circumferential measurements of the women with the symptom experiences of the women with lymphedema from study A. The participants, all of whom had known breast cancer, were recruited through physician and nurse practitioner referral, flyers, and personal invitations during clinic visits at a large Midwestern regional cancer center. All the participants were administered the LCBQ, and changes in limb volume were assessed by measuring arm circumference at five distinct anatomic points (wrist, midforearm, elbow, mid-upper arm, and axilla) on both limbs. The descriptive characteristics of the samples for study A and study B are included in Table 1.

Data Analysis

In study A, logistic regression found symptoms (variables) predictive of two distinct groups: participants with known post-breast cancer lymphedema ($n = 40$) and healthy participants with no history of breast cancer or lymphedema ($n = 40$). Predictive symptoms in the model of best fit were used to examine the maximal difference between left- and right-side circumferential measurements among breast cancer survivors in a second independent data set ($n = 103$) from study B. Therefore, two sets of procedures for symptom analyses with two independent samples were performed:

TABLE I. Descriptive Statistics for Samples A and B

| Population | Sample A | | | Sample B |
	Total	Lymphedema	Healthy	Total
Sample Size	80	40	40	103
Mean age	50.2 ± 14.9 (18–81)	59.4 ± 10.3 (33–81)	41.2 ± 13.1 (18–71)	59.0 ± 12.6 (31–88)
Mean years of education	16.8 ± 3.8 (8–27)	15.8 ± 3.9 (8–26)	17.9 ± 3.5 (12–27)	12.7 ± 2.6 (4–23)
Mean height (inches)	65.0 ± 2.6 (61–73)	65 ± 2.5 (61–70)	65 ± 2.6 (61–73)	64.7 ± 2.6 (60–71)
Mean weight (pounds)	160.3 ± 37.2 (18–88)	165 ± 38.8 (97–320)	155.6 ± 35.3 (105–244)	169.2 ± 37.8 (101–305)
Mean time since Tx (years)	N/A	6.4 ± 6.8 (0.3–32.8)	N/A	3.3 ± 5.3 (0.25–41.0)
Tx: S, C, R		47%		40%
Tx: S and R only		20%		28%
Tx: S and C only		22%		16%

Note. S = surgery; C = chemotherapy; R = radiation.
Tx = treatment

1. The experience of symptoms (now and in past year) as reported in study A ($n = 80$) was used to discriminate between participants with breast cancer lymphedema and those without breast cancer or lymphedema using logistic regression. A blockwise selection approach with steps theoretically dictated on the basis of research and clinical understanding was used (Pedhazur, 1997, p. 227-30). The strategy was to use a variation of a blockwise forward-selection model-building approach. In the typical forward selection, the computer would choose the "best" variable for predicting an outcome, keep that variable in the model, and then look for the next best variable, and so forth. In step 1 of the approach, the predictors were grouped in blocks based on theoretical considerations as well as the clinical experience of the investigators. The description of the blocks and the number of variables within each block are shown in Table 2. The blocks were ordered according to the authors' judgment of their value in predicting lymphedema, with the first block being the most important. Beginning with the first block, a stepwise selection procedure was applied to the predictors within the block. Variables with coefficients that had a p value less than .05 were inserted into the model. Then the analysis proceeded to the second block. Variables found to be significant at an earlier step were included in the model, and predictor variables from the next block were considered in a stepwise fashion. Variables were retained for later steps if the corresponding coefficients remained significant at the .05 level. Once shown to be significant at a value of .05 or less, no variables failed to maintain that level of significance. Therefore, none were removed.

2. As a means for validating the usefulness of the selected symptoms as predictors of lymphedema, the symptoms in the model of best fit obtained in the study A analysis were used to investigate the predictive value of the symptoms from study B. Using the symptoms selected in the best fit model, the average maximum circumferential difference among participants reporting those selected symptoms were compared with the difference among those who did not have the selected symptoms. Testing was conducted to determine whether the mean maximum circumference was significantly greater in the women with symptoms.

Findings

For the results corresponding to the first step of fitting a predictive model to the study A data, predictors of lymphedema were sought, or more precisely, variables that allowed distinction between healthy women and those "known" to have lymphedema.

Once the first and second variables considered most important ("heaviness in the past year" and "swelling now") were in the model, the only other symptom that entered the model was "numbness in the past year." The c-statistic, a measure of the predictive power of the logistic regression model, was .775 with one variable ("heaviness in past year") in the model, and .919 with two variables in the model ("heaviness in the past year" and "swelling now"). Introduction of the third variable ("numbness in the past year") contributed only a modest amount, bringing the c-statistic to .952 (Fig. 6).

The second step was to look at the study B data to see whether individuals with combinations of these three symptoms have larger differences in circumferential limb measurements. Two distinct methods were used for validation of the findings from the first step. One method compared the mean maximal differences in circumferential limb measurements, and the other method was a logistic

TABLE 2. Theoretically-Ordered Variables Entered Into Regression (Step 1)

Variables Block	Cluster of Symptom Variables Stepped In (Now and in the Past Year)	Symptoms in Variable	Number of Variables
#1	Heaviness	Heaviness	1
#2	Swelling (general)	Swelling; Swelling with pitting	2
#3	Swelling (trunk)	Chest swelling; Breast swelling	2
#4	Infection-related	Increased temperature; Redness; Rash; Blistering,	4
#5	Aching	Aching	1
#6	Numbness (neurological-type)	Numbness; Tenderness; Stiffness; Firmness/Tightness	4
#7	Physical functioning	Limited movement of shoulder, elbow, wrist, fingers; Weakness in arm or hand	5

regression based on the maximal difference being at least 2 cm. In this step, the authors first looked at the largest absolute value of the differences between left- and right-side measurements. The difference is sometimes used as evidence of (if not the definition of) lymphedema. This is meant to be a validation of the signs and symptoms chosen in the first step. If they are indicators of lymphedema, then a larger difference in measurements would be expected for those with the signs and symptoms than those without them. A significantly larger maximum difference for those with the symptom "heaviness in the past year" than those without this symptom was determined (the p value for the one-sided alternative for Wilcoxon rank sum test is .0279). For "swelling now," the corresponding p value is .0007. The "numbness in the past year" variable was lower on the list of anticipated predictors, and although predictive in the study A data, it was not associated with a larger maximum difference. In fact, the maximum difference was lower in those with the symptom. The p value for the Wilcoxon Rank sum test was .80.

The final model containing the three predictors is displayed in Table 3. The wide confidence interval for the odds ratio of the variable "swelling" reflects the fact that only 1 of 36 individuals with the symptom "swelling" did not have lymphedema. The Hosmer-Lemeshow Goodness of Fit test was acceptable with a p value of .25.

To give additional information as to the relation between the two symptoms "heaviness" and "swelling"

TABLE 3. Odds Ratio Estimates and Confidence Intervals for Three Variables of Significance (Step 1)

Variable	Point Estimate	95% Wald Confidence Limits
Heaviness	7.995	1.168–54.726
Swelling	96.889	9.865–951.611
Numbness	9.902	1.819–53.918

and the difference in circumferential measurements, another variable was studied. The largest of the absolute differences between left and right circumferential measurements was used again. The box plots in Figure 3 are of interest relative to the categories based on the presence of one, both, or neither of the two principal symptoms ("swelling now" and "heaviness in the past year"). A horizontal reference line at a value of 2 cm is included. From the box plots, it can be seen that a higher proportion of women with symptoms have maximal values exceeding 2 cm than those without symptoms. This result also can be seen from the results of a logistic regression analysis. In that analysis, "heaviness" and "swelling" both were predictive of lymphedema, defined as characterized by a maximal difference of at least 2 cm.

It was recognized that a large number of variables were considered in the first analysis. For this reason, all variables were not considered at once in the analysis. Rather, they were considered in blocks of variables ordered according to a judgment of their importance based on theoretical considerations and clinical observations. It was thought that the retention of two variables (one from block 1 and one from block 2) in the model as significant from among the first six considered lends credibility to their importance as predictors. Furthermore, the conclusions as to which variables are important predictors of lymphedema do not rest solely on study A. The participants in study B were used to validate the predictors found in the first study.

In summary, the following were found:

1. In study A, group membership (i.e., the experience of symptoms unique to women with lymphedema) was predicted by three symptoms: "heaviness in the past year," "swelling now," and "numbness in the past year." Thus, because they appear to predict the experience of lymphedema, these three symptoms were included in the model of best fit for study A.
2. Using this model of best fit, prediction of absolute maximal circumferential limb difference (i.e., ≥2 cm) in study B data showed the first two symptoms, "heaviness in the past year" and "swelling now," to be predictive of a maximal limb difference of 2 cm
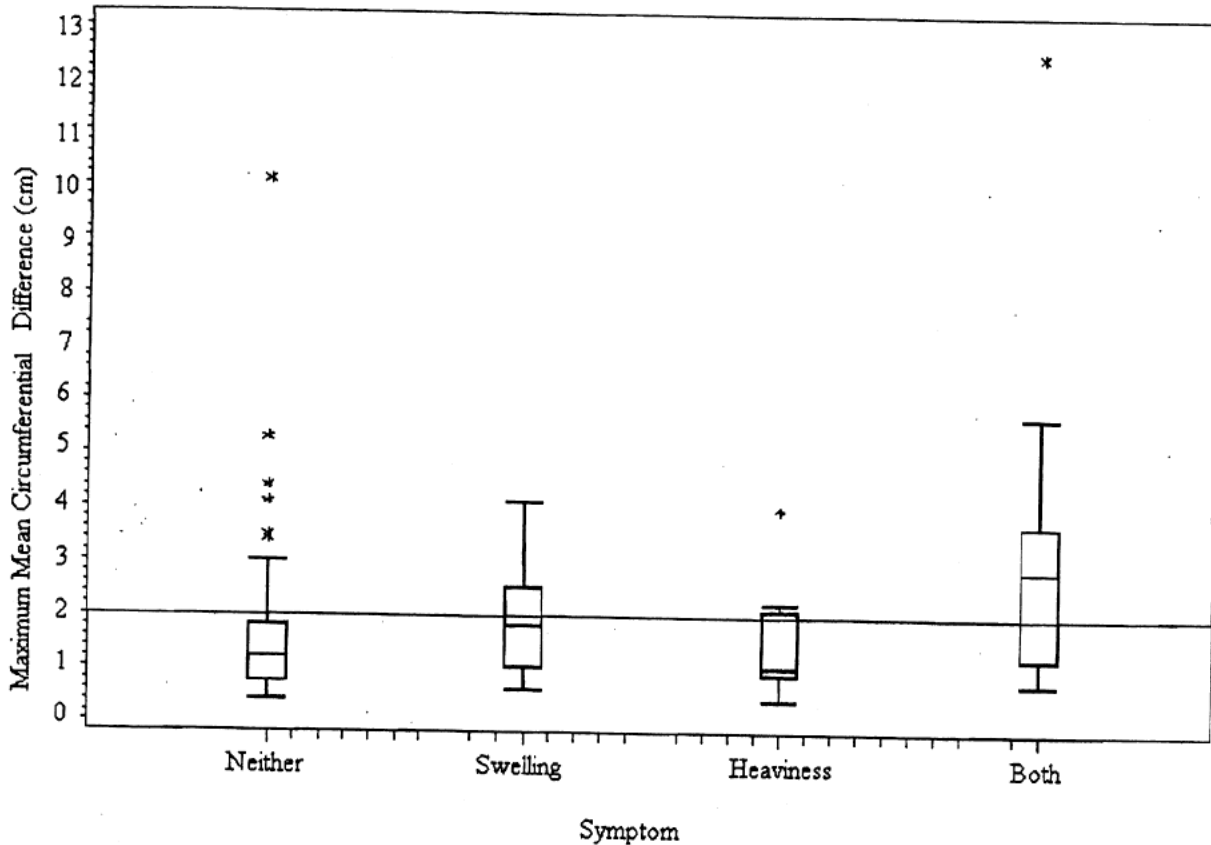
FIGURE 3. Boxplot of symptoms (swelling, heaviness, both and neither) and absolute limb volume differences (step 2 analysis of sample B data).

or more. The third variable, "numbness in the past year," was not predictive of membership in the group of participants with limb differences of 2 cm or more. Interestingly, "numbness" was reported more often by those with lesser limb differences. Thus, through logistic regression, validation of the predictive value of the first two variables was confirmed. Comparison of the maximum difference variable offered validation as well, in that the first two variables were associated with a larger maximum difference for those with the symptoms than those without them.

Discussion

The purpose of this study was to test the validity of using self-reported symptoms to discriminate between women with and those without lymphedema. The importance of using self-reported symptoms lies in the ability to use easily assessed symptoms to detect lymphedema at an earlier stage of development. Three symptoms (heaviness, swelling, and numbness) were significant in discriminating between women with lymphedema and healthy women.

These results validated the investigators' proposition, based on clinical and empirical evidence, that the symptoms

unique to women with known lymphedema are best predicted by these three symptoms. These symptoms were highly reported by women with lymphedema and rarely, if at all, by healthy women. Two of these symptoms were confirmed as predictive in the more subtle differentiation of women with breast cancer and women with breast cancer and lymphedema. Numbness was not predictive of increased limb volume differences when all the participants had been treated for breast cancer. Rather, the symptom of "numbness in the past year" was reported more often by those with lesser limb differences (i.e., <2 cm). This suggests that numbness may have more to do with status after breast cancer treatment than with having lymphedema. Further research is warranted to determine the effects of breast cancer treatment on the development of neurologic changes. For example, numbness may be one among a constellation of neurologic symptoms related to postmastectomy pain syndrome (Stevens, Dibble, & Miaskowski, 1995).

Despite the major limitation of one-time snapshots of symptoms and limb volume, the careful attention to the quality of measurement resulting in highly reliable data collection and a rigorous analytic process were strengths of this study. Indeed, in practice, clinicians and researchers generally have no knowledge of preexisting limb or symptom differences or changes over time. Without a preoperative base-

line of limb volume and symptoms, the assessment of change is quite limited, potentially contributing to under- or misdiagnosis of lymphedema. Furthermore, the advantages of using the same tool in two independent samples provided the opportunity to examine validity in greater depth.

The reported research is a first step in identifying a cluster of symptoms predictive of post-breast cancer lymphedema limb volume changes that may be used to guide posttreatment clinical assessment. The reported findings have served as the foundation for current research being done in the area of post-breast cancer lymphedema (Armer, 2001). In future studies, multisite enrollment and data collection are recommended to increase generalizability of findings beyond a single geographic region.

Implications for Practice

These findings suggest that changes in sensations and range of motion may be early indicators of developing lymphedema or other treatment-related sequelae, and that such changes must be assessed carefully at each follow-up visit. A combination of symptom assessment and limb volume measurement may provide the best clinical assessment data for identifying changes associated with post-breast cancer lymphedema. Selected specific symptoms highly associated with lymphedema may be targeted for the clinician's follow-up assessments. The presence of both symptoms and limb swelling would be key criteria for further diagnostic assessment by the physician, nurse practitioner, or physical therapist.

The refined LBCQ or a similar tool focused on lymphedema symptom experience has application as a succinct valid and reliable assessment tool for nurses working with patients at risk for lymphedema. For example, assessment of a small number of key symptoms and key anthropometric measurements at each follow-up visit for every breast cancer survivor can feasibly be incorporated as a part of routine clinical assessment. ▼

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