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Building better bras for women treated for breast cancer

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BUILDING BETTER BRAS FOR WOMEN TREATED FOR BREAST CANCER

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CERTIFICATION

I, Sheridan A. Gho, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Medicine, Faculty of Science, Medicine and Health, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Sheridan A. Gho
11 February 2014

Dedication

This thesis is dedicated to my parents.

My father, Robert Gho, for being the force of change that carried me here; and for lovingly and patiently teaching me "if you are going to do something, do it properly" - a lesson I am privileged to have learnt, and have relied on time and time again throughout this journey.

My mother, Tanya Whiteside, for being the single most inspirational person in my life. For teaching me everything from reading comprehension (at 6 am every morning!), to walking with my back straight and head level, to understanding the difference between knowledge and wisdom and how to persist in pursuit of both.
I am who I am today because of you.

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Publications

This thesis includes chapters that have been written as the following journal articles:

Chapter 2: S.A. Gho, J.R. Steele, S.C. Jones, and B.J. Munro, "Self-reported side-effects of breast cancer treatment: A cross-sectional study of incidence, associations, and the influence of exercise," *Cancer Causes and Control*, vol. 24, no. 3, pp. 517-528, 2013.

Chapter 3: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Perceived barriers explain exercise participation in women treated for breast cancer better than perceived benefits," *Physical Therapy*, Accepted April 2014.

Chapter 4: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Exercise bra discomfort is associated with insufficient exercise levels among Australian women treated for breast cancer," *Supportive Care in Cancer*, vol. 22, no. 3, pp. 712-729, 2014.

Chapter 5: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Evidence-based recommendations for building better bras for women treated for breast cancer," *Ergonomics*, DOI:10.1080/00140139.2014.897377, 2014.

Chapter 7: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Does a modified exercise bra reduce bra discomfort in women treated for breast cancer?" *Textile Research Journal*, To be submitted May 2014.

As the primary supervisor, I, Professor Julie Steele, declare that the greater part of the work in each article listed above is attributed to the candidate, Sheridan Gho. In each of the above manuscripts, Sheridan contributed to the study design, recruited participants, was solely responsible for data collection and data analysis, and was largely responsible for statistical analysis and data interpretation. The first draft of each manuscript was written by the candidate and Sheridan was then responsible for responding to the editing suggestions of her co-authors. The co-authors, Bridget Munro, Sandra Jones and Julie Steele were responsible for assisting in study design, data interpretation and editing the manuscripts. Sheridan has been solely responsible for submitting each manuscript for publication to the relevant journals, and she has

been primarily in charge of responding to reviewer's comments, with assistance from her co-authors. Sheridan also took the lead role in developing the Experimental bra described in Chapter 6, with feedback on design iterations from the supervisory team of Bridget Munro and Julie Steele.

Sheridan Gho	Julie Steele
11 February 2014	11 February 2014

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"For a dream comes with much business and painful effort" *Eccl 5:3*

Finally, thank you God for faithfully seeing me through the business and painful effort of realising this dream.

Building better bras for women treated for breast cancer

Sheridan A. Gho

A Thesis for Doctor of Philosophy

Faculty of Science, Medicine and Health
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ABSTRACT

Background: Regular exercise is highly beneficial for women who have been treated for breast cancer. Bra discomfort has been cited as a potential barrier to exercise for these women, due to the unique physical side-effects of breast cancer treatment. These women have specific needs in an exercise bra that must be met in order to enable them to participate in exercise with minimal bra discomfort.

Research Question: The overall aim of this thesis was to evaluate cause of, and extent to which, bra discomfort is a barrier to exercise; to systematically investigate what women treated for breast cancer required in an exercise bra; and to build a better exercise bra for these women based on this information.

Methods: To fulfil these aims, a series of studies were conducted, which are presented in three parts. In the first part of the thesis, a national online survey was conducted to understand the influence of exercise on treatment side effects, the benefits and barriers of exercise for women treated for breast cancer, and the impact bra discomfort had on the exercise levels of these women (Chapters 2-4). The second part of this thesis identified specific exercise bra design requirements for women treated for breast cancer, and designed an experimental bra solution (Chapters 5-6). In the final part of the thesis, a laboratory-based biomechanical study (Chapter 7) evaluated an experimental exercise bra design, which was based on the information concluded from the first two parts of the thesis.

Major Conclusions: Breast cancer treatment has lasting side-effects, which can be positively influenced by participating in regular exercise. However, exercise bra discomfort is a key barrier to exercise, such that reporting exercise bra discomfort is significantly linked to low levels of exercise among women treated for breast cancer. It is apparent that several unique issues surrounding breast cancer treatment side-effects exacerbate the bra discomfort experienced by these women, and understanding such issues provides a fundamental first step towards designing better exercise bra solutions. Based on the recommendations provided by women treated for breast cancer, an Experimental bra was designed, developed and evaluated. Although further iterations are required to improve the design, the initial success of the design permits the conclusion that a specifically-developed exercise bra can enable women treated for breast cancer to enjoy the benefits of exercise without suffering bra discomfort.

Chapter 1

The Problem

1.1 Introduction

Breast cancer has been identified as one of the leading types of cancer contributing to Australia's total burden of disease and the most common invasive cancer diagnosed among Australian women [1]. Between 1982 and 2008, the number of new primary and invasive breast cancer cases more than doubled from 5,310 to 13,567 per annum [1]. Given the aging population, the number of women diagnosed with invasive breast cancer is expected to increase. Projections suggest that in 2020, the number of new breast cases will be about 17,210, which equates to 47 women in Australia being diagnosed with breast cancer every day [1].

Once diagnosed with breast cancer, a patient will undergo several medical treatments, which include combinations of chemotherapy, radiation therapy, hormonal therapies or long term medications. Patients will also typically undergo one of two types of surgery, a lumpectomy (partial removal of breast tissue) or a mastectomy (removal of the entire breast). Tumour size and position are the prime determinants of patient choice between the two surgical options [2]. A lumpectomy, usually performed in conjunction with radiation therapy, is the most common form of surgery performed on

breast cancer patients, with 10,334 lumpectomies performed in Australia in 2009-10 [1]. For patients with a tumour of high risk size and position, a mastectomy is usually required, and, in 2009-10, 6,148 mastectomies were performed on women in Australia [1]. Although treatment is vital, side-effects from treatments contribute to the total burden of disease, resulting in breast cancer being the leading cause of all female burden of disease due to cancer [1].

Despite the increase in breast cancer cases, there has been a concurrent decline in mortality rates from the disease over recent years. Between 1994 and 2007, the age-standardised mortality rates for breast cancer decreased by 29%, improving the 5-year relative survival rate for breast cancer from 72% in the period 1982-1987 to 89% in the period 2006-2010 [1]. Improvements in treatment and population screening have been shown to contribute to this fall in mortality from breast cancer [1, 3–6], and at the end of 2008, 159,325 females were alive who had been diagnosed with breast cancer in the previous 27 years [1]. Consequently, more women than ever before are living with the permanent effects of breast cancer.

Although evidence-based research has examined the risk factors for, and presentation of, breast cancer in women, relatively less information is available related to the maintenance and improvement in health for women living with breast cancer [7]. With increasing incidence rates and a growing number of survivors, greater efforts must be directed towards improving the physical functioning and quality of life of women with a breast cancer diagnosis. An effective intervention that may address a broad range of quality of life issues, as well as enhance improvements in cardio-respiratory fitness, immune function during recovery, self-esteem and other psychological health parameters in breast cancer patients and survivors, is exercise [8–11]. Exercise has the potential to address (i) the physical needs of patients through improved strength, reduced fatigue, decreased heart and circulatory disease risk and decreased breast cancer risk [12–16];

(ii) the emotional and psychological needs of patients through improved self-esteem, decreased levels of anxiety and depression, and overall mood elevation [7]; and (iii) the social needs of patients, providing an opportunity of personal development and social interaction within either a group exercise, team, or competition context [17]. This provides a compelling reason for encouraging exercise participation and adherence among women treated for breast cancer.

One theoretical construct successfully applied when encouraging exercise participation in a breast cancer population is the Social Cognitive Theory (SCT) [18–21]. Self-efficacy is a key construct in the SCT, and the strongest predictor of physical activity behaviour in women treated for breast cancer [21, 22]. It has been suggested that in the context of these women, outcome expectations (perceived benefits), goals, and perceived barriers to exercise are key influences of exercise self-efficacy [23]. In a follow-up study of breast cancer survivors three months following an exercise intervention, barriers inference and barrier self-efficacy were the only SCT constructs to demonstrate significant mediation effects. Specifically, barrier inference mediated 39% of the intervention effect on physical activity maintenance three months after the intervention was completed [24]. These results highlight the influence of exercise barriers on exercise behaviours and it is clear that a better understanding of exercise barriers may assist health practitioners in planning effective exercise interventions which are acceptable to women treated for breast cancer. This process begins with identifying and minimising any potential barriers to exercise for women treated for breast cancer.

Along with a multitude of physical, social, and cognitive barriers to exercise, research has also raised the notion of exercise bra discomfort as a reason women treated for breast cancer do not adhere to exercise [25]. This is not surprising given that the fundamental purpose of a bra is to support the breasts and that during any breast cancer treatment the structure of the breasts will be substantially affected. A study

published in 2010 concluded that a significant proportion of women treated for breast cancer experienced bra discomfort when exercising [25]. However, that study was limited to a regional sample only, and did not hold sufficient statistical power to evaluate the impact bra discomfort has on the exercise behaviours of women treated for breast cancer, or the recommendations from this patient population towards improving exercise bra design. As bras may be an external barrier to exercise that has the potential to be reduced through better bra design, research is urgently required to examine the extent to which this exercise barrier impacts upon these women, and the design requirements that must be met in order to provide an exercise bra solution for women treated for breast cancer.

1.2 Statement of the Problem

The overall aim of this thesis was three-fold. Firstly, to evaluate the causes of exercise bra discomfort, and the extent to which bra discomfort is a barrier to exercise, among women treated for breast cancer. Secondly, to systematically investigate what women treated for breast cancer require in an exercise bra, and to build a better exercise bra for these women based on this information. And finally, to assess whether a bra designed to meet the needs of women treated for breast cancer was effective in controlling breast motion, and successful in improving exercise bra comfort.

To achieve this three-fold aim, a series of studies were conducted, which are presented in three thesis parts. The first part of this thesis aimed to establish the influence of exercise on breast cancer treatment side-effects, and the benefits and barriers of exercise for women treated for breast cancer. This part then also determined the extent to which bra discomfort was a barrier to exercise, and the impact bra discomfort had on the exercise levels of women treated for breast cancer (Chapters 2, 3 and 4). This was necessary to establish whether a need for better designed exercise bras

existed, and whether any sub-group of women treated for breast cancer experienced greater bra discomfort than others. The second part of this thesis aimed to identify the specific exercise bra design requirements for women treated for breast cancer; and to design an experimental exercise bra that met these unique needs (Chapters 5 and 6). Evidence-based bra design recommendations were then used to guide an iterative design process, to develop an experimental exercise bra for women treated for breast cancer. The third and final part of this thesis aimed to assess the comfort and effectiveness of the experimental exercise bra designed in Chapter 6, compared to what women treated for breast cancer currently wear, and a commercially available exercise bra marketed for these women (Chapter 7). This evaluation formed the basis upon which final recommendations with respect to building better bras for women treated for breast cancer were developed (Chapter 8). The aim of each study and how the individual studies contribute to the overall aim of the thesis is depicted in Figure 1.1.

1.3 Significance of the Thesis

With breast cancer survivors living longer than ever before, it is clear that identifying and addressing survivorship needs is an area requiring additional research commitment. Exercise is an effective intervention that enhances cardio-respiratory fitness, immune function during recovery, self-esteem and other psychological health parameters in women treated for breast cancer. However, as the long-term benefits of exercise can only be realised through regular participation, it is critical that any barriers that may prevent women participating in exercise are identified and minimised for this population. It is speculated that inadequate bra design may be a barrier to exercise that can be modified to enable women treated for breast cancer to participate comfortably in physical activity.

This thesis will be the first comprehensive study internationally to examine the

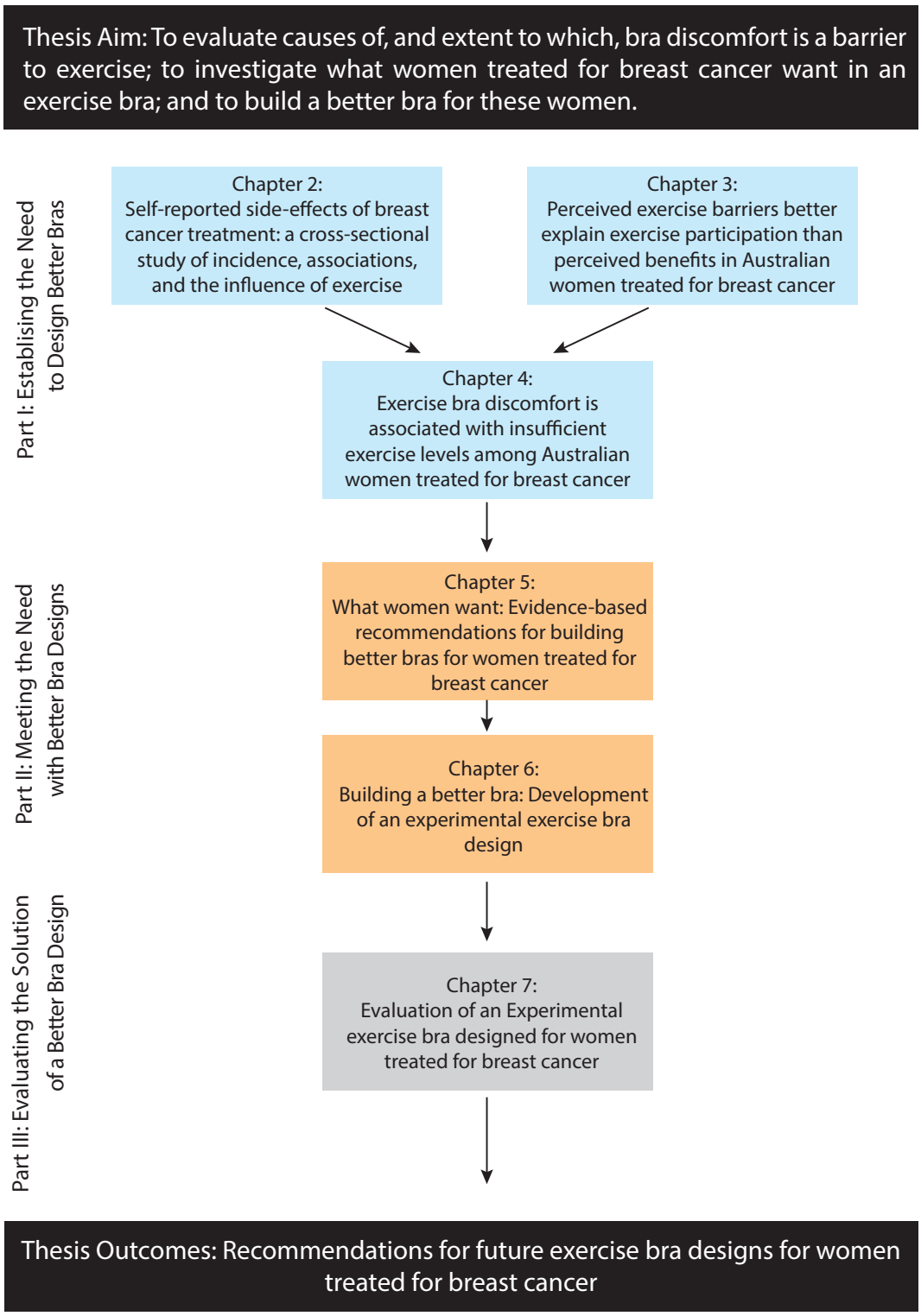


Figure 1.1: Schematic representation of the thesis structure, and how each study systematically contributes to address the overall thesis aim.

specific needs of women treated for breast cancer in terms of exercise bra design. The ultimate goal is to use this unique information to design a comfortable bra, which can empower women treated for breast cancer to be able to participate comfortably in physical activity and enjoy the health benefits associated with an active lifestyle, without being impeded by bra discomfort.

Part I

Establishing the Need to Design Better Bras

Chapter 2

Self-reported side-effects of breast cancer treatment: A cross-sectional study of incidence, associations, and the influence of exercise

This chapter is an amended version of the published manuscript: S.A. Gho, J.R. Steele, S.C. Jones, and B.J. Munro, "Self-reported side-effects of breast cancer treatment: A cross-sectional study of incidence, associations, and the influence of exercise," *Cancer Causes and Control*, vol. 24, no. 3, pp. 517-28, 2013.

Abstract

Purpose: Side-effects as a result of breast cancer treatment may have a lasting detrimental impact on quality of life. Exercise has been shown to be an effective intervention in post treatment care. This study aimed to gain a better understanding of breast cancer treatment-related side-effects through identifying potential patient

characteristic associations, including current levels of exercise.

Methods: 432 breast cancer patients completed an online survey covering their treatment and demographic background, current exercise levels, and self-reported treatment side-effects. Side-effects were considered in a binary logistic regression against age, surgery, currently undergoing treatment and exercise levels to ascertain significant relationships ($p < 0.05$) and associative values (Odds Ratio).

Results: Lumpectomy patients were less likely to report aching muscles (OR = 0.61, 95% CI 0.39-0.96), hot flushes (OR = 0.60, 95% CI 0.38-0.96) and weight gain (OR = 0.59, 95% CI 0.38-0.92) than mastectomy patients. Women currently undergoing treatment were more likely to report hot flushes (OR = 3.77, 95% CI 2.34-6.08), aching muscles (OR = 1.62, 95% CI 1.02-2.57) and weight gain (OR = 1.89, 95% CI 1.19-2.99) than women finished treatment. Sedentary women were more likely to experience shoulder limitations (OR = 1.77, 95% CI 1.14-2.77), muscular chest wall pain (OR = 1.69, 95% CI 1.07-2.65), weight gain (OR = 2.29, 95% CI 1.44-3.64), lymphoedema (OR = 1.68, 95% CI 1.04-2.71) and breathlessness (OR = 2.30 95% CI 1.35-3.92) than their sedentary counterparts.

Conclusions: Patient characteristics may inform interventions to improve care post breast cancer treatment. Sufficient levels of exercise were consistently associated with fewer side-effects, and should be encouraged.

2.1 Introduction

Primary treatment following a breast cancer diagnosis is surgery. Post-surgery, many women will also undergo radiotherapy, together with systemic adjuvant therapies, including chemotherapy, hormonal or endocrine therapy, or a combination of these.

Although increasingly effective in terms of disease control, negative side-effects of these breast cancer treatments are common [26]. These side-effects are often treatment specific and manifest in a range of symptoms. Local complications such as pain or numbness in the breast or chest wall, restricted arm motion, arm lymphoedema, and skin sensitivity are worse with more extensive surgery, more extensive radiation, or both [27, 28]. Compounding these local complications are common side-effects of systemic adjuvant therapy including vasomotor symptoms such as hot flushes; neuropsychiatric symptoms such as a lack of energy or fatigue; gastrointestinal symptoms such as weight gain and nausea; and gynecological symptoms such as breast sensitivity or tenderness [29]. In some cases, these side-effects can become a major cause of morbidity and treatment discontinuation, and may have prolonged negative effects on a breast cancer survivor's quality of life (QOL) [26, 29].

Breast cancer treatment side-effects have been shown to impact upon QOL dimensions, suggesting that reducing these side-effects will have a positive effect on QOL [26]. Greater side-effects during breast cancer treatment have also predicted greater post-treatment distress [30]. For example, fatigue as a treatment effect has emerged as a strong predictor of QOL within one year of treatment, and may continue to compromise QOL as long as five years post diagnosis [31, 32]. Impairments in upper body functioning as a result of breast cancer treatment have also been significantly related to reductions in QOL [33, 34]; and experiencing persistent arm lymphoedema is related to worse general mental health and physical function [26]. It has been suggested that all currently available endocrine therapies have side-effect profiles that can affect patient-related QOL outcomes [35].

Compounding the detrimental impact side-effects have on QOL, unpleasant side-effects as a result of taking medication are also significantly predictive of adherence to medication plans [29, 36]. Breast cancer treatment side-effects as a reason for non-

adherence provides a compelling argument to better understand the mechanisms of these adverse events, as restricting or cessation of treatment could severely diminish opportunities for health gains. It is expected that better management of treatment-related side-effects may trigger a 'cascade effect', through improving QOL outcomes, in turn improving medication adherence, and ultimately resulting in better patient outcomes [29].

Exercise is one of the most effective interventions that can assist in the management of breast cancer treatment side-effects through enhanced improvements in cardio-respiratory fitness, immune function during recovery, self-esteem and other psychological health parameters [10, 18, 37]. Breast cancer patients who exercise have reported decreased levels of anxiety and depression, and research reviews have also suggested physical activity during treatment and recovery may enhance breast cancer survival [38, 39]. Despite the well-established benefits of exercise, the effect of exercise on a broader range of breast cancer treatment side-effects is generally unknown. Review authors have therefore called for more attention to be focused on how exercise affects the multitude of frequently experienced, persistent side-effects of breast cancer treatment [18, 37].

Given the potential negative impact on QOL and prognosis, a better understanding of the prevalence of patient-determined side-effects is warranted, and the association of patient characteristics with these side-effects should be explored. Some studies have suggested that the experience of breast cancer treatment side-effects may vary as a function of age, stage of disease, and body mass index [40]; whereas other studies have suggested that socio-demographic characteristics generally do not help identify women who will have greater or lesser symptom experience [26, 32, 41]. Patient characteristics may provide a useful initial step towards developing intervention strategies to improve care for women treated for breast cancer.

Intervention strategies involving exercise have been identified as being effective, and further investigation into the influence of exercise on a wider range of breast cancer treatment side-effects is required. Therefore, the purpose of this study was to gain a better understanding of breast cancer treatment side-effects through identifying potential patient characteristic associations with age, type of surgery, currently undergoing treatment and levels of exercise. We hypothesised that (i) patient characteristics would hold moderate associative values for side-effect experience; and (ii) higher exercise levels would be associated with a lesser side-effect experience.

2.2 Participants and Methods

2.2.1 Participants and Survey Implementation

Breast cancer patients who had a registered email address with the Breast Cancer Network Australia (BCNA) Review and Survey group or the Cancer Councils of Victoria or Western Australia were invited by email to complete an online survey. Inclusion criteria were any women, over 18 years of age, with a breast cancer diagnosis prior to the survey distribution date. The survey invitation contained a brief introduction to the investigators and the study, as well as a direct link to the uniform resource location (URL) containing the internet-based survey. The URL was open to responses for 4 months, and closed when continued promotion of the survey did not illicit any further responses. Due to the anonymity of the data collection procedures, and the 'sharing' nature of the internet, the survey's response rate could not be tracked. However, of the 482 women who visited the initial URL, 432 completed the survey (89.6% completion rate). Participant informed consent was obtained whereby the first page of the survey was a participant information sheet to which participants clicked "I agree" in order to progress with the online survey. The University Human Research Ethics Committee

approved all data collection procedures (HREC08/326).

2.2.2 Online Survey Instrument

The online survey instrument was based on a previously validated paper-based questionnaire [42]. Seven focus groups with breast cancer patients were conducted (total participants = 20) at community centres around the greater Sydney area to assess the expert and content validity of the online version. During these groups, the think-aloud technique was employed [43] and participants were queried about their understanding, and about the relevance and sensitivity of each question, which lead to changes to facilitate the participants' understanding and ease in navigating the electronic version. Test-retest reliability over seven days was confirmed through administering the instrument to 12 breast cancer survivors (twice, seven days apart), and the instrument was deemed reliable with an intraclass correlation coefficient of 0.82 (0.78-0.85 95% CI).

The final survey instrument included 68 closed-ended and 11 open-ended items covering background variables such as health status, location, disease timelines, treatment methods, surgery types, treatment complications, and each respondents' current exercise habits. To prevent the submission of duplicate surveys, internet protocol (IP) addresses embedded in the responses, and the respondents' date of birth were checked. No identical IP addresses were submitted, and checking responses from women with the same date of birth also indicated no duplicates.

2.2.3 Independent Analytical Variables

2.2.3.1 Age

Participant age was an open-ended response to "What is your date of birth?", calculated with respect to the survey submission date (providing age at time of survey completion). Following this calculation, participants were split into categories of be-

ing 'Under 50 years old', or '50 years and over' for the purpose of the binary logistic regression.

2.2.3.2 Surgery type

Participant surgery type was assessed by a closed-ended question for which the responses were either a lumpectomy or mastectomy of either the right or left breast. Responses were presented in a 2 x 2 button grid (lumpectomy and mastectomy by left and right breast) and were not mutually exclusive, permitting participants to indicate if they had undergone surgery on both breasts, or had a lumpectomy, followed by a mastectomy. Women were instructed to skip the question if they had not undergone surgery. Only three participants did not respond with a surgery type. Participants were then grouped into categories of a 'Lumpectomy' or a 'Mastectomy' for the binary logistic regression.

2.2.3.3 Current treatment

Participants were asked "Are you CURRENTLY undergoing any of the following treatments for your breast cancer?" with closed-ended response categories of chemotherapy, radiotherapy and hormonal treatment. Examples of hormonal treatments were provided, and responses were not mutually exclusive. Women were also asked the date of their last treatment ever if they had finished these categories of treatment. The difference between the survey completion date, and treatment completion date was calculated to give a time since treatment completion. For the purpose of the binary logistic regression, participants were divided into categories of 'Current treatment' vs. 'Finished treatment'.

2.2.3.4 Exercise

The Recreational Activities domain of the Global Physical Activity Questionnaire Version 2 (GPAQ2) [44] was used to assess recreational exercise intensity and duration. The GPAQ2 calculates metabolic equivalents (METs) to express the intensity of reported physical activities [44]. The total time spent in physical activity during a typical week, the numbers of days, as well as the intensity of the physical activity are taken into account to calculate three categorical indicators (low, moderate, and high). The criteria for these levels are shown in Table 2.1, along with the number of women who met each criterion, and the percentage these women formed of the total sample. For the purpose of the binary logistic regression, all women meeting either the moderate or high levels of exercise (n = 158) were classified as 'Sufficiently active'.

2.2.4 Dependent Analytical Variables

2.2.4.1 Breast cancer treatment side-effects

Side-effects were reported as those experienced in the two weeks prior to completing the survey, and were evaluated by a closed-ended list of possible complications (see Table 2.4). Participants were asked to respond regarding their experience of that side-effect on a 5-point Likert scale from 'None' to 'Severe'. For the purpose of binary logistic regressions, women were divided into categories of 'No symptom experience' (Likert response = 1) vs. 'Any level of experience' (Likert response = 2-5).

2.2.5 Statistical Analysis

2.2.5.1 Descriptive analysis

Answers to the closed-ended side-effects items were coded and counted to determine the frequency response for each item. The number of responses to different questions may

Table 2.1: GPAQ2 Criteria for classifying women into high, moderate or low levels of physical activity [44]; the number of women who met each criterion; and the percentage this was of the sample population.

Category	Criteria	*n*	Sample %
High	Vigorous-intensity activity on ≥3 days per week achieving ≥1,500 MET-minutes	31	7.3%
	≥7 days of any combination of walking, moderate or vigorous intensity activities achieving ≥3,000 MET-minutes/week	27	6.4%
Total high	Women meeting any 'high physical activity level' criteria	**38**⋆	**9.0%**
Moderate	≥3 days/week of vigorous intensity activity of ≥20 minutes per day	28	6.6%
	≥5 days/week of moderate intensity activity or walking of ≥30 minutes per day	96	22.7%
	≥5 days/week of any combination of walking, moderate or vigorous intensity activities achieving ≥600 MET-minutes per week	120	28.4%
Total moderate	Women meeting any 'moderate physical activity level' criteria	**120**⋆	**28.4%**
Insufficiently active	Not meeting any of the above criteria	265	62.6%
Sufficiently active	Women who achieved a minimum recommended level of exercise (GPAQ2 high or moderate levels)	**158**	**37.4%**
Missing data		9	2.2%
Total sample		432	100%

⋆ The number of women calculated in the 'Total high' and 'Total moderate' levels of physical activity is not equal to the sum of women within each sub-criterion, as some may have met more than one of each sub-criterion.

vary as respondents were given the option to skip questions to minimise participant burden. Study population proportions were then calculated as a percentage of the number of women who answered that question. To provide an accurate representation of the data, non-responses were not assumed to represent not experiencing a particular side-effect, but rather data were analysed based only on the women who provided a response to that question. The mean of responses for each side-effect question was also calculated to show where most participants responded on the continuum of not experiencing that particular side-effect to experiencing it severely. The closer the mean

score was to '5', the more severely participants experienced that side-effect.

2.2.5.2 Relationship analysis: Binary logistic regression model

Each side-effect was considered in a binary logistic regression to ascertain any associated variables and significant relationships. Whether a participant reported experiencing a side-effect (None vs. Any level of experience) was inserted as a dependent variable against the independent variables of age (<50 years vs. ≥50 years), type of surgery (Lumpectomy vs. Mastectomy), currently undergoing treatment (Current vs. Finished treatment), and exercise levels (Not sufficiently active vs. Sufficiently active). This method of analysis has been successfully used in a previous cross-sectional survey data with a breast cancer population [45], and ensures each independent variable is analysed while controlling for the other three independent variables. All statistical analyses were completed using SPSS for Windows software (Version 17.0, SPSS Inc, Chicago, USA).

2.3 Results

2.3.1 Participant Characteristics

Participants were 432 female breast cancer patients and survivors aged 23-77 years (mean 53.3 ± 9.8 years). Table 2.2 provides information on the participant's characteristics with comparisons to Australia population data. In brief, the self-reported health status of the survey sample was comparable to that of the general Australian female population; and the survey sample was spread across Australian States and Territories in similar proportions to the wider breast cancer population, with the exception of the Australian Capital Territory, which formed 10% of the sample and only 2% of the national spread. The age spread of the sample was generally lower than the

age of the wider Australian breast cancer population, which may skew results towards a younger breast cancer population. The proportion of women deemed sufficiently active in the survey sample was very comparable to an age-matched general Australian female population (37.4% vs. 37.6%). Table 2.3 also provides a summary of the binary logistic regression groups used for statistical analysis as related to the sample's age, surgery, whether they were currently undergoing treatment, and exercise levels.

Table 2.2: Respondents' demographic information with comparisons to Australian population data.

	Present Study			Comparison Data (%)
	n	%		
Health Status	428			Australian General Female Population [46]
In general, would you say your health is:				
Excellent	55	12.9 %	51.9%	57% (Excellent or very good)
Very good	167	39.0%		
Good	150	35.0%		29% (Good)
Fair	44	10.3 %	11.7%	14% (Fair or poor)
Poor	6	1.4%		
Missing data	4	0.9%		
State or Territory	428			Australian Breast Cancer Population [1]
What is your postcode?				
New South Wales	114	26.6%		33.9%
Victoria	119	27.8%		25.0%
Queensland	65	15.2%		18.5%
Western Australia	26	6.1 %		9.5%
South Australia	41	9.6%		8.5%
Tasmania	15	3.5%		2.4%
Australian Capital Territory	44	10.3%		1.6%
Northern Territory	4	0.9%		0.5%
Missing data	4	0.9%		
Treatment received	431			
Have you EVER had any of the following treatments for breast cancer?				
Radiotherapy only	1	0.2%		
Surgery only	58	13.4%		
Surgery + Chemo + Radio	229	53.0%		
Surgery + Chemo only	75	17.4%		
Surgery + Radio only	67	15.5%		
No treatment	1	0.2%		
Missing data	1	0.2%		

2.3.2 Side-effects: Descriptive and Relationship Results

Table 2.4 provides a summary of the side-effects examined, the number of participants who responded to the question (out of a potential 432 participants), the mean of the Likert scores in response to each side-effect, and the percentage of the sample who experienced each side-effect. Hot flushes, sleep disorders, aching muscles and fatigue were the most commonly experienced side-effects with approximately two thirds of respondents reporting each (66.3%, 65.3%, 64.3% and 62.7%, respectively). Table 2.5 indicates the significance of each side-effect against age, surgery, current treatment and exercise participation, as determined by a binary logistic regression with odds ratios (OR) and 95% confidence intervals (95% CI). Approximately half of the side-effects (7 of 15) were associated with at least one of the independent variables. Weight gain was significantly related to all the independent variables except age.

2.3.2.1 Side-effects and surgery

Compared to women who had undergone a mastectomy, women who had undergone a lumpectomy were less likely to report fatigue (OR = 0.60; 95% CI 0.38-0.96; $p = 0.05$), aching muscles (OR = 0.61; 95% CI 0.39-0.96; $p = 0.023$), and weight gain (OR = 0.59; 95% CI 0.38-0.92; $p = 0.02$); while controlling for age, current treatment and exercise levels.

2.3.2.2 Side-effects and current treatment

Compared to women who were finished all treatment, women who were still taking medication for their breast cancer were more likely to report experiencing weight gain (OR = 1.89; 95% CI 1.19-2.99; $p = 0.007$), hot flushes (OR = 3.77; 95% CI 2.34-6.08); $p < 0.001$) and aching muscles (OR = 1.62; 95% CI 1.02-2.57; $p = 0.031$); while controlling for age, surgery type and exercise level.

Table 2.3: Respondents' characteristics divided into binary logistic regression groups.

Binary logistic regression groups	*n*	%	Categories
Age	432		
What is your date of birth?			
<30 years	2	0.0%	< 50 years old, *n*=144; 33%
30-49 years	142	33.0%	
50-69 years	271	63.0%	≥ 50 years old, *n*=288; 67%
>70 years	17	4.0%	
Exercise	432		
In a typical week, on how many days do you do (moderate-intensity or vigorous-intensity) sports, fitness or recreational activities?[Number of days per week]			
How much time do you spend doing (moderate-intensity or vigorous-intensity) sports, fitness or recreation ON A TYPICAL DAY? [Hours][Minutes]			
Insufficiently active	265	61.3%	Insufficiently active
Sufficiently active	158	36.5%	Sufficiently active
Missing data	9	2.2%	
Surgery undergone	429		
Please indicate ALL the surgeries you have undergone for your breast cancer. If you have not undergone any surgery, please skip this question. [Lumpectomy][Mastectomy] with [Right][Left]			
Unilateral lumpectomy	179	41.4%	Lumpectomy, *n*=188; 43.5%
Double lumpectomy	9	2.1%	
Unilateral lumpectomy followed by mastectomy	75	17.4%	
Double lumpectomy followed by mastectomy	24	5.6%	Mastectomy, *n*=241; 55.8%
Unilateral mastectomy	107	24.8%	
Double mastectomy	35	8.1%	
Missing data	3	0.7%	
Time since completion of treatment	387		
Are you CURRENTLY undergoing any of the following treatments? [Chemotherapy] [Radiotherapy] [Hormonal Therapies]			
For the treatments you have FINISHED, what was the date of your last session ever? [Month][Year]			
Current chemotherapy	14	3.2%	
Current radiotherapy	3	0.7%	Current treatment
Current hormonal therapies	226	51.4%	*n*=239; 55.3%
<1 years	20	4.6%	
1-2 years	50	11.5%	
3-4 years	23	5.3%	Finished all treatment
5-7 years	29	6.7%	*n*=148; 34.3%
8-10 years	9	2.1%	
>10 years	17	3.9%	
Missing data	45	10.4%	

Table 2.4: Reported side-effects, the number of participants who responded to the question (out of a potential 432), the Likert scores in response to each side-effect, mean Likert scores, and the percentage of the sample who experienced each side-effect.

Reported Side-effect		Level of Side-effect Experience⋆					Overall Scores	
	n of 432	None	Mild-Moderate	Moderate	Moderate-Severe	Severe	Mean (95% CI)	Experienced side-effect
Hot flushes	398	134	104	77	58	25	2.34 (2.21-2.46)	66.3%
Sleep disorder	392	135	116	66	52	23	2.27 (2.14-2.39)	65.3%
Aching muscles	392	140	142	65	33	12	2.07 (1.96-2.17)	64.3%
Fatigue	399	149	109	82	48	11	2.16 (2.04-2.27)	62.7%
Shoulder limitations	392	192	118	58	21	3	1.79 (1.70-1.88)	51.0%
Pain	378	189	120	43	23	3	1.76 (1.67-1.85)	50.3%
Muscular chest wall pain	379	198	124	33	20	4	1.70 (1.61-1.79)	47.8%
Weight gain	390	218	83	47	34	8	1.80 (1.69-1.91)	44.1%
Depression	390	222	90	49	21	8	1.73 (1.63-1.83)	43.1%
(Arm) Lymphoedema	388	257	87	33	9	2	1.48 (1.41-1.56)	33.8%
Burning/sensitive skin/chafing	370	248	74	31	13	4	1.52 (1.43-1.61)	33.0%
Breathlessness	378	274	65	27	8	4	1.42 (1.34-1.50)	27.8%
Other	190	153	12	9	11	5	1.44 (1.29-1.58)	20.0%
Nausea	367	303	35	14	11	4	1.31 (1.23-1.38)	17.7%
Broken/painful ribs	368	313	37	9	5	4	1.23 (1.17-1.30)	15.2%

⋆*In the LAST 2 WEEKS how much discomfort did you experience from the following side-effects?*

Table 2.5: Reported side-effects according to mean score; and significance of reported side-effects by age, surgery, currently undergoing treatment and exercise participation.

Reported Side-effect	Independent Variables Odds Ratio (95% CI)			
	Age	Surgery	Current Treatment	Exercise
	Under 50 years old vs. 50 years and over	*Lumpectomy vs. Mastectomy*	*Current treatment vs. Finished treatment*	*Insufficiently active vs. Sufficiently active*
Hot flushes	0.97 (0.59-1.61)	0.60* (0.38-0.96)	3.77** (2.34-6.08)	0.97 (0.60-1.59)
Sleep disorder	0.69 (0.43-1.10)	0.80 (0.51-1.25)	1.41 (0.89-2.24)	1.36 (0.86-2.15)
Aching muscles	0.87 (0.54-1.40)	0.61 * (0.39-0.96)	1.62* (1.02-2.57)	1.04 (0.65-1.66)
Fatigue	1.22 (0.77-1.95)	0.89 (0.57-1.38)	1.50 (0.96-2.35)	1.46 (0.93-2.29)
Shoulder limitations	1.14 (0.73-1.79)	0.74 (0.48-1.14)	1.02 (0.66-1.60)	1.77* (1.14-2.77)
Pain	1.33 (0.84-2.10)	0.90 (0.56-1.39)	1.05 (0.67-1.64)	1.41 (0.90-2.20)
Muscular chest wall pain	1.06 (0.67-1.66)	0.71 (0.46-1.10)	1.53 (0.97-2.40)	1.69* (1.07-2.65)
Weight gain	1.40 (0.88-2.22)	0.59*(0.38-0.92)	1.89** (1.19-2.99)	2.29** (1.44-3.64)
Depression	1.06 (0.68-1.67)	1.13 (0.74-1.74)	1.07 (0.68-1.68)	1.48 (0.95-2.32)
(Arm) Lymphoedema	1.00 (0.62-1.61)	0.92 (0.59-1.46)	1.38 (0.86-2.22)	1.68* (1.04-2.71)
Burning/sensitive skin/chafing	1.07 (0.65-1.73)	1.15 (0.72-1.83)	1.50 (0.91-2.46)	1.44 (0.88-2.35)
Breathlessness	1.12 (0.68-1.85)	1.01 (0.62-1.63)	0.82 (0.50-1.34)	2.30** (1.35-3.92)
Other	0.88 (0.39-2.03)	0.91 (0.41-2.00)	1.83 (0.80-4.21)	1.34 (0.59-3.06)
Nausea	1.39 (0.77-2.48)	1.04 (0.58-1.84)	1.84 (0.98-3.47)	1.13 (0.62-2.04)
Broken/painful ribs	1.21 (0.66-2.24)	1.03 (0.56-1.87)	1.02 (0.55-1.91)	1.38 (0.88-3.24)

* $p < 0.05$

** $p < 0.01$

2.3.2.3 Side-effects and exercise

Compared to women who were sufficiently active, sedentary women were more likely to report experiencing weight gain (OR = 2.29; 95% CI 1.44-3.64; $p < 0.001$), shoulder limitations OR = 1.77; 95% CI 1.14-2.77; $p = 0.012$), breathlessness (OR = 2.30; 95% CI 1.35-3.92; $p = 0.002$), muscular chest wall pain (OR = 1.69; 95% CI 1.07-2.65; $p = 0.023$), and arm lymphoedema (OR = 1.68; 95% CI 1.04-2.71; $p = 0.034$); while controlling for age, current treatment and surgery type.

2.4 Discussion

The present study sought to gain a better understanding of the side-effect experience of women following breast cancer treatment. It did so through a binary logistic regression analysis of selected patient characteristics against self-reported side-effects. Of 15 listed side-effects, 7 were significantly associated with at least one patient characteristic, confirming our first hypothesis that these characteristics have a moderate association with side-effect experience.

2.4.1 Age

Age did not emerge as being strongly associated with the side-effects experienced by breast cancer survivors, and was not linked to any of the examined side-effects. The study cohort is younger than the wider breast cancer population, which may have limited our ability to elicit an association with this variable.

2.4.2 Surgery

Women who had undergone a mastectomy were more likely to experience aching muscles, weight gain and hot flushes than women who had undergone a lumpectomy.

Findings from previous research regarding relationships between surgery type and symptom experience have been mixed. For example, whereas Janz et al. [26] found no clinically meaningful differences in symptom experience between women who received a mastectomy and those who received breast conserving surgery, Rabin et al. [47] found women who underwent a mastectomy indicated lower QOL scores in the physical and psychological domains than their breast conserving surgery counterparts. The finding of an association between aching muscles and having a mastectomy is not unexpected. Pain and numbness in the breast, chest wall, or axilla are common complications of breast cancer surgery, affecting 15-75% of survivors, and are often related to the extent of surgery performed [27].

Unexpectedly, weight gain also emerged as being significantly related to undergoing a mastectomy. As a side-effect, weight gain is of particular importance as it can predispose breast cancer survivors to other morbidities, such as cardiovascular disease and orthopaedic problems [48]. Weight gain can also negatively impact upon self-esteem and other psychological aspects of QOL [49]. Furthermore, weight gain and obesity have been significantly linked to higher relapses and poorer survival [18], arm swelling and symptoms of persistent lymphoedema [27, 40]. Previous research has indicated that weight gain is more common in women receiving adjuvant chemotherapy, particularly for extended treatment durations, and appears to be more pronounced in premenopausal women [48]. No research could be located which explored the link between specific surgery types and weight gain, making this the first study to suggest this association.

Finding an association between hot flushes and surgery was also unexpected, particularly as in the absence of ovarian ablation, the primary treatment responsible for hot flushes is adjuvant endocrine therapy, not surgery. Although the binary logistic regression model used in this analysis controlled for age and whether women were

currently undergoing adjuvant endocrine therapy, it was not possible to control for the extent of adjuvant endocrine therapy, or menopausal status, which may have influenced this outcome. Nevertheless, it is possible that although surgery *per se* is not responsible for experiencing hot flushes, the experience of other adverse events linked to surgery may play a significant role. Particularly, correlations between weight gain and experiencing hot flushes exist [50], and given the significant association between weight gain and surgery in the present study, it is possible these events are interrelated in their link to experiencing hot flushes. Therefore, rehabilitation efforts for women post-surgery should also be aware of the associations between weight gain and hot flushes, and the risk a greater extent of surgery poses towards experiencing these side-effects.

2.4.3 Current Treatment

Women who were currently taking medication for their breast cancer were more likely to experience hot flushes, weight gain, and aching muscles than women who had completed all breast cancer treatment. However, the finding that 12 of the 15 listed side-effects were not significantly associated with treatment completion is also clinically relevant, as it suggests that side-effects as a result of treatment can present a lasting burden for some women, due to these side-effects being experienced equally by women undergoing treatment, and those who are not (average 4.3 years post treatment completion).

The present study found women were more likely to experience hot flushes while currently undergoing breast cancer treatment, which supports previous research suggesting a strong link between hot flushes and primary breast cancer treatment [51]. Treatment-induced hot flushes have been linked to abrupt and premature menopause (among premenopausal women) as a result of chemotherapy and ovarian ablation; and

commonly used adjuvant therapies in breast cancer, such as tamoxifen and aromatase inhibitors [51]. Estrogen withdrawal as a result of these treatments is thought to be an initiator of hot flushes, as changes in estrogen levels may affect functioning of the thermoregulatory centres in the hypothalamus [51]. Up to 65% of women report hot flushes during or following breast cancer treatment and 64%-82% of these patients rate these episodes as moderate to severe [52]. In the present study hot flushes were the most commonly reported side-effect, experienced by 66.3% of participants.

Current breast cancer treatment was also significantly associated with weight gain. These results are similar to a study in which one year after treatment began, 62.5% of study participants experienced a significant weight gain of 2.27 kg (5 pounds) or more [49]. After two years, 68% of those women who gained weight in the initial year maintained a clinically significant weight gain. This percentage was reduced to 40% after three years, suggesting, as with the present study, that the greatest effect of weight gain was experienced in the initial stages of breast cancer treatment. Furthermore, the vast majority of women undergoing treatment in the present study were undertaking hormonal therapies (n = 226, which was 95% of the women currently undergoing treatment). Decreased serum estradiol levels are a significant factor in weight gain and are commonly linked to hormonal therapies, although evidence is mixed [49, 53]. It is likely that menopausal status contributes to inconsistent evidence regarding weight gain and hormonal therapies because common treatments such as tamoxifen have both antiestrogenic and estrogenic properties, depending on the natural hormonal environment of the target patient [49]. Although menopausal status was not controlled for in the present study, the strong association between weight gain and currently taking medication, predominantly hormonal therapies, still poses a significant link that health professionals who are assisting women in long-term management of their breast cancer treatment side-effects need to be aware of.

2.4.4 Exercise

Previous research has confirmed that exercise can reduce the burden of some side-effects of breast cancer treatment such as fatigue and pain [32], as well as have positive effects on physical function, physical capacity, and muscular fitness, during and after cancer treatment [10, 18, 37]. Confirming our second hypothesis, women who were insufficiently active were more likely to experience a range of side-effects, including shoulder limitations, muscular chest wall pain, weight gain, lymphoedema or breathlessness. Previous research has noted improvements in shoulder limitations, weight gain and arm lymphoedema among breast cancer patients who exercise [54–56], but no research could be located which directly considered the side-effects of breathlessness or muscular chest wall pain.

Upper limb dysfunction, including a reduced range of motion in the shoulder, muscle weakness, and pain and numbness, are common postoperative complications for breast cancer patients [55, 57]. These dysfunctions not only impact on physical health, as breast cancer survivors with clinically defined arm/shoulder problems also have significantly poorer QOL than survivors without arm/shoulder pain [34]. A comprehensive Cochrane Review recently concluded that "exercise can result in significant and clinically meaningful improvements in shoulder ROM [range of motion] in women with breast cancer" [55]. As such, the result that shoulder limitations are less likely to occur among breast cancer survivors who were sufficiently active is not surprising.

Muscular chest wall pain was also significantly associated with not being sufficiently active. Pain as a result of breast cancer treatment is an ill-defined syndrome ranging from mild pain to significant nociceptive pain and neuromas [58, 59]. Upper-body pain is a commonly experienced breast cancer treatment side-effect, and the extent of pain experienced is generally linked to more invasive surgery and aggressive radiation treatments [45, 57, 60]. Although evidence is limited, commonly-used clinical

approaches to upper-body morbidities such as muscular chest wall pain include gentle exercises, which promote normal muscular recruitment patterns and enhance tissue extensibility [57]. Therefore, it is postulated that women who sufficiently exercise, and particularly promote controlled use of pectoralis, serratus anterior and latissimus dorsi musculature, would also be less likely to experience muscular chest wall pain.

The present study also found weight gain was significantly related to not being sufficiently active. For women undergoing breast cancer treatment, evidence suggests weight gain occurs without concurrent gains in lean body mass, and is not caused by overeating but rather is a result of reduced physical activity [54]. Previous research concluded that exercise is an effective intervention for managing or preventing weight gain in women undergoing breast cancer treatment [54], which is consistent with the current finding.

Arm lymphoedema is caused by an accumulation of fluid in interstitial space, and occurs in 10 to 25% of women treated for breast cancer [27]. The risk of arm lymphoedema is directly related to the extent of surgery, or radiation treatment or both [27], and it is regarded as a persistent or chronic condition [57]. Even when symptoms appear resolved, a patient remains at an increased risk of redeveloping lymphoedema [57]. Traditionally, clinicians have been cautious with the prescription of exercise, particularly weight lifting, to women who may be at risk of developing arm lymphoedema, as increases in resistance within the muscle, along with increased blood flow as experienced during exercise, may increase lymph production in the arm [57]. However, a recent randomized controlled trial concluded weight lifting did not significantly affect arm lymphoedema, but rather, resulted in a decreased incidence of exacerbations of lymphoedema, reduced symptoms, and increased strength [56]. Other studies have also concluded no evidence of negative effects from upper-body exercise on the incidence of arm lymphoedema; and slowly progressive resistance training is protective

against lymphoedema flare-ups among women at risk [37, 61]. These findings agree with the present study in that sufficiently active women were less likely to report arm lymphoedema.

Finally, women who were sufficiently active were less likely to report breathlessness than their more sedentary counterparts. This may be linked to an improved or maintained state of cardio-respiratory fitness. We postulate that breast cancer treatment could itself impact upon a patient's cardio-respiratory system or, alternatively, experiences of other treatment-related side-effects, could lead to sedentary behaviours and consequential cardio-respiratory de-conditioning. Studies examining the effects of exercise during breast cancer treatment have concluded that exercise can have a positive influence on cardio-respiratory outcomes [10, 18, 62]. Similar to improvements in shoulder limitations, these effects go beyond exclusively physical benefits, with cardio-respiratory improvements having also been positively correlated with QOL scores in a breast cancer cohort [63].

2.4.5 Study Strengths, Limitations and Recommendations

Although a validated survey instrument was used, this study was limited in the use of self-reported data and by its cross-sectional design, and therefore conclusions regarding causality cannot be drawn. Furthermore, it was not possible to analyse side-effects against chemotherapy or radiotherapy because almost all the women in the study had undergone some form of either chemotherapy or radiotherapy, making the split into groups for a binary logistic regression unfeasible. This also inhibited an in-depth separation of chemotherapy, radiation, and surgical treatments for analysis with respect to the specific side-effects likely to be linked to these specific treatments. Future studies with a larger study population, which can draw meaningful sample sizes for exclusive treatment groups, would be required to achieve this type of analysis. Health status

also provides insight into patient outcomes, and future studies should consider including this in analysis. The present study was also limited in a lack of menopausal status data for the participants. Considering the mean sample age was 53 years, it is likely some women were peri-/menopausal. Therefore, it is possible that side-effect experiences such as weight gain or hot flushes were linked to natural menopause, rather than being treatment induced menopausal symptoms. Finally, as most of the sample consisted of members of the BCNA Review and Survey group, these women may be more motivated to participate in research and were younger than the general Australian breast cancer population, which may limit the generalisability of the study results.

Despite the aforementioned limitations, this study holds much merit as an investigation into how patient characteristics and exercise may be associated with self-reported side-effects to breast cancer treatment. Currently, this is the largest cross-sectional study on the side-effects of breast cancer in an Australian population, and one of the most comprehensive lists of self-reported side-effects of breast cancer published to date. The project engaged a multi-state and multi-centre recruitment strategy, although it is acknowledged that it was limited to women who were part of a support system for their breast cancer. Despite this, the sample was closely matched to an Australian population in terms of location spread, health status and physical activity levels. Finally, by using an online questionnaire, the study was able to randomise the list of side-effects presented in each survey; thereby eliminating any list ordering biases, as well as limiting any potential transcription errors during analysis.

2.5 Conclusion

The objective of this study was to gain a better understanding of breast cancer treatment-related side-effects through identifying their association with patient characteristics such as age, type of surgery, whether women were currently undergoing

treatment, and exercise levels. Given that 7 out of 15 listed side-effects were significantly associated with at least one patient characteristic, these characteristics may hold moderate value as potential indicators of a greater or lesser side-effect experience, and may therefore be useful when planning supportive care following breast cancer treatment. Targeting individuals who are at a high risk of developing breast cancer treatment side-effects could help improve the focus of resources to those patients most likely to benefit [40]. However, patient characteristics such as age, surgery and current treatment are not readily changeable and, while awareness of symptom experiences and high-risk groups may assist in better targeting clinical resources, deviations from required treatments are limited. On the other hand, exercise was associated with a lesser symptom experience for shoulder limitations, muscular chest wall pain, weight gain, lymphoedema and breathlessness. Combined with the growing body of knowledge regarding the positive effects of exercise on QOL and breast cancer survival, this finding supports the call for further research into the adherence to, and promotion of, physician-approved exercise for women treated for breast cancer.

Chapter 3

Perceived exercise barriers explain exercise participation in women treated for breast cancer better than perceived exercise benefits

This chapter is an amended version of the manuscript: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Perceived barriers explain exercise participation in women treated for breast cancer better than perceived benefits," *Physical Therapy*, Accepted April 2014.

Abstract

Purpose: Although exercise is highly beneficial for women treated for breast cancer, exercise participation rates in this population remain low. This study aimed to determine the effect of perceived exercise benefits and barriers on exercise levels among women who have been treated for breast cancer, and who were not part of formal

exercise interventions.

Methods: 432 women treated for breast cancer completed an online survey covering their treatment and demographic background, current exercise levels, and perceived exercise benefits and barriers. Each perceived benefit and barrier was considered in a binary logistic regression against reported exercise levels to ascertain significant relationships ($p < 0.05$) and associative values (odds ratio).

Results: Sixteen out of 19 exercise barriers were significantly related to reporting insufficient exercise levels, whereas 6 out of 15 exercise benefits were significantly related to reporting sufficient levels of exercise. Feeling too weak, lacking self-discipline and not being a priority were the barriers with the largest association to insufficient exercise levels (OR = 10.97, 8.12, and 7.43, respectively). Exercise enjoyment, improved feelings of well-being, and decreased feelings of stress and tension were the three benefits with the largest association to sufficient exercise levels (OR = 0.21, 0.21, and 0.31, respectively).

Conclusions: Agreement with perceived barriers were strongly associated with poor exercise participation. Therefore, targeting exercise barriers specific to women treated for breast cancer may improve exercise participation levels in this cohort. Awareness of the impact of exercise barriers identified in the present study will enable physical therapists to better plan exercise interventions that support all women treated for breast cancer.

3.1 Introduction

Ensuring the prolonged quality of life for breast cancer patients is a challenge facing cancer care practitioners, particularly as the number of breast cancer cases are rising

and cancer survivorship rates are improving [64]. A growing body of research suggests that exercise is beneficial for women after breast cancer treatment [10, 65, 66]. In particular, exercise has the potential to address the physical needs of patients through improved strength [55], improved cardio-respiratory fitness [18], reduced fatigue [67], decreased heart and circulatory disease risk through effective weight management [54], and improved survival with a decreased recurrence risk [38]. Exercise can also improve the emotional and psychological outcomes of cancer patients through improved self-esteem [8, 66], decreased levels of anxiety and depression [7, 66], overall mood elevation [7], and improved quality of life [68]. Despite these benefits, exercise participation rates among women who have been treated for breast cancer remain low.

Cross-sectional population-based studies comparing a breast cancer cohort to age-matched women with no history of cancer have found that exercise behaviours generally do not differ between breast cancer and non-cancer cohorts [69, 70]. For example, in a cross-sectional Australian National Health Survey sample, 26.9% (no cancer history) versus 27.7% (adult cancer survivors) of respondents were sufficiently active [69]. Longitudinal studies, however, have shown that exercise participation decreases significantly within the first 12 months following a breast cancer diagnosis [71–73]. Specifically, breast cancer survivors who are not involved in a structured exercise intervention are up to 50% less active within their first year of diagnosis than they were one year before diagnosis [71, 73]. These low exercise levels begin to approach pre-diagnosis levels between 13-30 months post diagnosis [73], and at the third year post diagnosis approximately 32% of breast cancer survivors engage in 150 minutes/week of moderate to vigorous intensity physical activity [72], a proportion comparable to that of the general population [69]. However, the increased risk of co-morbidity within a breast cancer population supports an urgent need for better strategies to improve exercise adherence in women treated for breast cancer, particularly in the early period

after treatment [65].

Valuable insight has been provided by studies that have examined barriers to exercise for women treated for breast cancer. However, the generalisability of the results from these previous studies to a non-clinical community-dwelling breast cancer cohort is limited. Specifically, two of the five previous studies in this field assessed barriers experienced during a supervised exercise intervention [74, 75]. Because exercise programs and the support and advice of exercise specialists are not routinely offered to women treated for breast cancer, those participants studied in the context of a supervised exercise intervention do not represent the wider breast cancer population [76]. The third and fourth previous studies were limited by relatively small sample sizes of women treated for breast cancer ($n = 23$ [77]; and $n = 74$ [42]), which again inhibits the generalisability of their results to the wider breast cancer population. The fifth previous study [76] was a community-based, cross-sectional survey, but included participants with a variety of cancer types in the sample ($n = 452$; 291 (64.4%) breast cancer). Breast cancer data were not reported separately, and given that exercise barriers, correlates and preferences may vary based on cancer type, research focusing on a specific breast cancer cohort is warranted to gain a better understanding of any unique barriers to exercise experienced by these women.

It is likely that a range of exercise barriers contribute to the poor exercise participation rates noted among breast cancer survivors. Similarly, outcome expectations and perceived exercise benefits could potentially influence exercise participation. Despite this, studies that have examined the benefits and/or barriers to exercise perceived by women treated for breast cancer who were not part of a structured exercise intervention are sparse, with research design limitations as described above. A better understanding of what these exercise barriers and benefits are, and their influence on exercise levels, are likely to assist physical therapists when prescribing exercise to this

cohort. Therefore, the primary aim of this study was to determine a comprehensive list of the perceived barriers to, and benefits of, exercise for women who have been treated for breast cancer, and who were not part of any formal exercise intervention. The secondary aim of this study was to determine the effect that these perceived barriers and benefits had on self-initiated exercise participation among this cohort. Specifically, we hypothesize that women who agree with the benefits of exercise are more likely to achieve a minimal recommended level of exercise as outlined by the World Health Organisation [78] whereas women who agree with the barriers to exercise are less likely to achieve a minimal recommended level of exercise.

3.2 Participants and Methods

Breast cancer patients who had a registered email address with the Breast Cancer Network Australia (BCNA) Review and Survey group or the Cancer Councils of Victoria or Western Australia were invited by email to complete an online survey. The research invitation was written by the research team and then sent to potential participants by the BCNA and respective Cancer Councils. It contained a brief introduction to the investigators and the study, as well as a direct link to the uniform resource location (URL) containing the Internet-based survey. Due to the anonymity of the data collection procedures, and the fact that participants could forward the URL to other breast cancer patients who may or may not have completed the survey, the survey's response rate could not be accurately tracked. However, of the 482 women who visited the initial URL, 432 completed the survey (89.6% completion rate). Participant informed consent was obtained whereby the first page of the survey was a participant information sheet to which participants clicked "I agree" in order to progress with the online survey. The University Human Research Ethics Committee approved all data collection procedures (HREC08/326).

Recreational exercise intensity and duration were determined using the Recreational Activities domain of the Global Physical Activity Questionnaire Version 2 (GPAQ2) [44]. The GPAQ2 allows metabolic equivalents (METs) to be calculated in order to express intensity of the reported physical activities [44]. To calculate weekly MET-minutes, the total time spent exercising during a typical week, the numbers of days, and the intensity of the exercise were taken into account. Based on GPAQ2 analysis guidelines, respondents were then classified into those who met the GPAQ2 threshold for achieving moderate or high levels of exercise and those who achieved low levels or no exercise. These classifications included any combination of moderate or vigorous intensity exercise resulting in $\geq$600 MET-minutes a week; $\geq$3 days/week of vigorous intensity exercise of $\geq$20 minutes a day; or $\geq$5 days/week of moderate intensity exercise or walking for $\geq$30 minutes a day, as per GPAQ2 guidelines [44]. For the purpose of the binary logistic regression analysis, women who achieved moderate or high levels of exercise were deemed as 'Sufficiently active' whereas women who achieved only low levels or no level of exercise were deemed as 'Insufficiently active' (see Table 3.1). Data were missing for nine participants.

Perceived exercise benefits and barriers were determined using a researcher developed, 4-point, Likert-style Benefits and Barriers scale, which contained commonly expressed exercise benefits ($n = 15$) and barriers ($n = 19$). Participants were required to respond on the 4-point Likert scale from strong agreement ('4') to strong disagreement ('1') to each closed-ended question, with a fifth 'Not applicable' option. Participants were also given an option of filling out an open-ended 'Other' benefit or barrier to exercise. A paper-based version of the survey instrument had been previously developed and validated following a three-stage process, including a review of the literature [74, 77], seeking expert opinions, and conducting focus groups with breast cancer patients [42]. This paper-based instrument was converted to an online version, and in

order to validate the online version, seven focus groups with breast cancer patients (total participants = 20), were conducted at community centres around the greater Sydney area. During these focus groups, the think-aloud technique was employed [43] and participants were queried about their understanding, and the relevance and sensitivity of each question, which lead to changes to facilitate the participants' understanding and ease in navigating the electronic version of the scale. Participants were also invited to discuss any other benefits or barriers to exercise that they encountered, although nothing substantially new was discussed, and no further items were added to the online instrument. Test-retest reliability over seven days was confirmed through administering the instrument to 12 breast cancer survivors (twice, seven days apart), and the instrument was deemed reliable with an intraclass correlation coefficient of 0.82 (0.78-0.85 95% CI). Finally, the Benefits and Barriers scale items were presented in a randomly generated list in the online survey to remove potential ordering bias.

Answers to the closed-ended benefits and barriers items were coded and counted to determine the response frequency for each item. The mean of responses for each question was also calculated to show where most participants responded on the continuum of strong agreement to strong disagreement. The closer the mean score was to '4', the more participants agreed with that benefit or barrier. The standard deviation (SD) for each question was also calculated to show the variance of the responses.

For the purpose of relationship analysis, each benefit and barrier was placed in binary categories of overall agreement (scores '3' and '4') or disagreement (scores '1' and '2'). Agreement with each benefit or barrier was then considered in a binary logistic regression against the respondents' exercise levels to ascertain any significant relationships. Whether a respondent agreed with a benefit or barrier ('Agreement' versus 'Disagreement') was inserted as a dependent variable against the independent variable of exercise ('Sufficiently active' versus 'Insufficiently active'). This method of

analysis has been previously employed in a cross-sectional survey data analysis with this population [79, 80](see Chapters 2 and 3), and results were interpreted based on statistical significance ($p < 0.05$) and Odds Ratios (OR). All statistical analyses were completed using SPSS for Windows software (Version 19.0, SPSS Inc, Chicago, USA).

3.3 Results

Table 3.1 provides a summary of the respondents' demographic and treatment information, and comparisons to relevant Australian population data. In brief, participants were 432 women who had been treated for breast cancer, aged between 23-77 years (mean 53.25 $\pm$ 9.83 years). The present sample was slightly younger than the general breast cancer population in Australia [64], and had a similar proportion of women sufficiently active when compared to the general Australian female population [81]. Similar to other non-clinical community-dwelling cancer populations studied [75, 76], most of the present sample had undergone surgery for their breast cancer (99.5%), along with combinations of chemo- and radiotherapy (86%). Also similar to previous research [76], most respondents (86%) were less than 5 years post-treatment, with the largest group (68%) being within 1 year of treatment, or currently still taking medication for their breast cancer.

The top three benefits ranked according to mean score were that exercising improves physical health, improves heart and lung functioning, and improves feelings of well-being (see Table 3.2). Six of the 15 benefits were significantly associated with exercise levels ($p < 0.05$), with ORs indicating that a respondent who agreed with that benefit were more likely to achieve a minimum recommended level of exercise. Based on ORs, the top three benefits were exercise enjoyment (OR = 0.21, 95% CI 0.11-0.39), improved feelings of well-being (OR = 0.21, 95% CI 0.07-0.63), and decreased feelings of stress and tension (OR = 0.31, 95% CI 0.15-0.63).

Table 3.1: Respondents' demographic and treatment information with comparisons to Australian population data.

	Present Study		Comparison Data (%)
	n	%	
Age	432	100%	Australian Breast Cancer Prevalence [64]
<39 years	39	9.0%	1.9%
40-59 years	268	62.0%	33.5%
60-79 years	125	28.9%	48.9%
80+ years	0	0.0%	15.7%
Surgery	429	99.3%	
Lumptectomy	188	43.5%	
Mastectomy	241	55.8%	
Missing data	3	0.7%	
Treatment received	431	99.8%	
Radiotherapy only	1	0.2%	
Surgery only	58	13.4%	
Surgery + Chemo + Radio	229	53.0%	
Surgery + Chemo only	75	17.4%	
Surgery + Radio only	67	15.5%	
No treatment	1	0.2%	
Missing data	1	0.2%	
Time since completion of treatment	387	89.6%	
On treatment	239	55.3%	
Current chemotherapy	14	3.2%	
Current radiotherapy	3	0.7%	
Current hormonal therapies	226	51.4%	
Off treatment	148	34.3%	
<1 years	20	4.6%	
1-2 years	50	11.5%	
3-4 years	23	5.3%	
5-7 years	29	6.7%	
8-10 years	9	2.1%	
>10 years	17	3.9%	
Missing data	45	10.4%	
Exercise	432	97.6%	Age-matched Australian females [81]
Sufficiently active*	158	36.5%	37.6%†
Insufficiently active	265	61.3%	
Missing data	9	2.2%	

*Any combination of moderate or vigorous intensity exercise resulting in ≥600 MET-minutes a week; ≥3 days/week of vigorous intensity exercise of ≥20 minutes a day; or ≥5 days/week of moderate intensity exercise or walking for ≥30 minutes a day, as per GPAQ2 guidelines [44].

†Any combination of moderate or vigorous intensity exercise for 30 minutes on at lwast 5 days of the week, resulting in 150 minutes a week [82]. When converting to MET-minutes, GPAQ2 assigns 4 METs to moderate activity, and 8 METs to vigorous. Therefore, 150 minutes of moderate actuvuty = 600 MET-minutes a week, which is equivalent to the minimum assignment of activity in GPAQ2.

Table 3.2: Self-reported benefits of exercise ranked by mean score. Agreement with, and binary logistic regression values (with odds ratios and 95% CI) of, each perceived benefit against exercise levels.

Benefits of Exercise	*n*	Mean	SD	Agree%*	Insufficiently active vs. Sufficiently active	
					Odds Ratio†	95% CI
Exercise improves my physical health	411	3.43	0.64	98%	0.74	0.22-2.44
Exercise improves the functioning of my heart and lungs	406	3.42	0.65	99%	2.10	0.56-7.94
I have improved feelings of well-being from exercise	405	3.30	0.75	94%	0.21§	0.07-0.63
Exercise improves my mental health	398	3.28	0.81	95%	0.31§	0.12-0.83
My muscle tone is improved with exercise	404	3.28	0.74	95%	0.44	0.17-1.11
Exercise increases my muscular strength	402	3.28	0.78	95%	0.40‡	0.16-0.99
Exercise decreases feelings of stress and tension for me	398	3.11	0.87	89%	0.31§	0.15-0.63
Exercise improves my self-esteem	395	3.09	0.92	89%	0.73	0.41-1.30
Exercise improves the way my body looks, and makes me feel more attractive	395	3.05	0.92	85%	0.80	0.47-1.36
I enjoy exercise	405	2.96	0.86	79%	0.21§	0.11-0.39
Exercising helps me lose weight	387	2.91	0.99	85%	1.22	0.75-1.99
Exercising makes me feel less tired	400	2.75	0.82	72%	0.49§	0.31-0.78
Exercising lets me have contact with friends and persons I enjoy	349	2.43	1.25	67%	0.74	0.49-1.11
Exercising improves my job performance	323	2.25	1.34	74%	0.90	0.60-1.35
Exercise helps me feel less nausea	169	0.94	1.21	35%	0.85	0.49-1.50

*The number of responses to different questions may vary as respondents were given the option to skip questions to minimise participant burden, and in some cases the 'Not applicable' option was selected. Any percentages given are therefore calculated as a percentage of the number of women who answered that question with a response other than 'Not applicable'. Agree% was the percentage of women who responded with either "Agree" or "Strongly agree".

†Binary logistic regression of each benefit statement against achieving a minimal recommended level of exercise ($p<0.05$). If OR = 1, agreement with that benefit is equally likely in both groups; OR > 1, agreement with that benefit more likely in first group (insufficiently active); OR < 1, agreement with that benefit more likely in second group (sufficiently active).

‡$p<0.05$

§$p<0.01$

The top three barriers ranked according to mean score were procrastination, being fatigued by exercise, and not being able to find a comfortable bra to exercise in (see Table 3.3). Sixteen of the 19 perceived barriers were significantly associated with exercise levels ($p < 0.05$), with ORs indicating that a respondent who agreed with that barrier, was significantly less likely to achieve a minimum recommended level of exercise. The top three barriers, based on ORs, were feeling too weak to exercise (OR = 10.97, 95% CI 3.90-30.86), a lack of self-discipline (OR = 8.12, 95% CI 4.73-13.93), and exercise not being a priority (OR = 7.43, 95% CI 3.72-14.83).

3.4 Discussion

This study provides a comprehensive list of the perceived barriers to, and benefits of, exercise that physical therapists need to be aware of when developing evidence-based strategies to encourage exercise among women treated for breast cancer. This is the largest study to date, which has consulted breast cancer survivors who were not part of any formal exercise intervention, and the results provide insight into barriers that prevent exercise uptake and maintenance for these women. Over three quarters of the perceived barriers to participating in exercise were significantly related to being insufficiently active; whereas less than half of the perceived benefits of exercise were significantly associated with being sufficiently active. This finding suggests that perceived barriers are better able to explain exercise participation in women treated for breast cancer than perceived benefits. Addressing perceived barriers to exercise is therefore likely to have a significant effect on the exercise behaviours of women treated for breast cancer.

Women in the present study had a high level of agreement with exercise benefits (85-99% agreement with the top 10 benefits), which aligns with previous research investigating a breast cancer cohort [77, 83]. When ranked according to mean score,

Table 3.3: Self-reported barriers to exercise ranked by mean score. Agreement with, and binary logistic regression values (with odds ratios and 95% CI) of, each perceived barrier against exercise levels.

Barriers to Exercise	*n*	Mean	SD	Agree%*	Insufficiently active vs. Sufficiently active	
					Odds Ratio†	95% CI
I procrastinate when it comes to exercise	384	2.37	1.02	55%	4.68§	3.02-7.25
I am fatigued by exercise	397	2.35	0.91	49%	2.31§	1.52-3.49
I can't find a bra that is comfortable to exercise in	392	2.33	1.01	47%	2.02§	1.34-3.05
I lack the self-discipline to exercise	388	2.18	1.01	40%	8.12§	4.73-13.93
I feel too tired to exercise	391	2.11	0.92	36%	6.94§	4.01-12.01
I find exercise boring	392	2.04	0.90	30%	3.20§	1.94-5.30
I wouldn't use the communal changing facilities at exercise venues	358	2.03	1.14	40%	1.31	0.86-2.00
I feel uncomfortable in exercise clothing	380	2.03	0.97	33%	3.32§	2.03-5.46
I do not enjoy exercise	393	1.92	0.85	23%	5.16§	2.70-9.84
Exercise is not a priority for me	387	1.89	0.92	25%	7.43§	3.72-14.83
I have no time for exercise	388	1.82	0.78	17%	6.22§	2.76-14.00
Exercising takes too much time away from family relationships	379	1.77	0.80	14%	2.02‡	1.05-3.92
I need to consult a fitness expert before I begin exercising	358	1.76	0.98	22%	1.68	0.98-2.88
Exercise facilities do not have convenient schedules for me	316	1.73	1.17	34%	2.17§	1.33-3.55
I feel too weak to exercise	380	1.73	0.90	16%	10.97§	3.90-30.86
I do not have access to exercise equipment	362	1.72	0.96	20%	2.08‡	1.18-3.71
I am not interested in exercise	382	1.66	0.88	14%	3.98§	1.82-8.68
I don't know how to exercise	376	1.60	0.80	9%	3.53§	1.33-9.37
I feel too much nausea to exercise	275	1.16	0.94	4%	1.64	0.43-6.28

*The number of responses to different questions may vary as respondents were given the option to skip questions to minimise participant burden, and in some cases the 'Not applicable' option was selected. Any percentages given are therefore calculated as a percentage of the number of women who answered that question with a response other than 'Not applicable'. Agree% was the percentage of women who responded with either "Agree" or "Strongly agree".

†Binary logistic regression of each barrier statement against achieving a minimal recommended level of exercise ($p<0.05$). If OR = 1, agreement with that barrier is equally likely in both groups; OR > 1, agreement with that barrier more likely in first group (insufficiently active); OR < 1, agreement with that barrier more likely in second group (sufficiently active).

‡$p<0.05$

§$p<0.01$

the top three perceived benefits of exercise in the present study were that exercising improves physical health, improves heart and lung functioning, and improves feelings of well-being. However, this high overall agreement with exercise benefits did not translate into exercise behaviours, with only 6 out of 15 benefits having a significant effect on exercise behaviour. This lack of statistical association between perceived benefits to exercise and exercise behaviour could be attributed to the uniformity of the data, as nearly all women agreed with the functional benefits of exercise (improved physical health, heart and lung functioning). This was also reflected by the fact that the only notable relationships between exercise benefits and exercise behaviour were of a more subjective, personal aspect, with exercise enjoyment (OR = 0.21, 95%CI 0.11-0.39), and improved feelings of well-being (OR = 0.21, 95% CI 0.07-0.63), displaying the strongest association with being sufficiently active. Despite this, the correlations are consistent with previous research, which has found that cancer survivors identified 'fun' as being the top factor that would facilitate their exercise participation [76], and exercise enjoyment was significantly related to self-reported exercise levels among breast cancer patients during treatment [19].

Unlike perceived benefits, agreement with perceived barriers to exercise was only moderate (25-55% agreement with the top 10 barriers). This is possibly due to the more personalised nature of exercise barriers rather than the factual understanding associated with exercise benefits. When ranked according to mean score, the top three barriers to exercise were procrastination, being fatigued by exercise, and not being able to find a comfortable bra to exercise in. Procrastination and fatigue have been previously identified as major barriers to exercise for women treated for breast cancer [74–76]. One other study which identified bra discomfort as a potential barrier to exercise [42] also noted similar results to the present study, whereby procrastination, a lack of self-discipline, being fatigued by exercise, and not being able to find a comfort-

able bra to exercise in, were the top four barriers to exercise [42]. Bra discomfort is an exercise barrier with unique implications for women who have undergone breast cancer treatment due to the substantial physical changes to the breast and surrounding tissue as a result of this treatment. Although further research is warranted to determine the requirements of bras worn by women treated for breast cancer when they exercise, physical therapists should be aware of this potential barrier, and educate women so they can independently and correctly fit themselves into a well supportive sports bra. Physical therapists are in an ideal position to provide this education, [84] and should familiarise themselves with professional bra fit criteria [85] in order to provide evidence-based patient education.

Over three-quarters of the perceived barriers examined in this study significantly influenced exercise behaviours. The most significant correlations were feeling too weak to exercise, a lack of self-discipline, and exercise not being a priority, which were each linked with being insufficiently active. Research exploring exercise adherence and motivation issues among women treated for breast cancer is sparse, and have produced mixed outcomes [74–76]. For example, some research suggests that the strongest correlates of exercise adherence among women treated for breast cancer are not demographic, socio-economic or medical variables but rather social and/or cognitive variables such as attitudes, perceptions of control and subjective norms [75, 86]. In contrast, other research has indicated that treatment or disease variables account for most exercise barriers among these women [74, 76]. It is likely, however, that the social and/or cognitive variables are themselves influenced by the disease state. Therefore, although barriers such as 'a lack of self-discipline' and 'exercise is not a priority' are not disease specific, they may still present as a greater challenge for women treated for breast cancer compared to the general population [77]. Similarly, although only 16% of respondents agreed with the barrier 'I feel too weak to exercise',

this barrier had a large and significant negative impact on the ability of these women to achieve a minimal recommended level of exercise. This physical weakness poses as a disease-specific barrier to exercise, likely attributed to the side effects of breast cancer treatment, and physical therapists must be made aware of the significant impact this perceived barrier has on a patients' ability to exercise, and account for this accordingly when encouraging these women to exercise.

Other barriers with a substantial effect on exercise (OR > 5.0), included feeling too tired to exercise (OR = 6.94, 95% CI 4.01-12.01), having no time to exercise (OR = 6.22, 95% CI 2.76-14.00), and a lack of exercise enjoyment (OR = 5.16, 95% CI 2.70-9.84). Four of the six barriers presented here with an OR >5.0 may be classified as being of a motivational/psychological aspect rather than disease or treatment-related. Conversely, Courneya et al. [87] reported motivational variables, such as intention, attitude, perceived behavioural control and subjective norm, were not predictors of adherence to exercise during a supervised exercise intervention trial. These authors suggested it is likely that women who enrol in exercise interventions are already motivated to engage in exercise [87], an observation reflected by the fact that although adherence to exercise trials are high, uptake into these trials is generally low [87, 88]. Therefore, consulting women who are not involved in a supervised exercise intervention, may provide insight into barriers that prevent exercise uptake and maintenance and, based on present findings, these barriers are likely to be of a motivational and psychological aspect, with physical weakness and tiredness also playing an important role. Understanding barriers that prevent exercise uptake is important, as it informs strategies aimed at encouraging sedentary women and women currently not meeting exercise guideline levels to begin exercising. This encouragement to exercise should stem from the integration of accurate exercise prescription and behaviour theory, that result in initial exercise uptake, and a shift towards long term exercise adherence.

3.4.1 Study Strengths, Limitations and Recommendations

It is acknowledged that a primary limitation of this study is that the data were based on self-reported measures. In an attempt to mitigate this limitation, the Benefits and Barriers scale was systematically developed based on previous literature [42] and validated through focus group discussions with the target population. Seven-day test-retest reliability (ICC = 0.82) was also confirmed. Similarly, although a valid and reliable physical activity questionnaire was used (GPAQ2), exercise was self-reported rather than objectively gathered. Furthermore, although the sample was community-based, most respondents were still part of a support network for their breast cancer. Additionally, as nearly all women agreed with the factual benefits of exercise, uniformity of the data may inhibit a meaningful finding of an association between these benefits and exercise levels. Furthermore, the larger variations of agreement, coupled with smaller sample sizes noted in some responses to exercise barriers, may be responsible for the high odds ratios and wide confidence intervals observed for these variables. Finally, 32% of the women in the study reported experiencing other medical conditions that may impact on their ability to exercise. However, when this was analysed in a binary logistic regression against exercise levels, the outcome was not significant, indicating no significant impact of other medical conditions on exercise in this sample. Despite these limitations, the online survey completion rate was high (89.6%), and the study was solely focused on breast cancer survivors, providing valuable new knowledge and insight into the effect of motivational barriers on exercise participation among breast cancer survivors who were not part of any formal exercise intervention. Finally, a distinct strength of the study is that the list of benefits and barriers developed in the study were generated by women treated for breast cancer, with the validity and reliability of this list established through focus groups, and test-retest methods. This provided insight into barriers unique to this cohort, which may

not commonly occur in other clinical populations, such as issues with bra discomfort, or feeling uncomfortable in exercise clothing.

3.5 Conclusion

In summary, with a rising number of breast cancer cases predicted, and increasing survival rates, focus must shift towards long-term care of women following breast cancer treatment. Exercise is important for long-term survivorship, and the results of this study provide a comprehensive list of the most common benefits of and barriers to exercise perceived by women treated for breast cancer, and the effect of these items on their exercise behaviour. Motivational issues of self-discipline, exercise not being a priority, having no time, and a lack of enjoyment had a large negative effect on exercise behaviour. Physical issues such as feeling too weak to exercise, and too tired to exercise also displayed large and significant associations with insufficient exercise levels, and must be accounted for when attempting to promote exercise to these women. Agreement with exercise benefits such as exercise enjoyment, improved feelings of well-being and decreased feelings of stress and tension were significantly associated with being sufficiently active. Creating exercise enjoyment is likely to be a key factor in promoting exercise with this cohort, and improving exercise enjoyment is likely to be a key step in encouraging sedentary women, or women not currently meeting recommended guidelines, to begin to undertake exercise. Accounting for physical weakness and tiredness, as well as acknowledging that even motivational barriers may be influenced by the disease state, is imperative for physical therapists when encouraging exercise in this population. Barriers identified in the present study will enable physical therapists to better plan behaviour-theory based exercise interventions to support all women treated for breast cancer, particularly those women who are not currently part of any formal exercise intervention.

Chapter 4

Exercise bra discomfort is associated with insufficient exercise levels among Australian women treated for breast cancer

This chapter is an amended version of the published manuscript: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Exercise bra discomfort is associated with insufficient exercise levels among Australian women treated for breast cancer," *Supportive Care in Cancer*, vol. 22, no. 3, pp. 712-29, 2014.

Abstract

Purpose: Although participating in exercise is beneficial for breast cancer survivors, not being able to find a comfortable exercise bra can be a barrier to exercise. It is likely that side-effects specific to breast cancer treatment exacerbate exercise bra discomfort. This study aimed to determine the relationship between patient characteristics, phys-

ical side-effects, exercise bra discomfort and exercise behaviours.

Methods: 432 breast cancer survivors completed an online survey related to their treatment and demographic background, current exercise levels, reported exercise bra discomfort and breast cancer treatment side-effects. Patient characteristics and exercise levels were considered in a binary logistic regression against reporting bra discomfort to ascertain significant relationships ($p < 0.05$) and predictive value (odds ratio). Pearson's Chi-Square statistics were used to determine significant relationships between reporting a side effect and exercise bra discomfort.

Results: Eight out of nine physical side-effects were significantly related to reporting exercise bra discomfort. Reporting exercise bra discomfort was significantly related to not achieving a minimal recommended level of exercise.

Conclusions: This is the first study in the scientific literature that systematically links the reporting of exercise bra discomfort to not achieving recommended levels of exercise. This effect of bra discomfort on exercise was found after controlling for age, surgery type and current treatment among a large cohort of women treated for breast cancer. Furthermore, results from this study suggest that physical side-effects, as a result of surgery and treatment associated with breast cancer, are linked to experiencing bra discomfort during exercise.

4.1 Introduction

Participating in exercise has repeatedly been shown to be highly beneficial for the health and well-being of women who are treated for breast cancer [10, 18, 55, 62, 66]. Current literature indicates, however, that perceived barriers to exercise are associated with a reduced ability of these women to achieve recommended exercise

levels [24, 74, 89, 90]. Therefore, to encourage exercise participation among breast cancer survivors, these barriers to exercise need to be identified and minimised or removed [18]. In a recent study investigating 19 potential barriers to exercise, a lack of discipline, procrastination, being fatigued by exercise and not being able to find a comfortable bra to exercise in, were ranked as the top four barriers to exercise by women treated for breast cancer [42]. Of these 19 barriers, bra discomfort is the highest ranked barrier that can be modified through an external intervention, such as by providing exercise bras that suit the needs of breast cancer survivors.

Bra discomfort presents a unique challenge to women treated for breast cancer due to the significant physical changes to the breast and surrounding tissue as a result of breast cancer treatment. Despite this, only one other study could be located which investigated the impact of bra discomfort on exercise levels among breast cancer survivors [42]. In that study, a significant proportion of respondents (70%) experienced exercise bra discomfort, although this was not related to weekly exercise levels or reported physical side-effects. This previous work, however, was limited by a small sample size, and an investigation of the effect of exercise bra discomfort on exercise behaviour, with sufficient statistical power to control for confounding demographic and treatment variables, is warranted.

Targeting patients who would benefit the most is vital when planning health or lifestyle interventions. As such, a better understanding of the women more likely to report exercise bra discomfort is essential when identifying women most likely to benefit from interventions aimed at improving exercise bra design. Patient characteristics such as age, surgery type, or whether the respondent was undergoing current treatment, have previously provided moderate associative value when analysed with respect to potential side-effects of breast cancer treatment [79]. We postulate that using these same patient characteristics to identify women who are more likely to experience ex-

ercise bra discomfort could be an informative first step in developing strategies to improve exercise bra comfort. These strategies may include improving bra design or educating women towards improving bra fit.

Given the impact exercise barriers can have on exercise levels [24, 74, 89, 90], and that exercise bra discomfort has been reported as a potential barrier to exercise [42], the effect of exercise bra discomfort on exercise behaviour, while controlling for participant characteristics should be explored. In order to develop strategies aimed at improving exercise bra comfort for women treated for breast cancer, a clearer understanding of the women who experience bra discomfort the most, as well as the physical side-effects related to this bra discomfort is needed. Therefore, the primary aim of this study was to determine the relationship between exercise bra discomfort, exercise behaviours and patient characteristics among a large cohort of women who had been treated for breast cancer. The secondary aim of this study was to assess the relationship between physical side-effects of breast cancer treatment and exercise bra discomfort. We hypothesised that women who experience exercise bra discomfort do not achieve sufficient levels of exercise, after controlling for patient characteristics. We also hypothesised that experiencing exercise bra discomfort is related to experiencing physical side-effects as a result of breast cancer treatment.

4.2 Participants and Methods

4.2.1 Participants and Survey Implementation

Breast cancer patients who had a registered email address with the Breast Cancer Network Australia (BCNA) Survey and Research Group or the Cancer Councils of Victoria or Western Australia were invited by email to complete an internet-based survey. Of the 482 women who visited the initial URL, 432 completed the survey

(89.6% completion rate). This surpasses the calculated $n = 384$ required sample size (based on a conservative 50% probability of obtaining statistical significance, assuming 95% confidence interval, and a 10% margin of error), thus providing sufficient statistical power for the following analysis [91]. Participant informed consent was obtained and the University Human Research Ethics Committee approved all data collection procedures (HREC08/326). The survey used in the present study formed part of a larger body of work, and details of the development, validation and content of the online survey instrument have been published elsewhere [79](see Chapters 2 and 3). Survey items specific to the aims of the present study are described below.

4.2.2 Analytical Variables

4.2.2.1 Participant characteristics

Participant age was an open-ended response to "What is your date of birth?", calculated with respect to the survey submission date (providing age at time of survey completion). Following this calculation, participants were split into categories of being 'Under 50 years old', or '50 years and over' for the purpose of the binary logistical regression. Participant surgery type was assessed by a closed-ended question for which the responses were either a lumpectomy or mastectomy of either the right or left breast. Responses were not mutually exclusive, permitting participants to indicate whether they had undergone surgery on both breasts, or had a lumpectomy, followed by a mastectomy. Participants were then grouped into categories of a 'Lumpectomy' or a 'Mastectomy' for the binary logistic regression.

Finally, participants were asked "Are you CURRENTLY undergoing any of the following treatments for your breast cancer?" with closed-ended, non-mutually exclusive, response categories of chemotherapy, radiotherapy and hormonal treatment. For the purpose of the binary logistic regression, participants were divided into categories

of 'Currently undergoing treatment' vs. 'Finished treatment'. Women who were still taking any medication for their breast cancer were classified as 'Currently undergoing treatment'. Women were also asked the date of their last treatment ever if they had finished treatment. The difference between the survey completion date and treatment completion date was calculated to give a time since treatment completion at the time of survey completion.

4.2.2.2 Side-effects

Physical side-effects deemed to potentially have a direct effect on bra discomfort included lymphoedema, broken and painful ribs, weight gain, shoulder limitations, aching muscles, hot flushes, burning, sensitive skin or chafing, pain and muscular chest wall pain. Participants were asked to rate their experience of each of these side-effects on a 5-point Likert scale from none ('1') to severe ('5'). For the purpose of binary logistic regressions, women were divided into categories of 'No symptom experience' (Likert response = '1') vs. 'Any level of experience' (Likert response = '2-5').

4.2.2.3 Exercise bra discomfort

The exercise bra discomfort question was a direct, closed-ended response item which queried "Do parts of the bra you wear during exercise cause you discomfort?", to which participants responded either 'Yes' or 'No'.

4.2.2.4 Exercise levels

Recreational exercise levels were assessed using the Recreational Activities domain of the World Health Organisation's (WHO) Global Physical Activity Questionnaire Version 2 (GPAQ2) [44]. Based on GPAQ2 analysis guidelines, respondents were then classified into those who met the GPAQ2 threshold for achieving moderate or high levels of exercise and those who achieved low levels or no exercise. These classifications

included any combination of moderate or vigorous intensity exercise resulting in ≥600 MET-minutes a week; or ≥3 days/week of vigorous intensity exercise for ≥20 minutes a day; or ≥5 days/week of moderate intensity exercise or walking for ≥30 minutes a day, as per GPAQ2 guidelines [44]. Achieving moderate or vigorous exercise as identified by GPAQ2 is also equivalent to meeting the WHO's recommendation of 150 weekly minutes of moderate exercise, or 75 weekly minutes of vigorous exercise, or an equivalent combination of both [78]. For the purpose of the binary logistic regression analysis, women who achieved moderate or high levels of exercise were deemed as 'Sufficiently active' whereas women who achieved only low levels or no level of exercise were deemed as 'Insufficiently active'.

4.2.3 Statistical Treatment

4.2.3.1 Characteristics, exercise levels and exercise bra discomfort

Exercise bra discomfort was considered in a binary logistic regression against patient characteristics and exercise levels to ascertain any significant relationships. Whether a participant reported experiencing bra discomfort (None vs. Any level of discomfort) was inserted as a dependent variable against the independent variables of age (<50 years vs. ≥50 years), type of surgery (Lumpectomy vs. Mastectomy), whether women were currently undergoing treatment (Current treatment vs. Finished treatment), and exercise levels (Sufficiently active vs. Insufficiently active). This method of analysis has been previously employed in a cross-sectional survey data analysis with this population [45, 79], and ensures each independent variable is analysed while controlling for the other three independent variables.

4.2.3.2 Side-effects and exercise bra discomfort

Whether a participant reported a side effect (None vs. Any) was analysed by a 2x2 cross-tabulation relative to whether the participant reported exercise bra discomfort in response to direct questioning (Yes/No). Relationship significance was assessed using a Pearson Chi-square test of independence ($p < 0.05$). All statistical analyses were completed using SPSS for Windows software (Version 17.0, SPSS Inc, Chicago, USA).

4.3 Results

4.3.1 Sample Overview

Participants were 432 women who had been treated for breast cancer, aged between 23-77 years (mean 53.3 $\pm$ 9.8 years). Table 4.1 provides information on the participants' self-reported health status, location, age and exercise levels with comparisons to Australian population data. The age spread of the sample was generally lower than the age of the wider Australian breast cancer population, which may skew results towards a younger breast cancer population. Despite this, the self-reported health status of the participants' was similar to the general Australian female population; and the survey sample was spread across Australian States and Territories in similar proportions to the wider breast cancer population, with the exception of the Australian Capital Territory, which formed 10.3% of the sample and only 1.6% of the national spread. The proportion of women deemed sufficiently active in the survey sample was comparable to an age-matched general Australian female population (36.5% vs. 37.6%).

One hundred and eighty eight women had under gone a lumpectomy during treatment for their breast cancer, 241 women had undergone a mastectomy and 3 women reported no surgery (43.5%, 55.8% and 0.7%, respectively; see Table 4.2). None of the women had differing procedures on both breasts, and the mastectomy classification

included women who had a lumpectomy followed by a mastectomy. Two hundred and thirty nine women were currently undergoing treatment (or still taking medication for their breast cancer), 148 women finished all treatment and 45 women did not respond to the question (55.3% and 34.3% and 10.4%, respectively; see Table 4.2).

Table 4.1: Respondents' demographic information with comparisons to Australian population data.

	Present Study			Comparison Data (%)
	n	%		
Health Status		428		Australian General Female Population [46]
In general, would you say your health is:				
Excellent	55	12.9 %	51.9%	57% (Excellent or very good)
Very good	167	39.0%		
Good	150	35.0%	35.0%	29% (Good)
Fair	44	10.3 %	11.7%	14% (Fair or poor)
Poor	6	1.4%		
Missing data	4	0.9%		
State or Territory		428		Australian Breast Cancer Population [1]
What is your postcode?				
New South Wales	114	26.6%		33.9%
Victoria	119	27.8%		25.0%
Queensland	65	15.2%		18.5%
Western Australia	26	6.1 %		9.5%
South Australia	41	9.6%		8.5%
Tasmania	15	3.5%		2.4%
Australian Capital Territory	44	10.3%		1.6%
Northern Territory	4	0.9%		0.5%
Missing data	4	0.9%		
Age		432		Australian Breast Cancer Prevalence [64]
What is your date of birth?				
<39 years	39	9.0%		1.9%
40-59 years	268	62.0%		33.5%
60-79 years	125	28.9%		48.9%
80+ years	0	0.0%		15.7%
Exercise	432	97.6%		Age-matched Australian females [81]
Sufficiently Active*	158	36.5%		37.6%
Missing data	9	2.2%		

Only 158 women (36.5%) were considered sufficiently active, which is close to the percentage of sufficiently active women in an age-matched general Australian female population (37.6%; see Table 4.1) [81]. Exercise data were missing for nine participants. In all categories, missing data were treated using listwise deletion, and although this resulted in data loss of up to 13%, this approach was deemed appropriate to provide unbiased parameter estimates.

4.3.2 Patient Characteristics, Exercise Levels and Exercise Bra Discomfort

Among respondents aged 50 years and over, the proportion of women reporting bra discomfort (28%) was lower than the proportion who reported no bra discomfort (36%). The same trend was observed to a smaller extent among women under 50 years old (15% reporting discomfort; 17% reporting no discomfort). Among both lumpectomy and mastectomy groups, the same trend was observed again, whereby the proportion of women reporting bra discomfort (18% lumpectomy; 25% mastectomy) was lower than the proportions of women reporting no bra discomfort (24% and 28%, respectively). This trend was also observed in current treatment groups, whereby the proportion of women reporting bra discomfort (25% current treatment; 14% finished all treatment) was lower than the proportions of women reporting no bra discomfort (29% and 19%, respectively). However, the trend was reversed among insufficiently active respondents, whereby the proportion of women reporting bra discomfort (31%) was greater than the proportion who reported no bra discomfort (29%).

Consistent with these sample proportion observations, none of the patient characteristics of age, undergoing current treatment, or surgery type was significantly related to whether a participant reported experiencing exercise bra discomfort (see Table 4.3). However, reporting exercise bra discomfort was significantly related to a participant

being sufficiently active. Specifically, women who reported exercise bra discomfort were less likely to be sufficiently active, while controlling for age, time post treatment and surgery type (OR = 2.04, 95% CI 1.32-3.16; $p = 0.04$).

Table 4.2: Respondents' characteristics divided into binary logistic regression groups.

Binary logistic regression groups	*n*	%	Categories
Age	432		
<30 years	2	0.0%	< 50 years old, *n*=144; 33%
30-49 years	142	33.0%	
50-69 years	271	63.0%	≥ 50 years, *n*=288; 67%
>70 years	17	4.0%	
Exercise	432		
Insufficiently active	265	61.3%	Insufficiently active
Sufficiently active	158	36.5%	Sufficiently active
Missing data	9	2.2%	
Surgery undergone	429		
Unilateral lumpectomy	179	41.4%	Lumpectomy, *n*=188; 43.5%
Double lumpectomy	9	2.1%	
Unilateral lumpectomy followed by mastectomy	75	17.4%	
Double lumpectomy followed by mastectomy	24	5.6%	Mastectomy, *n*=241; 55.8%
Unilateral mastectomy	107	24.8%	
Double mastectomy	35	8.1%	
Missing data	3	0.7%	
Time since completion of treatment	387		
Current chemotherapy	14	3.2%	
Current radiotherapy	3	0.7%	Currently undergoing
Current hormonal therapies	226	51.4%	treatment *n*=239*; 55.3%
<1 years	20	4.6%	
1-2 years	50	11.5%	
3-4 years	23	5.3%	Finished all treatment
5-7 years	29	6.7%	*n*=148; 34.3%
8-10 years	9	2.1%	
>10 years	17	3.9%	
Missing data	45	10.4%	

*Two respondents were simultaneously undergoing chemotherapy and hormonal therapies, while another two respondents were simultaneously undergoing radiotherapy and hormonal therapies.

4.3.3 Side-effects and Exercise Bra Discomfort

The most frequently reported physical side-effects were hot flushes ($n = 257$), aching muscles ($n = 242$), shoulder limitations ($n = 190$) and pain ($n = 185$). Across all physical side-effects except hot flushes, the proportion of women reporting exercise bra discomfort was greater than the proportion of women not reporting this discomfort (see Figure 4.1). Also with the exception of hot flushes, all of the physical side-effects reported by the respondents were significantly related to exercise bra discomfort (Pearson Chi-Square statistic; $p < 0.05$).

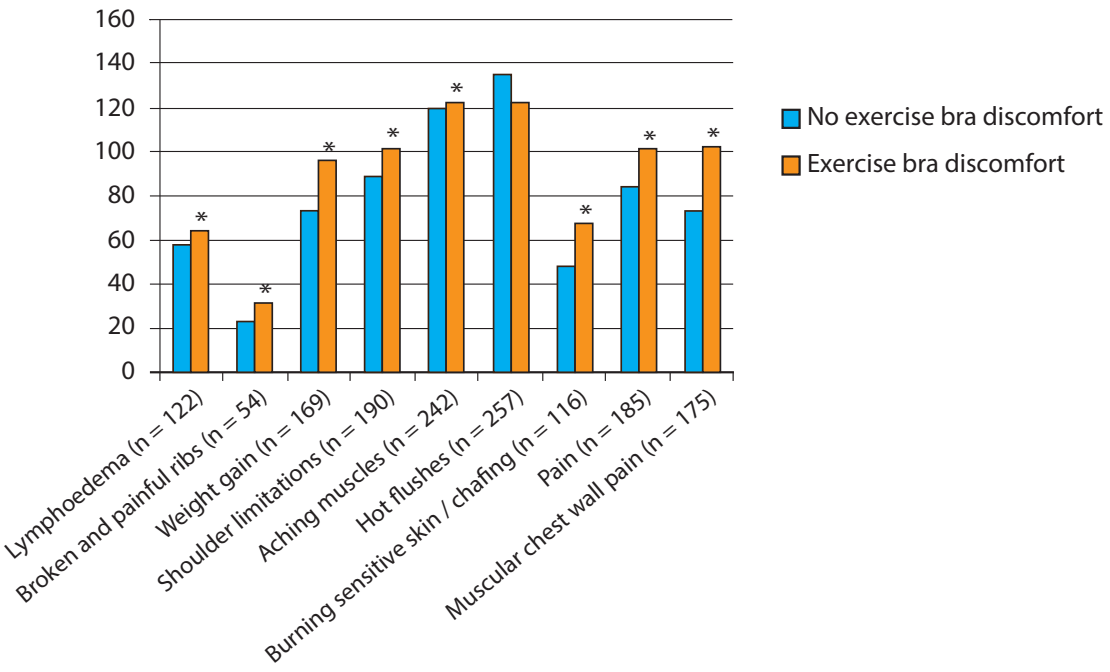


Figure 4.1: Proportion of women who reported experiencing exercise bra discomfort and associated physical side-effects. Asterisk (*) denotes significance (Pearson's χ^2 statistic; $p < 0.05$).

Table 4.3: Group percentage numbers and binary logistic regression values (with odds ratio) of patient characteristics and exercise levels against reported bra discomfort.

Bra discomfort*	Independent variables							
	Age Under 50 years old vs. 50 years and over		Surgery Lumpectomy vs. mastectomy		Current treatment Current treatment vs. finished treatment		Exercise Insufficiently active vs. sufficiently active	
Odds ratio (95%CI)†	1.01 (0.65 - 0.58)		1.25 (0.81 - 1.92)		0.88 (0.58 - 1.35)		2.04‡ (1.32 - 3.16)	
	<50 years	≥ 50 years	Lumpectomy	Mastectomy	Current treatment	Finished treatment	Insufficiently active	Sufficiently active
Number reporting bra discomfort (%)	64 (15)	120 (28)	76 (18)	107 (25)	106 (25)	59 (14)	133 (31)	51 (12)
Number reporting no bra discomfort (%)	74 (17)	156 (36)	105 (24)	123 (28)	126 (29)	82 (19)	125(29)	105 (24)
Data missing	18 (4%)		21 (5%)		59 (13%)		18 (4%)	

*'Do parts of the bra you wear during exercise cause you discomfort?'; closed-ended response question, 'Yes' or 'No' response options.

†OR = 1: event equally likely in both groups; OR >1 event more likely in the first group; OR <1, event more likely in the second group.

‡$p = 0.04$

4.4 Discussion

As exercise bra discomfort has been identified as a significant barrier to exercise for women treated for breast cancer [42], this study aimed to increase the body of knowledge in this sparse area of research by determining whether any relationships existed between patient characteristics, exercise levels and exercise bra discomfort. In agreement with our first hypothesis, women who experienced exercise bra discomfort were more likely to not achieve sufficient levels of exercise, after controlling for patient characteristics. In agreement with our second hypothesis, results from this study suggest that the physical side-effects experienced as a result of surgery and treatment associated with breast cancer are linked to experiencing bra discomfort during exercise. The implications of these unique findings are discussed below.

4.4.1 Exercise Bra Discomfort and Exercise Levels

To maintain overall health, the WHO recommends adults aged 18-64 years should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week; or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week; or an equivalent combination of moderate- and vigorous-intensity activity [78]. Within this study, irrespective of age, current treatment or type of surgery, women who reported bra discomfort were significantly less likely to achieve the minimum recommended level of exercise. We postulate that this result implies that the level of bra discomfort experienced by a respondent was sufficient to impede that respondent's ability to achieve these recommended levels of exercise. This finding is of concern given the well-established benefits of exercise for this cohort, and the potential for this barrier to be alleviated or reduced by providing more effective and comfortable exercise bra designs, which are specific to the needs of breast cancer survivors. The specific exercise bra design needs of breast cancer survivors are likely linked to the side-effects

of their treatment, and so an investigation into the relationship between treatment side-effects and exercise bra discomfort was also warranted. The present study found that, with the exception of hot flushes, all the reported physical side-effects associated with respondent's breast cancer treatments were significantly related to the reporting of exercise bra discomfort.

4.4.2 Side-Effects and Bra Discomfort

4.4.2.1 Surgical side-effects

Surgery for breast cancer is associated with considerable short and long-term morbidity, which may include lymphoedema, shoulder limitations and pain [92, 93]. Upper-body morbidity, which encompasses both lymphoedema and shoulder limitations, is a severe and chronic condition affecting 19-54% of breast cancer patients even up to 3 years post treatment [57]. Although outcomes are variable, the more extensive surgeries, such as axillary dissections and accompanying radiation- and chemo- therapies, are linked to the development of upper body morbidities. Many women who undergo breast surgery also suffer from ill-defined pain syndromes [59]. Pain that is a direct consequence of surgery can be nociceptive (resulting from injury to ligament or muscle); or neuropathic (resulting from injury to the nerves innervating the region), and affects 20% to 75% of women following a mastectomy [58, 93]. Nociceptive pain usually resolves as the damaged tissues heal, whereas neuropathic pain may develop into a chronic syndrome [58]. Of particular relevance to bra designs for women following surgery for breast cancer is the development of neuroma pain, a chronic neuropathic pain arising from peripheral nerves being severed or injured and entrapped within scar tissue. These scars can cause spontaneous pain and severe mechanosensitivity [58], which can be exacerbated by both breast motion and contact of the bra over the scar tissue.

The present study found reporting lymphoedema, shoulder limitations, aching muscles, pain and muscular chest wall pain was significantly related to reporting exercise bra discomfort. Considering this link, and given that breast cancer surgery side-effects are common and may persist for many years post surgery [26], there is clear need for further investigation into specialised breast support designs for women following surgery for breast cancer, who wish to reap the health benefits associated with exercise.

4.4.2.2 Radiotherapy side-effects

The physical side-effects of broken and painful ribs, as well as burning, sensitive skin and/or chafing, are typically linked to radiation therapy [93]. For the remainder of their lives, breast cancer survivors who have undergone radiation therapy are also at risk of developing long-term radiation effects such as lymphoedema, shoulder limitations and fibrosis [93]. Acute skin reactions due to radiation therapy are primarily due to a damaging effect on the basal layer of the epidermis [94]. Within three months of radiation, 61% of the patients report erythema, and 55% report pain and tenderness of the skin or breast [94]. Even six months after radiation, up to 44% of patients still experience pain and tenderness in the breast region, and up to 25% report erythema [94]. It has been suggested that radiation effects have the same frequency and intensity regardless of the type of surgery undergone, and acute and late radiation-related morbidities are independent adverse effects, without a mechanistic relationship [95]. Factors such as treatment technique, beam energy, bra cup size and dose variation across the target volume all have a significant effect on the acute skin reaction observed [96].

The axilla and inframammary fold are commonly the sites of the most severe skin injury following radiation therapy [97]. The band of an exercise bra provides the primary support for the breasts, and will sit on these sites, which may lead to greater

discomfort as a result of bra band pressure on the skin and underlying hypodermis. Therefore, exercise bras for breast cancer survivors must account for and minimise the exacerbation of this radiation damage by minimising the bra band pressure experienced at these sites.

In some cases, an early skin reaction to radiation therapy can progress to a chronic injury. A common chronic skin condition following breast cancer radiation is fibrosis, which is characterised by an increase in 'stiffness' or loss of compliance in the soft tissue [98, 99]. Fibrosis is typically permanent, and in skin, subcutis and muscle, fibrosis can cause limitations in the range of motion and substantially affect function [98, 99]. This late effect of fibrosis has implications for exercise bra design for women following radiation therapy for breast cancer, as a 'stiffer' breast may impair natural breast motion. An exploratory biomechanical study [100] found that, compared to the unaffected breast, the natural affected breast of four lumpectomy patients moved in an altered and restricted pattern when they ran on a treadmill, which was perceived by the participants as asymmetrical breast motion. We postulate that a prosthetic or reconstructed breast will also display motion changes, which may be detected by patients. These asymmetrical breast motion patterns are not accounted for in bras worn during exercise by breast cancer survivors, and thereby may result in exercise bra discomfort, or self-consciousness, which may be interpreted as feeling 'uncomfortable' in the bra. In fact, breast cancer survivors frequently report a fear of their prosthesis moving or falling out of their bra, which may be exacerbated by exercise, and excessive asymmetrical breast movement may draw unwanted attention to the survivor [101, 102]. Further study is therefore urgently required in order to ensure exercise bras designed for women treated for breast cancer account for the differences in movement likely to be displayed by the affected breast or prosthesis compared to the natural breast of these women.

The present study also found respondent weight gain was significantly linked to exercise bra discomfort. Weight gain is a common side effect of breast cancer treatment and carries with it an increased risk of secondary cancer, and the development of other morbidities [54, 93]. Weight gain is also associated with a change in body composition and an increase in body weight without concurrent increases in lean muscle mass (sarcopenic obesity) [54, 93]. Women who gain weight following breast cancer treatment often find asymmetrical gains between their affected and unaffected side, and this is even more poignant for women who use a prosthesis as a result of breast tissue removal [101]. As a result, fluctuations in weight will affect how balanced a survivor feels towards her unaffected side, and will also change the fit of a bra. Specifically, breast cancer survivors have reported difficulty matching the affected or unaffected breast, and/or prosthesis cup sizes within a bra [100]. Correct bra fit is imperative in order to achieve exercise bra comfort [85], which may explain why women treated for breast cancer who report weight gain also report exercise bra discomfort.

4.4.3 Study Strengths, Limitations and Recommendations

We acknowledge that the primary limitation of this study is that the exercise data are based on self-reported measures. Demographic data regarding marital status, income, education level, region or residence (regional/remote or metropolitan), as well as data regarding exercise behaviours prior to treatment for breast cancer, were not collected, and therefore could not be controlled for in the analysis of exercise behaviour. As this is the first study to investigate exercise bra discomfort and exercise levels among women living with breast cancer, the study was limited in the comparisons that could be made to existing literature specific to this field of research. Finally, we acknowledge that the coding of side-effects into 'No symptoms' vs. 'Any level of that symptom' was broad. However, division into categories that accounted for the

extent of symptom experience (none, mild to moderate, moderate to severe) was not feasible due to a limited distribution of respondents across the spectrum of symptom experience. Furthermore, even with this broad level of coding, the sub-sample sizes of these side-effects were lower than what was deemed sufficient by a conservative proportional sample size calculation, and may limit the significance of these findings. Future studies with a larger study population, which can draw meaningful sub-sample sizes would be required to achieve this level of analysis. Future research should also gather greater details of which parts of the bra cause discomfort for women treated for breast cancer. Despite these limitations, this study provides valuable insight into an otherwise limited research area. The strengths of the study are that the online survey completion rate was very high (89.6%), providing responses from a large sample of Australian women treated for breast cancer. Furthermore, the electronic nature of survey delivery allowed for side effect items to be randomised preventing any ordering bias; and limited the human error potential, which is present during manual paper-survey data transcriptions into electronic statistical packages.

4.5 Conclusion

This study links the reporting of exercise bra discomfort to not achieving recommended levels of exercise among women treated for breast cancer. This study also suggests that the physical side-effects experienced as a result of breast cancer treatment are linked to experiencing bra discomfort during exercise. Based on these findings it is postulated that providing better bra designs, which are specific to the needs of breast cancer survivors, may eliminate or reduce one of the important barriers to exercise. This, in turn, will enhance exercise participation in this patient population and enable women treated for breast cancer to enjoy the health benefits associated with an active lifestyle.

Part II

Meeting the Need with Better Bra Designs

Chapter 5

What women want: Evidence-based recommendations for building better bras for women treated for breast cancer

This chapter is an amended version of the manuscript: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Evidence-based recommendations for building better bras for women treated for breast cancer," *Ergonomics*, DOI:10.1080/00140139.2014.897377, 2014.

Abstract

Participating in exercise is beneficial for women who have been treated for breast cancer. However, not being able to find a comfortable exercise bra can be a barrier to exercise participation. This study aimed to systematically investigate what breast support women treated for breast cancer want when they exercise in order to provide

evidence-based recommendations to improve exercise bra designs for these women. Based on 432 responses from a national online survey, frequency and relationship data were analysed (binary logistic regression) to understand exercise bra issues pertinent to this population. These issues included being able to control for asymmetrical cup sizes, managing heightened skin sensitivity, managing fluid (size) fluctuations, managing a prosthesis, and restoring body image by restoring shape. This study provides evidence-based recommendations to inform an exercise bra design that will meet the unique needs of women treated for breast cancer. Rigorous, evidence-based evaluations of exercise bras for women treated for breast cancer may contribute to their well-being and quality of life through enhanced designs.

Practitioner Summary: Exercise bras worn by women treated for breast cancer were investigated with the aim of improving exercise bra designs, which may ultimately contribute to the well-being and quality of life of these women. Evidence-based recommendations to inform an exercise bra design for women treated for breast cancer are provided.

5.1 Introduction

Exercise is consistently regarded as being highly beneficial for women treated for breast cancer [10, 18, 62, 66]. In particular, exercise has the potential to improve strength and cardiovascular fitness [18, 55, 56], reduce fatigue [15, 67], decrease levels of anxiety [7, 66], improve quality of life [68, 103], and improve survival through a decreased risk of reoccurrence [38, 104]. Research suggests, however, that barriers to exercise play a significant role in limiting healthy exercise behaviours among these women [24]. In fact, emerging research indicates that for breast cancer survivors, the highest ranked barrier to exercise that can be externally modified is exercise bra discomfort [42].

Furthermore, women who report exercise bra discomfort are less likely to achieve a minimal recommended level of exercise, even when controlling for age, current breast cancer therapies and surgery type [80]. It has been suggested that side-effects of breast cancer treatment such as scarring, lymphoedema and reduced functional ability of the arms contribute to the disproportionate bra discomfort experienced by breast cancer survivors as they attempt to exercise . Although this previous research has established that exercise bra discomfort is a leading barrier to exercise participation, no evidence-based literature is currently available to provide recommendations pertaining to what women treated for breast cancer require in an exercise bra.

Supported only by the skin and thin fibrous bands called Cooper's ligaments, the female breast is relatively free to move over the chest wall [105]. Given that excessive breast motion has been linked to the reporting of breast discomfort and pain [106–109], this lack of anatomical support within the breast results in women requiring external support in the form of a bra in order to reduce breast discomfort during exercise [105]. However, subjective judgements of how comfortable a bra feels to the wearer, or how good a bra looks on the wearer, is as important as limiting breast motion when considering ideal exercise bra design. In one study, McGhee and Steele [110] found that, although three high support bras displayed no significant difference in vertical breast displacement, the study participants reported a clear favourite bra, and even perceived their favourite bra to elicit less breast movement than the other bra conditions. Given overall comfort is a key factor in encouraging women to wear supportive bras during exercise, the subjective measures of the 'look and feel' of an exercise bra must be accounted for when developing exercise bra designs for any cohort of women [110].

How a woman considers the 'look and feel' of her breasts following breast cancer treatment, particularly surgical removal of a breast or breast tissue, is complex. For

some women, the loss of a breast can negatively influence perceptions of their self-image, self-identity and sexuality [111]. For other women, it is a small price to pay for survival and the ongoing enjoyment of life [101]. Regardless of outlook, every survivor will experience a 'new normal' whereby, following diagnosis, treatment and post treatment periods, the survivor attempts to adjust to the substantial changes their physical, emotional, psychosocial and existential self has undergone as a result of their breast cancer [112]. During this period, the restoration of body image through a well-fitted external breast prosthesis or reconstruction, and an appropriate bra, is vital for women negotiating breast cancer survivorship [113].

Despite a growing evidence base on the importance of bras to exercise participation, there is currently no scientific evidence focused on exercise bra design for women following their treatment for breast cancer. This is a pertinent issue as bra discomfort is associated with lower levels of exercise, which is linked to poorer health outcomes among this cohort. Furthermore, a rigorous, evidence-based evaluation of exercise bras with an aim to improve exercise bra design, may ultimately contribute to the well-being and quality of life of breast cancer survivors. Therefore, the purpose of this study was to systematically investigate what breast support women treated for breast cancer want when they exercise in order to provide recommendations for improving exercise bra designs for these women. These evidence-based recommendations will inform exercise bra designs that will ultimately meet the unique needs of women treated for breast cancer when they attempt to exercise.

5.2 Participants and Methods

5.2.1 Participants and Survey Implementation

Breast cancer patients who had a registered email address with the Breast Cancer Network Australia (BCNA) Review and Survey group or the Cancer Councils of Victoria or Western Australia were invited by email to complete an online survey. Inclusion criteria were any women over 18 years of age, with a breast cancer diagnosis prior to the survey distribution date. The survey invitation contained a brief introduction to the investigators and the study, as well as a direct link to the uniform resource location (URL), which contained the internet-based survey. The URL was open to responses for 4 months, and closed when continued promotion of the survey did not elicit any further responses. Due to the anonymity of the data collection procedures, and the 'sharing' nature of the internet, the survey's response rate could not be tracked. However, of the 482 women who visited the initial URL, 432 completed the survey (89.6% completion rate). Participant informed consent was obtained via a participant information sheet on the first page of the survey to which participants clicked "I agree" in order to progress with the online survey. The University Human Research Ethics Committee approved all data collection procedures (HREC08/326).

5.2.2 Online Survey Instrument

The online survey instrument was based on a previously validated paper-based questionnaire [42]. To validate the online version, seven focus groups with breast cancer patients were conducted (total participants = 20) at community centres around the greater Sydney area. During these groups, the think-aloud technique was employed [43] and participants were queried about their understanding, and about the relevance and sensitivity of each question, which lead to changes to facilitate the participants un-

derstanding and ease in navigating the electronic version. Test-retest reliability over seven days was confirmed through administering the scale to 12 breast cancer survivors (twice, seven days apart), and the scale was deemed reliable with an intraclass correlation coefficient of 0.82 (0.78-0.85 95% CI).

The final survey instrument included 68 closed-ended and 11 open-ended items and formed part of a larger body of work with regards to survivorship issues after a breast cancer diagnosis [79][80](see Chapters 2-4). The areas of relevance to the outcomes of the present study were bra cup sizes, types of bras worn during exercise, parts of the exercise bra causing discomfort, important factors when purchasing a bra, and an open-ended query on recommendations for bra designs. Other independent participant variables used to analyse these outcomes included age, type of surgery undergone, current treatment, and current levels of exercise. The differentiation of these independent participant variables have been described in depth elsewhere [79]. Briefly, the women were divided into groups of being 'Under 50 years old', or '50 years and over' (Age); having undergone a 'Lumpectomy' or a 'Mastectomy' (Surgery); whether they were in 'Current treatment' or 'Finished treatment' (Current treatment); and whether they were 'Sufficiently active' or 'Insufficiently active' (Exercise) [44] based on their responses.

5.2.3 Statistical analysis

5.2.3.1 Descriptive analysis

Answers to the closed-ended items were counted to determine the frequency response for each item. The number of responses to different questions may vary as respondents were given the option to skip questions to minimise participant burden. Study population proportions were therefore calculated as a percentage of the number of women who answered that question.

5.2.3.2 Relationship analysis (Binary logistic regression model)

The parts of a bra causing discomfort were considered in a binary logistic regression to ascertain any associated variables and significant relationships. Whether respondents reported the band, straps, cups or underwire of a bra as causing discomfort was inserted as a dependent variable against the independent variables of age, type of surgery, currently undergoing treatment, and exercise levels. This method of analysis has been successfully used in previous cross-sectional survey data with a breast cancer population [79], and ensures each independent variable is analysed while controlling for the other independent variables. All statistical analyses were completed using SPSS for Windows software (Version 17.0, SPSS Inc, Chicago, USA).

5.2.3.3 Open-ended recommendations

Open-ended responses were coded into key reoccurring themes, which were then re-coded into higher order themes, based on specific parts of the bra, and eventually formed into recommendations for exercise bra design. All open-ended responses were analysed using NVivo 8 for Windows software (QRS International, Melbourne, Australia).

5.3 Results

5.3.1 Participant Characteristics

Participant characteristics of age, surgery undergone, current treatment, exercise levels, and exercise bra discomfort are provided in Table 5.1. Only 158 women (36.5%) were considered sufficiently active, which closely matches the percentage of sufficiently active women in an age-matched general Australian female population (37.6%) [81]. One hundred and eighty-four women reported the bra they currently exercised in was

Table 5.1: Participant characteristics data.

	n	%
Age		
Mean Age	53.5 ± 9.8 years	
< 30 years	2	0.0%
30-49 years	142	33.0%
50-69 years	271	63.0 %
≥ 70 years	17	4.0%
Missing	0	0.0%
Surgery		
Lumpectomy	187	43.3%
Masteectomy	242	56.0%
Missing	3	0.7%
Current Treatment		
Still being treated	239	55.3%
Finished all treatement	148	34.3%
Missing	45	10.4%
Exercise Levels	432	97.6%
Sufficiently active	158	36.5%
Insufficiently active	265	61.3%
Missing data	9	2.2%
Exercise Bra Discomfort		
Yes	184	42.6%
No	230	53.2%
Missing data	18	4.2%

uncomfortable, compared to 230 women who reported no discomfort, and 18 who did not respond to this question (42.6%, 53.2% and 4.2%, respectively).

5.3.2 Bra Size

Table 5.2 provides a summary of the left and right bra cup sizes of the sample. The C-cup bra size was the most common, with most respondents ($n = 83$; 20.0%) having

Table 5.2: Bra cup size for the left and right breasts for respondents ($n = 432$). The values in the central diagonal line (shaded) indicate the number of respondents with matching cup sizes ($n = 275$). The values outside the central line indicate the number of women with mismatched cup sizes ($n = 157$). The 'none' value may have indicated no breast (or prosthesis) of a non-response.

	Left										
Right	None	A	B	C	D	DD	E	F	G	Other	Total
None	23		2	18	3	3		21			50
A	5	21	5	1							32
B	11	8	61	11	2					1	94
C	13	2	10	83	6	1	1			2	118
D	8		1	8	48	7				1	73
DD	3				2	4	16	2			27
E	2				2		9			1	14
F								1			1
G	1							1	3		5
Other			2	2	2	1	1			10	18
Total	66	31	81	125	67	28	13	3	3	15	432

Survey Question: "What is your bra cup size?" : Right Breast [closed-ended options]: Left Breast [closed-ended options].

both left and right C-cup size breasts. Over half the respondents ($n = 274$; 63.4%) had bra cup sizes of C-cup or smaller, although whether this was a natural cup size or due to surgery is unknown, with 157 women (36.3%) reporting asymmetrical cup sizes.

5.3.3 Types of Exercise Bras Worn

Mastectomy bras were the most commonly worn exercise bras, with 100 respondents (24.5%) reporting wearing these during exercise (see Figure 5.1). A standard everyday bra with underwire was the next most commonly worn exercise bra ($n = 91$; 22.2%). Only one fifth ($n = 80$; 19.5%) of respondents wore a sports bra (with or without an underwire) as their exercise bra.

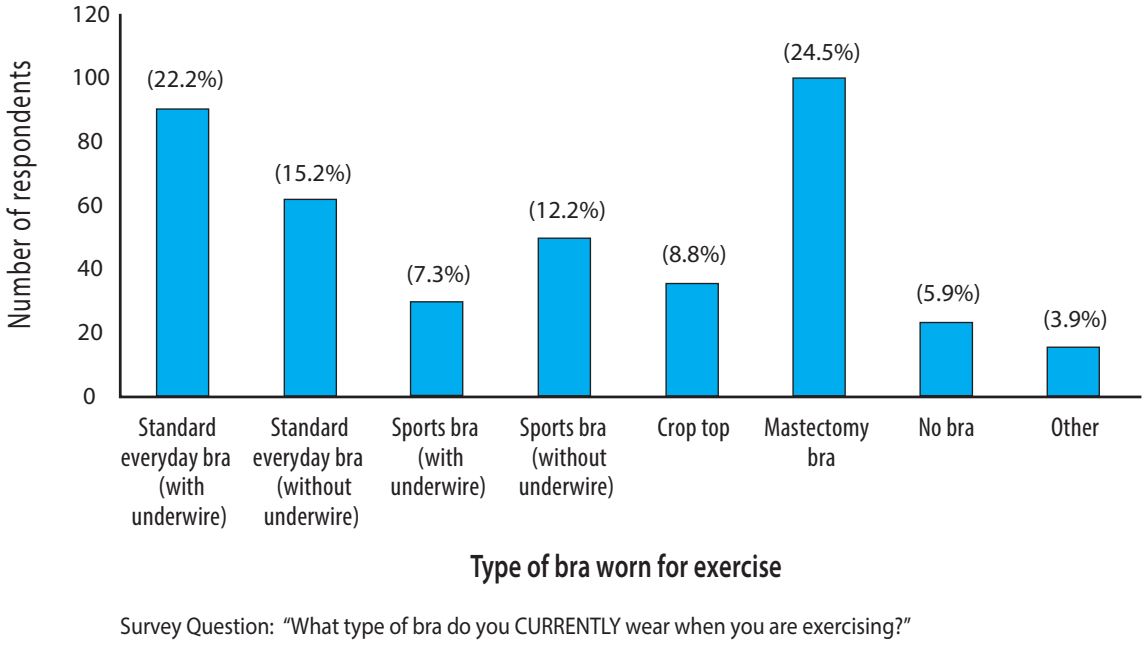


Figure 5.1: Types of bras worn by respondents during exercise, by the frequency and proportion of the sample (in parentheses) who reported their exercise bra type (n = 409).

5.3.4 Most Uncomfortable Parts of an Exercise Bra

Respondents who reported exercise bra discomfort (n = 184) were asked to indicate which parts of their exercise bra caused this discomfort (total responses = 466). Figure 5.2 indicates that 64.7% of these respondents found the band to be the most uncomfortable part of the bra (n = 119), followed by the straps (n = 83; 45.1%), cups (n = 70; 38.0%) and underwire shape (n = 49; 26.6%). When these four main uncomfortable bra parts were considered in a binary logistic regression model against age, surgery, current treatment, and exercise levels, only the cups and underwire shape showed significant associations (see Table 5.3). Specifically, women who reported the cups of a bra as uncomfortable were more likely to have undergone a lumpectomy (OR = 2.78; 1.28 - 6.03 95% CI); and women who reported the underwire shape as uncomfortable were more likely to have finished active treatment, or finished taking medication for their breast cancer (OR = 0.44; 0.20 - 0.93 95% CI).

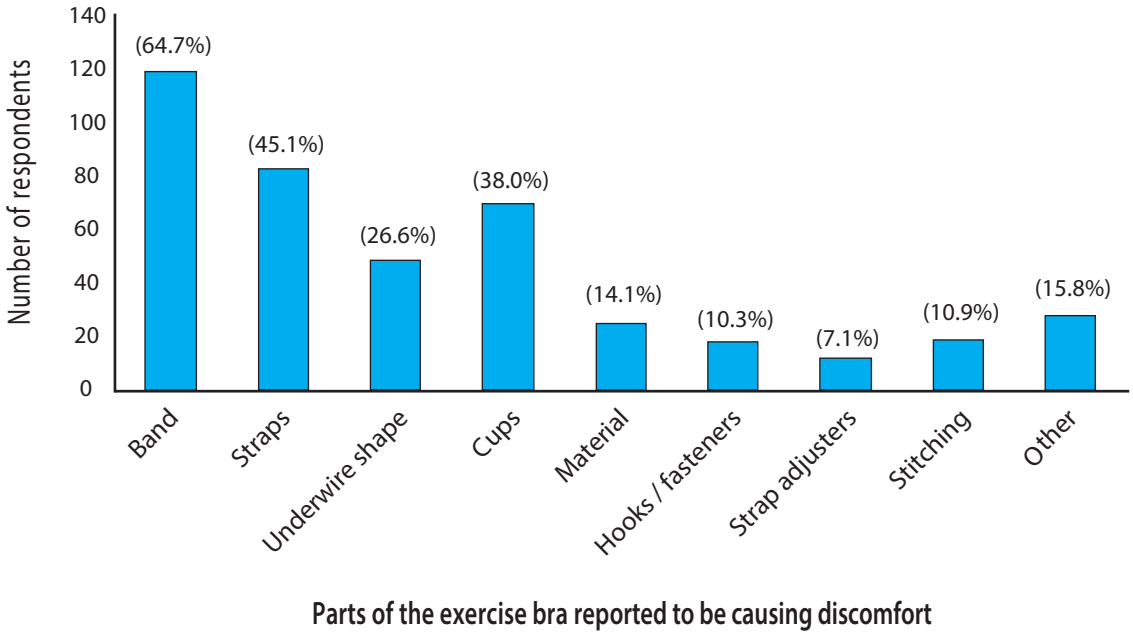


Figure 5.2: Overall parts of the bra causing discomfort during exercise, by the frequency and proportion of the sample (in parentheses) who reported exercise bra discomfort (total responses = 466; total $n = 184$).

Table 5.3: Binary logistic regression of participant characteristics against uncomfortable parts of a bra.

		Band ($n = 119$)			Straps ($n = 83$)			Cups ($n = 70$)			Underwire ($n = 49$)		
	n	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI
Age													
$<$ 50 years	144	0.55	1.28	0.57-2.88	0.49	0.77	0.37-1.62	0.67	1.18	0.54-2.61	0.08	0.51	0.24-1.09
$\geq$ 50 years	288												
Missing	0												
Surgery													
Lumpectomy	187	0.26	0.65	0.30-1.39	0.34	1.41	0.69-2.87	0.01*	2.78	1.28-6.03	0.11	0.56	0.26-1.16
$\geq$ Mastectomy	242												
Missing	3												
Current treatment													
Still being treated	239	0.97	0.99	0.45-2.16	0.07	1.98	0.95-4.12	0.45	1.36	0.61-3.05	0.03*	0.44	0.20-0.93
Finished all treatment	148												
Missing	45												
Age													
Insufficiently active	265	0.27	0.60	0.25-1.49	0.90	0.95	0.43-2.12	0.95	0.97	0.41-2.29	0.94	1.03	0.46-2.33
Sufficiently active	158												
Missing	9												

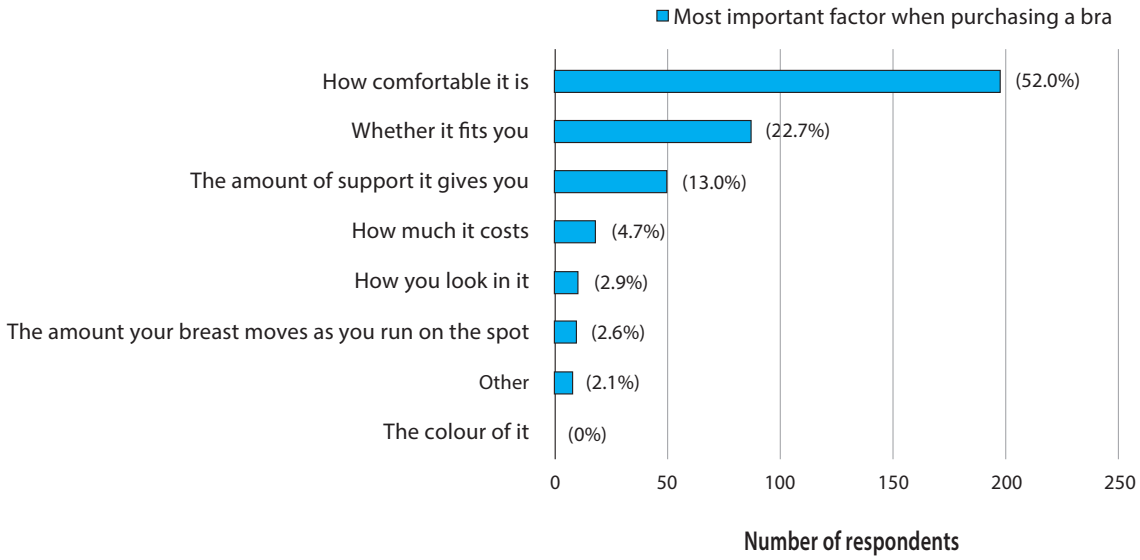
Survey Question: "Which parts of your bra do you feel most uncomfortable when you exercise?"

5.3.5 Causes of Exercise Bra Discomfort

Respondents who reported exercise bra discomfort ($n = 184$) were also asked to indicate what caused this discomfort (total responses = 425; see Table 5.4). The top 10 causes of bra discomfort during exercise were band being too tight, straps slipping off, band riding up, straps too tight, mismatched cup sizes, band hurts or irritates breast scar, underwire shape hurts or irritates breast scar, cups do not support unaffected breast, cups do not support affected breast, and stitching hurts or irritates breast scar.

5.3.6 Important Factors When Purchasing an Exercise Bra

Most respondents (52.0%) ranked bra comfort as the most important factor when purchasing an exercise bra (total responses = 383; see Figure 5.3). Secondary to this was whether the bra fitted (22.7% of respondents) and the amount of support it provided (13.0% of respondents).



Survey Question: "Rank the following factors that you think are most important when selecting a new bra to EXERCISE in. For each rank, please select the appropriate factor from the drop-down menus. Rank 1 is the most important and 7 is the least important."

Figure 5.3: The most important factor when purchasing an exercise bra by the frequency and proportion of the sample (in parentheses) who reported it (item ranked 1 out of possible 7; $n = 383$).

Table 5.4: Parts of, and causes of, discomfort in an exercise bra reported by the respondents.

	Response frequencies													
	Too tight	Sits on drain site	Rides up	Hurts/ irrates my breast scar	Chafing/ rubbing	Does not support unaffected breast	Does not support affected breast	Mis-matched cup sizes	Slip off	Too narrow	Too wide	Too hot	Other	Total
Band	35[1]	7	30[3]	17[6]	10	1	4	3	1	2		1	5	116*
Straps	23[4]		4	2	3	2	2	2	33[2]	6	2		4	83*
Cups		1	4	8	3	14[8]	12[9]	20[5]	1		1	2	3	69*
Underwire shape	8	1	5	15[7]	7		1	3	1				2	44*
Material				5	8			2				10		25
Hooks/ fasteners	3	1	3	1	6		1			2	1		1	19
Strap adjusters	2		1	1	2	3		1	2					12
Stitching		1		11[10]	6								1	19
Other	7		2	2	1			4				1	2	19
Total	78	11	49	62	46	20	20	35	38	10	4	14	18	425*

*Overall totals do not match frequencies in Table 5.3 and Figure 5.2, as not all women reported a cause for their bra part discomfort

[1−10]Top 10 causes of bra discomfort.

5.3.7 Open-ended Recommendations

A total of 551 references from 306 open-ended responses were coded into key themes and categorised under the main parts of the bra causing discomfort. The four main parts of the bra identified were: (i) the band, with underarm, fabric and sizing recommendations; (ii) the cups with seam-free, underwire free, and padding recommendations; (iii) the bra straps with fit and orientation recommendations; and (iv) fastener recommendations - particularly around ease of removal. Other themes relative to overall comfort, fit, price, and availability were also identified. Open-ended responses supported many of the themes that emerged through the closed-ended data, and quotes to show this are provided throughout the discussion. The need for a bra to 'look attractive' was a key theme identified in the open-ended responses that was not apparent from the closed-ended data.

5.4 Discussion

The purpose of this study was to systematically investigate what breast support women treated for breast cancer want when they exercise, and to provide evidence-based recommendations for improving exercise bra designs for these women. The study gathered information about current exercise bra use of women treated for breast cancer and the main causes of discomfort these women experienced with their exercise bra. The study also gathered information on what women want in an exercise bra, and their personal recommendations for exercise bra design. This is the first study to examine these outcomes in the literature to date, and these results will provide evidence to inform exercise bra designs for women treated for breast cancer.

5.4.1 Bra Size

The marked asymmetrical bra cup sizes reported in this cohort is a factor not usually accounted for in exercise bra design. In fact, the proportion (36.3%) of respondents reporting breast asymmetry is significantly larger than the natural breast asymmetry seen among women without a history of breast cancer treatment (approximately 10% deemed clinically significant) [114]. Historically, exercise bras have not needed to accommodate for breast asymmetry, as studies of a general female population have found no significant difference in the vertical breast displacement between a right and left breast [115]. However, among women treated for breast cancer, it is apparent that to provide optimal breast support during exercise, the exercise bra must control motion of both the affected breast (and prosthesis), and unaffected breast [100]. To do this, the ability to inter-change cup sizes or adjust each cup size should be considered.

> *"Make allowance for different size breasts. Since radiotherapy my affected breast does not change in size as my weight fluctuates, so I always have one breast a different size to the other which makes fitting very hard - very tight on one side or loose on the other."* [55 years old; undergone a lumpectomy]

5.4.2 Types of Exercise Bras Worn

Only about one fifth (n = 80; 19.5%) of respondents wore a sports bra (with or without an underwire). This is much lower than the proportion of women in the general population (41%) who report wearing a bra designed specifically for sport while exercising [105]. Researchers attribute the low levels of sports bra usage in the general population to be primarily due to a lack of awareness regarding the importance of good breast support during physical activity [105]. Although this is likely to also contribute to the low levels of sports bra usage among women who have been treated

for breast cancer, respondents also cited a lack of availability as a reason for not using an exercise specific bra.

> *"I would like a mastectomy bra specifically made for exercise - haven't come across any."* [50 years old; undergone a mastectomy]

5.4.3 Most Uncomfortable Parts of an Exercise Bra

Women who reported the cups of a bra as uncomfortable were more likely to have undergone a lumpectomy and women who reported the underwire as uncomfortable were more likely to have finished active treatment, and finished taking medication for their breast cancer. Lumpectomy patients are less likely to wear a prosthesis, and may experience the effect of breast asymmetry to a larger degree in standard bra cup sizes than mastectomy patients [100]. This was also expressed in the open-ended responses as women requested a bra with the option to be "padded out" to fit the cup and match the unaffected breast.

> *"To have an exercise bra which is slightly padded to give a fuller/more rounded even shape for women who have had lumpectomys but no reconstruction and whose breasts may now be of different shapes (difference between the left and right breasts)."* [49 years old; undergone a double lumpectomy]

It is also probable that women currently undergoing treatment for breast cancer would wear a soft, post surgery bra that does not contain underwire. As they move beyond treatment, however, finding an attractive, supportive bra without underwire becomes a significant issue.

> *"After surgery I wore maternity bras because at 18DD it is difficult to get a supportive bra without underwire. The underwire type is still painful*

after nearly 10 years." [71 years old; undergone a lumpectomy]

5.4.4 Causes of Exercise Bra Discomfort

Bra band tightness was reported as the top cause of bra discomfort during exercise. Women without a history of breast cancer treatment have also reported feeling their exercise bra band was too tight around the chest [116]. To explore this, Bowles et al. [117] examined the pressures exerted by a sports bra and a fashion bra on the torso of women as they performed sub-maximal and maximal exercise. The authors found that wearing a professionally fitted encapsulating sports bra resulted in no significant difference in comfort when compared to a fashion bra, and resulted in no decrease in exercise performance. This result highlighted the importance of being correctly fitted for an exercise bra. Furthermore, women who have been treated for breast cancer will experience fluctuations in fluid retention in the axillary area, and around the torso, to an extent not experienced by the general female population. Problems associated with fluctuations in fluid retention are underlined by the finding that the top four reasons cited for bra discomfort in this cohort were two extremes of the same functional bra component; namely, a bra band being too tight or too loose (riding up); and the straps of a bra being too tight or slipping off (too loose). This finding indicates women treated for breast cancer may not be adjusting their bras to fit in response to fluctuations in body weight or fluid retention; or their bras do not permit the adjustability this cohort requires.

The other top causes of breast discomfort that were cited imply the need for better bra cup design to permit better fit, and to provide the support required during exercise, both for the affected and unaffected breasts. Although not highly ranked through response frequencies, issues surrounding the aggravation of breast surgical scars appear to be consistent across a range of bra components. Key design features recommended

for exercise bras for the general population include a high front to fully enclose breast tissue and limit anterior-posterior breast motion; a large side depth to ensure side breast tissue is kept fully within the cup; and extendable yet semi-rigid shoulder straps that stay in contact with the body throughout the movement [118]. These features are relevant to the breast cancer cohort, but must also be combined with improved adjustability for fit, and an awareness of the aggravation of breast scar tissue by the functional bra components (band, underwire and stitching).

> *"The change in shape, position and consistency of breasts can make it difficult to find a bra which suits both breasts. Also scaring and damaged skin from radiotherapy can be irritated by the shape of cups and underwire."* [51 years old; undergone a mastectomy]

5.4.5 Important Factors When Purchasing an Exercise Bra

"How comfortable the bra is" was the most important factor influencing bra purchasing in this study. Interestingly, in a study of 13 women aged 45-65 years and not affected by breast cancer, a leading theme influencing everyday bra purchasing was the effect that the bra may have on outward aesthetics, and the woman's shape in it [119]. Although similar themes have been expressed as being important to women treated for breast cancer, aesthetics ranked fifth (2.9%), following comfort, fit, support, and cost, in this cohort. As the following quote illustrates, for many women in the study comfort displaces aesthetic appeal.

> *"I now buy my sport (pull over the head) or soft front opening bras (no padding) from the home delivery magazines. Comfort is the most important, I can no longer wear pretty."* [68 years old; undergone a lumpectomy]

Nevertheless, although aesthetics did not rank highly as a bra purchasing factor for women treated for breast cancer, research has identified the important role body image

and appearance to self plays in the psychological and emotional well-being of these women [120]. Therefore, exercise bra designs that focus on both functionality and attractiveness, rather than forcing women to choose between comfort and aesthetics, will be more readily accepted by these women, and better contribute to overall quality of life through both exercise benefits, and improved body image.

> *"I would like to be able to wear a bra that has some elegance to it as well as support and comfort. A bra that enables you to look and feel feminine."*
> [51 years old; undergone a lumpectomy]

5.4.6 Summary of Exercise Bra Design Recommendations

To fulfil the purpose of this study, closed and open-ended responses from an online survey were systematically analysed to provide evidence-based recommendations pertaining to exercise bra designs for women treated for breast cancer. These recommendations have been discussed throughout this paper, and are summarised in Table 5.5. It is unlikely that any one bra design or style will satisfactorily meet all these recommendations across a variety of breast shapes and sizes [121]. Rather, it is important that bras are designed to fit a range of breast shapes, while maintaining the design features required to effectively limit breast motion, and to accommodate the effects of breast cancer treatment.

5.4.7 Study Strengths, Limitations and Recommendations

Although a validated survey instrument was used, this study was limited in the use of self-reported data and by its cross-sectional design. In particular, women have a poor ability to select correct bra cup sizes, and therefore any self-reported bra size must be interpreted with caution. Furthermore, as this is the first study to investigate the exercise bra design needs of women treated for breast cancer, comparisons to existing

Table 5.5: Summary of exercise bra design recommendations.

The band of an exercise bra should:
◦ be wide enough to provide an appropriate level of breast support
◦ be firm, but not too tight, when fitted properly
◦ not ride up, especially when there is a lack of an infra-mammary fold
◦ be made of soft, breathable and natural materials to prevent skin irritation and to dissipate
◦ be adjustable to accommodate for changes in torso circumference due to factors such as fluid retention
◦ not cut in under the arm
◦ have minimal seams to limit scar aggravation
The straps of an exercise bra should:
◦ be wide and padded to distribute loads borne by the straps over a greater area to prevent bra straps digging into the shoulders
◦ be adjustable to accommodate for changes in breast size
◦ not slip off shoulders
◦ ensure any fasteners and buckles are well encased so they do not 'dig in'
The cups of an exercise bra should:
◦ encase the prosthesis well so it does not fall out
◦ be padded to hide the nipple (or lack of), and should provide breast shape
◦ have no stitching or seams that could irritate sensitive breast tissue
◦ have no underwire that could dig into scar tissue or sensitive breast tissue
◦ be adaptable to accommodate asymmetrical breast sizes
◦ be made of soft, breathable, natural materials to prevent skin irritation and to dissipate
Other recommendations:
◦ The bra should look attractive, and provide shape to the wearer to assist in restoring body image and self-confidence
◦ Bra fit education tools specific to a breast cancer cohort should be developed so that women treated for breast cancer can select a well-fitted bra suited to their exercise needs

literature specific to this field of research could not be made. Despite these limitations, this study provides valuable insight into an otherwise limited research area. The strengths of the study are that the online survey completion rate was very high (89.6%), providing responses from a large sample of Australian women treated for

breast cancer. Furthermore, the electronic nature of survey delivery limited the human error potential, which is present during manual paper-survey data transcriptions into electronic statistical packages.

5.5 Conclusion

Similar to the general female population, women treated for breast cancer require an exercise bra that effectively minimises breast motion during physical activity, fits properly, and is comfortable to wear. However, the findings of this study highlight that women treated for breast cancer also require an exercise bra that can accommodate their asymmetrical breast sizes, heightened skin sensitivity, increased fluid fluctuations and, if relevant, prosthesis movement. To assist in restoring body image, exercise bras for these women also need to provide a flattering profile, be constructed of soft, breathable, natural materials, and provide complete adjustability. The restoration of body image and self-confidence plays a major role in the unique needs of women treated for breast cancer. To this end, if an exercise bra can be designed to look good, and give the wearer shape and confidence, as well as be a functional garment, women may be more likely to use them. Furthermore, although minimising breast motion, and the associated breast discomfort, is a fundamental purpose of exercise bras, the findings of this study highlights the importance of first meeting the unique fit and comfort needs expressed by women treated for breast cancer. Finally, evidence-based recommendations for exercise bra designs for women treated for breast cancer, such as provided by this paper, can enhance the development of better bra designs, and ultimately contribute to the well-being and quality of life of breast cancer survivors.

Chapter 6

Building a Better Bra

"Bra design is a lengthy process requiring a combination of design creativity, precision pattern making and a detailed knowledge of fabric performance." [122]

6.1 Introduction

Exercise is consistently regarded as being highly beneficial for women treated for breast cancer [10, 18, 62, 66]. Research suggests, however, that exercise bra discomfort plays a significant role in limiting healthy exercise behaviours among these women [80] (see Chapter 4). In fact, exercise bra discomfort is the highest ranked barrier to exercise that can be externally modified among women treated for breast cancer [123] (see Chapter 3). It has also been suggested that the physical side-effects of breast cancer treatment, such as scarring, lymphoedema and increased skin sensitivity contribute to the disparate bra discomfort experienced by breast cancer survivors as they attempt to exercise [80] (see Chapter 4).

As a result of these physical side-effects, bra research has highlighted several key considerations that should be accounted for when designing a bra for women treated

for breast cancer [80, 124] (see Chapters 4 and 5). These considerations include an exercise bra that can accommodate asymmetrical bra cup sizes, heightened skin sensitivity, increased fluid fluctuations, and, if relevant, prosthesis movement. To assist in restoring body image, exercise bras for these women also need to provide good shape to the breast and/or prosthesis, contain pockets for a prosthesis, be constructed of soft, breathable, natural materials, and provide complete adjustability to account for changes in torso dimensions associated with lymphoedema and weight fluctuations. And finally, central to all these considerations is that a bra designed for exercise, whether for a general female population, or a woman treated for breast cancer, must provide sufficient support to effectively control breast motion and fit well [85].

There are currently no guidelines or standards that a bra must meet to be classified as an exercise bra [105]. Historically, exercise bras that encapsulate the breasts individually in separate cups (encapsulation bras) have been shown to be more effective in limiting breast motion and related breast pain than bras that compress the breasts as a single unit against the chest wall (compression bras) [107, 108]. Recent studies, however, indicate that for women with small breasts, a compression bra appears most effective [118], whereas women with larger breasts find a combination of encapsulation, elevation and compression most effective [110]. Regardless of style, a good exercise bra must be comfortable to wear, limit breast motion and be constructed from materials which are primarily non-elastic, non-abrasive and have good moisture management properties [125]. Other key features recommended for exercise bras include a high front to fully enclose breast tissue, and limit anterior-posterior breast motion; a large side depth to ensure side breast tissue is kept fully within the cup; and extendable yet semi-rigid shoulder straps which stay in contact with the body throughout the movement [118].

Although previous research has provided recommendations for good exercise bra

design, as well as specific considerations for women treated for breast cancer [124] (see Chapter 5), there is currently no exercise bra available which encompasses these recommendations. Therefore, the aim of this chapter was to develop an experimental bra founded on the evidence-based recommendations pertaining to the exercise bra needs of women treated for breast cancer [124] (see Chapter 5). To achieve this aim, an iterative bra design process, based on industry practice and educational resources, was followed and is described in this chapter. The expected outcome was an exercise bra designed specifically for women treated for breast cancer, which will enable these women to participate in exercise while minimising the bra discomfort they may experience.

6.1.1 The Bra Design Process

The bra design process progresses through concept development, pattern development and grading and is outlined in Figure 6.1. The following sections of this chapter have been structured to reflect the progression through this process diagram.

6.2 Concept Development

6.2.1 Key Design Recommendations

Key bra design recommendations as identified in previous research, are outlined in Table 5.5 (see Chapter 5) [124]. These recommendations formed the foundation for concept development and was the first step in the design process.

6.2.2 Design Sketches

Free-hand sketches of potential bra designs, which incorporated the evidence-based recommendations were produced. This iterative process allowed rapid incorporation

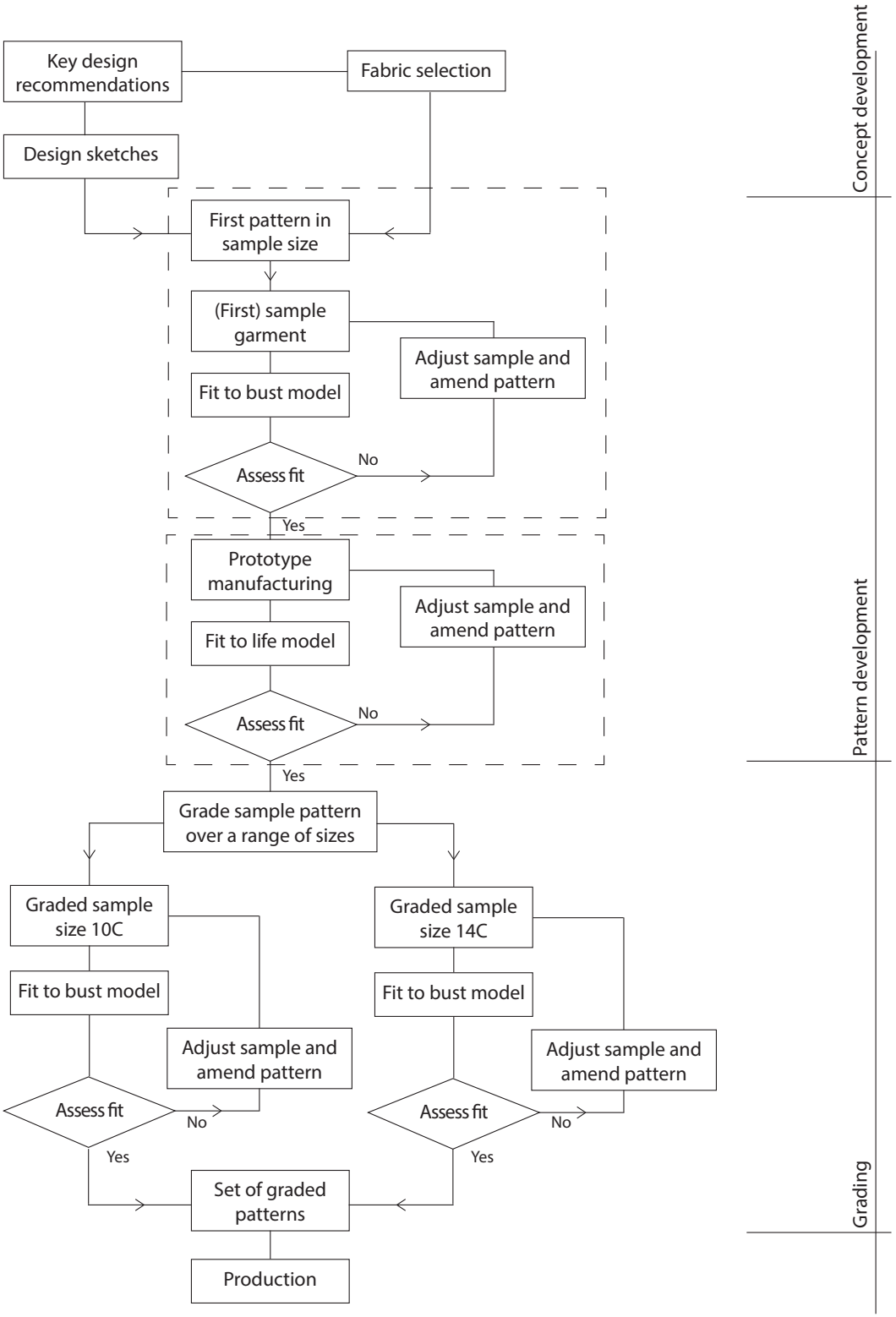


Figure 6.1: A schematic representation of the bra design process (adapted from Hardaker and Fozzard [122], pg 312).

of ideas into a visual representation of possible bra designs, which prompted design concept problem-solving and creativity. The final sketches were then drawn into a computer-assisted drawing program (CAD; Adobe Illustrator for Windows, Adobe Systems Software, Ireland Ltd) to provide an overall impression of the bra design.

6.2.3 Fabric Selection

Fabric properties form a critical part of the structure and support provided by a bra [118, 122]. Most fabrics used in bra design are stretch fabrics, although their construction is varied - woven or knitted. The tensile strength of a stretch fabric is indicated by the warp and weft moduli and the higher the modulus, the more breast motion control is provided [122].

Good sports bra design must be comfortable to wear, limit breast motion and be constructed from materials that are primarily non-elastic, non-abrasive and have good moisture management properties [125]. In addition, fabric considerations identified specifically by women treated for breast cancer were that the bra must be constructed of soft, breathable, and natural materials that account for heightened skin sensitivity and impaired thermoregulation. Following an extensive search of available fabrics which met all the above criteria, a bamboo charcoal and spandex blend was selected. Similar to viscose, bamboo textiles are woven from regenerated cellulose fibres, classifying it as a 'human-made, regenerated fibre' [126, 127].

Bamboo textiles have excellent thermoregulation properties, primarily due to their hollow fibre structure with micro gaps and micro holes, that allow for better moisture absorption and ventilation relative to other fibres [126]. Bamboo textiles also have better absorbency and higher water permeability, which contributes to better thermoregulation, than 100% cotton fabrics [127]. Manufacturers also claim a natural antibacterial function of bamboo textiles. This function, however, is limited to the

lignin chemical constituent of the plant, and the retention of this lignin constituent after raw bamboo has been processed into textiles is still unknown [128].

Tactile properties such as flexibility, compressibility, elasticity, resilience, density and surface friction also form important considerations in the selection of fabrics for bras. It has been suggested that 100% bamboo fabrics outperform 100% cotton fabrics in objective tests of these tactile properties [127]. A textiles' performance, however, will be influenced by the extraction and regeneration of fibres, and the weave and finish applied to the final fabric. The final bamboo charcoal and spandex blend was therefore selected because of its appealing visual appearance, subjective tactile qualities and stretch properties. The final fabric was bright in colour, soft, light and breathable. It also exhibited a predominantly one-way stretch, which when orientated in the medio-lateral direction across the bra cup, was postulated to enhance breast cup fit, but limit breast vertical displacement during exercise.

6.3 Pattern Development

The overall anatomy of a bra, highlighting the bra pattern sections that were developed, are illustrated in Figure 6.2.

6.3.1 First Pattern in Sample Size

Iterative process ('trial and error') is a predominant feature of the pattern development process and is widely accepted as the industry approach to new bra pattern development [122]. Techniques most commonly used in bra patternmaking include:

(1) Draping: creating pattern pieces by applying fabric directly onto a three-dimensional dress form;

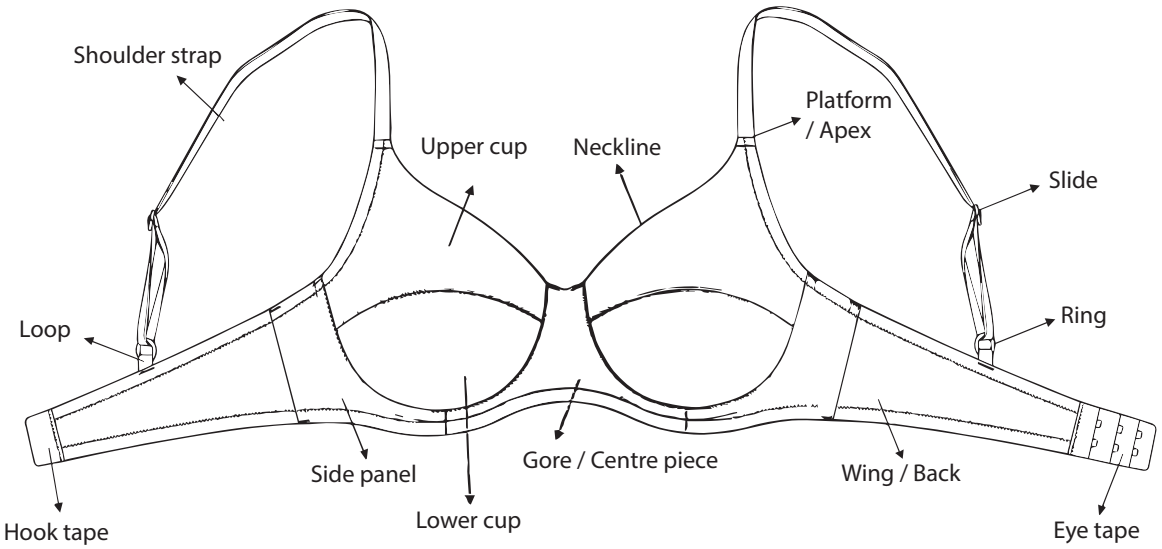


Figure 6.2: Anatomy of a bra (adapted from Shin [129], pg 14).

(2) Pattern drafting: creating the pattern pieces by using body measurements directly; and

(3) Flat patternmaking: a system of creating pattern pieces by manipulating a basic block.

These methods can be used individually or blended. For the purpose of this study, a combination of pattern drafting and draping was utilised to develop the first pattern in a sample bra size. Bra sizes are defined by a band size, and a cup size. Bra band size is defined in the metric system by a direct measurement of the woman's under bust girth. Based on body measurement charts, the under bust girth will correlate to a manufacturers' sizes of usually 6-20+ defined in increments of '2'. For example, in Australia bra band sizes of 8, 10, 12, 14 and above are available. Bra cup size is defined by the difference between the woman's full bust girth and under bust girth, and based on this difference, correlates to an letter from 'A' onwards, with some double letters used to define some sizes. For example, in Australian sizes, a difference of 12.5 cm is defined as cup size 'A'; 15 cm as cup size 'B'; 17.5 cm as cup size 'C'; and 20 cm as cup

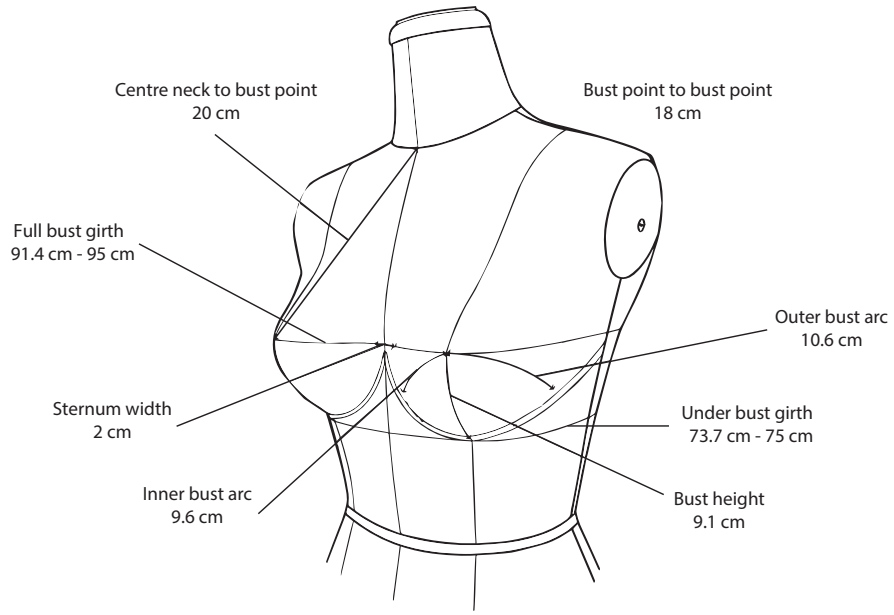


Figure 6.3: Standard body measurements for an Australian 12C used for pattern drafting (adapted from Shin [129], pg 8).

size 'D' [129]. The standard body measurements used to draft the initial Australian size 12C bra pattern are provided in Figure 6.3.

6.3.1.1 Patternmaking Step 1: Drafting the gore, side panel and band

Bra band patternmaking starts with the shape of the underwire [129]. Although no underwire was incorporated into the final design, underwire shape was required to define the curve of the gore and side panel. This, in turn, defines the shape and height of the cup, and the height of the band. To draft the pattern in the present study, a high centre height wire was used in conventional pattern drafting methodology. To do this, body measurements of a size 12C band and cup model (see Figure 6.3) were applied to step-by-step band drafting instructions [129]. Figure 6.4 displays the measurements and draft of the gore, and the resulting pattern draft [129]. The draft was then split into paper pattern pieces of the gore and side panel, which formed the inner cradle, and the band with approximately 5-8 mm seam allowance around each (see Figure 6.5).

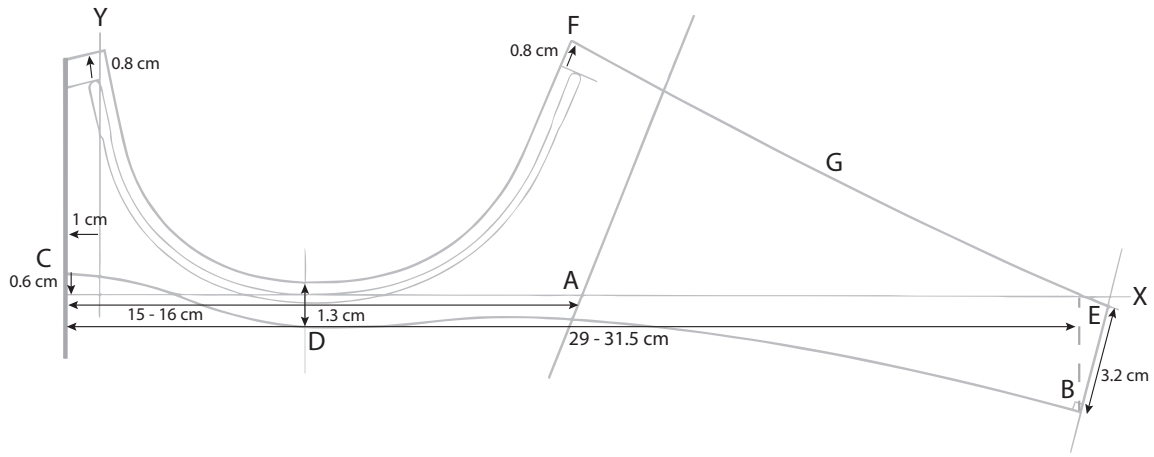


Figure 6.4: Example of a pattern draft for Australian size 12 gore, side panel and band (adapted from Shin [129], pg 53).

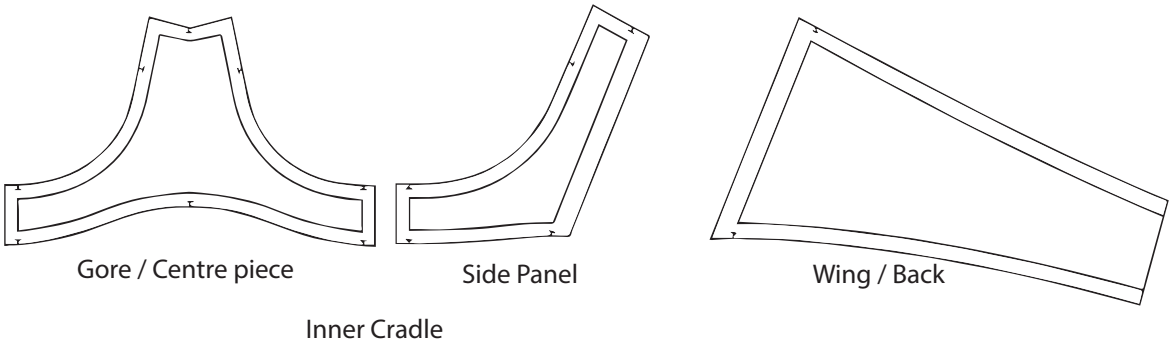


Figure 6.5: Example of pattern pieces created for the gore, side panel and band (adapted from Shin [129], pg 8).

The gore, side panel and band provide the main support for the breasts, and therefore must be constructed of strong, semi-rigid material. To achieve this, a 'powernet' of nylon blended with spandex was layered into this section of the bra as a stabiliser.

Band design recommendations indicated the band must be wide, must not cut in under the arms, and should have no seams [124] (see Chapter 5). To meet these recommendations, the basic pattern draft was refined into one piece to make the bra a seam-free as possible (see Figure 6.6).

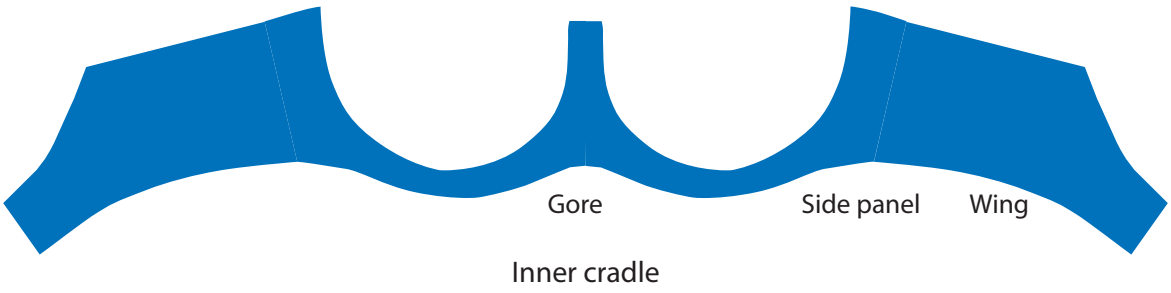


Figure 6.6: The final gore, side panel and band pattern pieces formed into a singular piece.

6.3.1.2 Patternmaking Step 2: Drafting the straps

Conventionally, the straps of a bra are pre-made lengths of elastic and semi-rigid sections, which are attached to the apex of the cup and approximately mid-point between the lateral edge of the cup, and the end of the band (see point G, in Figure 6.4). Strap adjustment is usually achieved through the interplay of ring, slide and hook fasteners (see Figure 6.2), which permit the lengthening and shortening of a looped section of the strap, thus modifying strap overall length. Exercise bra strap orientation is most commonly limited to straight vertical orientation (U-back) or a variation of cross-over straps (either Racer back or Cross back), as these orientations are deemed to provide the most support (see Figures 6.7 and 6.8).

Figure 6.7: Example of a 'U-back' strap orientation (adapted from Shin [129], pg 19).

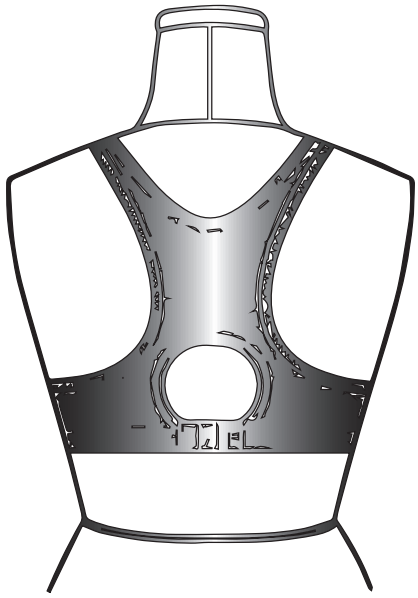


Figure 6.8: Example of a 'Racer-back' (cross-over) strap orientation (adapted from Shin [129], pg 19).

Bra straps that cut in, or slip off, have been identified as the most disliked feature of exercise bras worn by women in the general population [116]. Similarly, key complaints by women treated for breast cancer regarding bra straps is that a vertical strap orientation tends to slip off their shoulders during exercise [124] (see Chapter 5). Although the cross-over strap orientation alleviates this issue, research indicates that, compared to a vertical strap orientation, a cross-over strap exerts greater mean pressure and force on the wearer, particularly on muscles close to the neck, which may result in greater bra strap discomfort [130]. Conversely, the cross-over straps cannot slip off shoulders, and vertical straps tend to sit wider on shoulders, potentially reducing discomfort associated with compressing muscles close to the neck. To take advantage of the benefits of each strap orientation, a blend of the cross-over and vertical orientation was designed (see Figure 6.9). Specifically, the design incorporated curved, cross-over straps that could not slip off the shoulders, but were designed to sit wider on the shoulders. Furthermore, to provide extra support, the straps were designed to wrap over the shoulder and join back into the band at the top of the cup. To this end, conventional pre-made straps could not be utilised, and a flat pattern draft of the new strap design had to be drawn. Given there was no precedent for designing this form of strap, initially a flat pattern was free-hand sketched based only on the desired shape, width and insertion of the new strap design. Body measurements for the size 12C torso were used to approximate the required strap length. Finally, the wing pattern designed in Figure 6.6 had to be modified to incorporate the new strap design to connect seamlessly to the apex of the opposite bra cup (see Figure 6.10).

6.3.1.3 Patternmaking Step 3: Drafting the cups

A key recommendation of the cup design was that it should be seam-free and padded to hide the nipple (or lack of) and provide shape to each breast [124] (see Chapter 5). As a result, the cup had to be moulded as a single piece - a method which requires specialised

Figure 6.9: New strap orientation design.

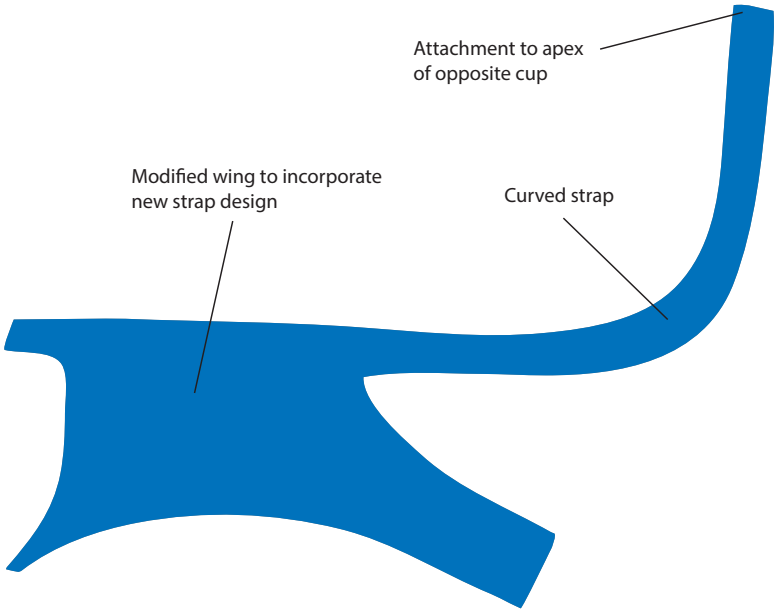


Figure 6.10: First pattern draft of new strap design and modified wing pattern draft.

equipment and expertise. Therefore, the manufacturing of the cup was out-sourced to BreezeComfort, Hong Kong, and no cup pattern was drafted. BreezeComfort was the manufacturer of choice as they were able to integrated a patented 'breathable' perforated bra cup pad into the prototype bra cup.

6.3.1.4 Patternmaking Step 4: Drafting of the first sample

The final gore, band and strap paper patterns were traced onto a stretch knit cotton fabric and cut out. A powernet layer was added to the gore to provide extra stability in this region of the bra. The flat pattern pieces were then sewn together for the first draft sample. This sample was then fitted to a 12C bust model (dress form) to check the bra fitted and supported the female bust, and followed the contours of a three-dimensional body without any distortion of the garment. Adjustments necessary to achieve this fit were made with garment pins. During this process it became clear that the initial strap pattern drawn did not translate to the desired length or shape of the strap design on a three-dimensional body. To rectify this problem, a conventional draping method was used, whereby a semi-rigid polyester blend fabric was draped across the back of the bust model, and the desired shape of the straps was sketched directly onto this fabric. The marked fabric was then used to re-draw the new strap pattern.

6.3.1.5 Patternmaking Step 5: Pattern amendment

Once fit was achieved on the model bust, the prototype bra with garment pin adjustments was laid flat and re-traced into a new pattern. This was the start of the prototyping loop, which involved another iteration of fitting the draft sample to the model bust and amending the pattern to achieve a bra pattern that was considered to fit the model bust well.

Figure 6.11: Final pattern pieces of the experimental bra.

6.3.1.6 Patternmaking Step 6: Final pattern drawing

Following the final model bust fit, the prototype was unpicked into flat panels of fabric. These fabric pieces were scanned (CanoScan 3000F, Canon Inc.) and the image imported into the CAD program. Using this program the pattern was traced into a vector shape from the imported image to make pattern correction, sizing, and reproducibility more efficient [122]. The final vector pattern is provided in Figure 6.11.

6.3.2 Prototype Manufacturing

The final pattern was sent to a bra manufacturer (BreezeComfort, Hong Kong) with the selected fabric and detailed manufacturing instructions. Outsourcing the bra production was done to achieve correct finish to the product, and to allow the incorporation of a seamless cup mould.

Once a prototype sample of the experimental bra was developed, it was fitted to a life model (Australian size 12C), and with the assistance of an experienced seamstress (over 20 years experience in garment fitting and adjustment), the prototype sample was reviewed and modified (movement of strap insertion on back). This adjustment was in part required due to the fabric and finish provided on the prototype bra being different to the fabric and finish of the first bra sample. The CAD vector pattern was updated to reflect these changes, and re-sent to the manufacturer (BreezeComfort,

Hong Kong) for a second prototype. Once received, the second prototype was again fitted to the life model, and based on professional bra fit criteria [85], fit was deemed satisfactory, and the sample bra prototype considered final.

The final bra sample (see Figure 6.12) had a wide elastic band under the original gore and band pattern for extra stability; padded cups with patented 'breathable' perforated pads (BreezeComfort, Hong Kong); and soft cotton inner pockets to contain a prosthesis within the cup. The bra also utilised sliding fasteners on the band and straps as these have been shown to provide better size adjustability, compared to conventional hook and eye attachments, in a previously produced bra prototype [25]. These fasteners were custom-made as no existing fasteners were located that were wide enough, but with a profile deemed low enough for placement on a bra strap. To further enhance adjustability, the sliding fasteners for the straps were placed on the front of the bra, so the wearer could easily adjust the straps while wearing the bra. Finally, the bra was designed to open at the front, in response to comments from women treated for breast cancer regarding limited shoulder mobility creating difficulties in fastening a bra behind their back [80, 124] (see Chapters 4 and 5).

6.4 Grading

Grading describes the process of modifying a pattern shape in order to develop (grade) the pattern into different sizes. Once the final sample was received from the manufacturer, it was fitted to a bust model, which could be adjusted to an industry standard Australian size 10C, 12C and 14C. These band sizes were deemed appropriate as they are the sizes most commonly found in the general population, and C cup was deemed appropriate as it was the most common cup size found in literature regarding exercise bra cup size for women treated for breast cancer [124] (see Chapter 5).

The fit of the bra to each bust model was assessed and the sample was adjusted

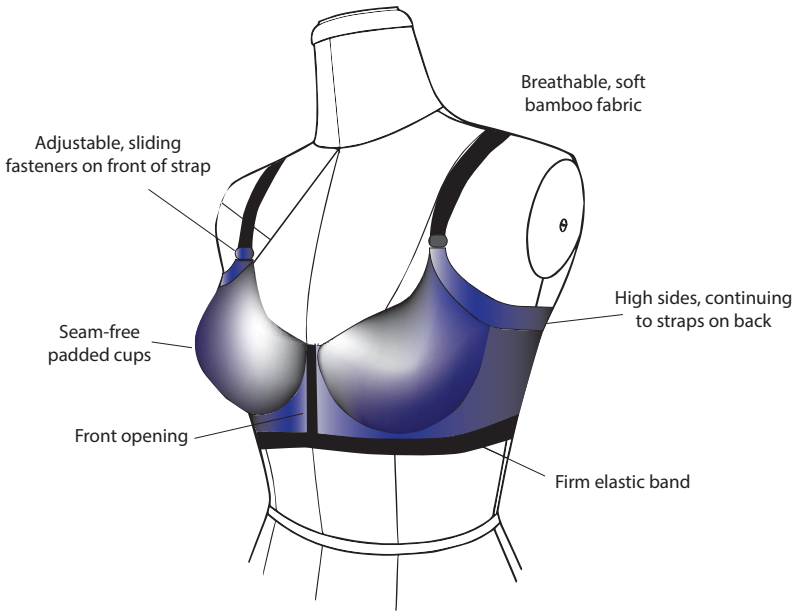


Figure 6.12: Final design impression of the experimental bra.

and the pattern amended for each size (10C and 14C). The new grading patterns were then scanned into the CAD program, and redrawn as vector patterns. The difference in size patterns were measured and then scaled up (sizes 16 and 18) by the mean grading factor noted between sizes 10, 12 and 14. This scaling was done by specifying the required amount of growth at grade points around the piece in the CAD program, and is considered standard industry practice in the form of 'grade rules' [122].

6.5 Production

The final graded patterns were sent to the manufacturer for production, and the final experimental bra was produced. Images of the final experimental bra are provided in Figures 6.13, 6.14, 6.15, and 6.16.

Figure 6.13: Front view of the experimental bra, showing moulded seamless cups, seamless gore into wings and sliding strap fasteners.

Figure 6.14: Front view of the experimental bra showing the front opening, and sliding band fasteners.

Figure 6.15: Profile view of the experimental bra with a breast prosthesis in the cup, and showing seamless wide wings leading up over the cup into the straps attachment at the apex.

Figure 6.16: Rear view of the experimental bra, showing new strap orientation, sliding back fasteners and internal pockets for a prosthesis.

6.6 Discussion

There is a well-established need for innovative bra designs that address several exercise bra discomfort issues among women treated for breast cancer. This study aimed to develop an exercise bra for these women, founded on key evidence-based recommendations identified in the literature, and outlined in this thesis. The development of an experimental bra was achieved through an iterative process, which was guided by industry practice, and educational resources. The final experimental bra met most of these key recommendations, including a wide, seam free band; moulded and padded seam free cups; a soft inner pocket for a prosthesis; wide straps that did not slip off the shoulders; sliding fasteners that were adjustable; and being constructed of a lightweight, breathable fabric. An assessment of how the experimental bra performs as an exercise bra needs to be undertaken to evaluate how well the bra meets the needs of women treated for breast cancer.

6.6.1 Study Strengths, Limitations and Recommendations

This study produced a novel exercise bra designed specifically to address bra discomfort issues for women treated for breast cancer. To our knowledge, this is the first study internationally to achieve this aim. Although the encapsulating, seamless moulded cups and novel new strap design met several of the recommendations identified by women treated for breast cancer, it is unlikely that any one bra design or style will be deemed suitable across a variety of breast shapes and sizes. Although several designs were considered in the initial concept development phase, only one design was selected as multiple designs were beyond the scope of the present study, and would not have been feasible. As such, the restriction of this sample production to only one design is considered a limitation of the present study.

A second limitation of this design process was that manufacturers will not produce

the new moulds as required for seamless cup production, for such small sample order sizes as required by this study. Therefore, the inability to acquire a larger range of bra cup sizes, limited the potential evaluation testing range to 10B, 10C, 12B, 12C, 14B and 14C. This limitation is compounded by the fact that although companies use the same size notations to classify bra sizes, this classification does not correlate to a 'true' breast size or volume, and each company will use its own size chart during production [122]. Therefore, while the out-sourcing of bra manufacturing was necessary, it may have introduced sizing error into the design and development process. To some extent this error was mitigated by the fact that the experimental bra design employed sliding fasteners on both the straps and the band, which permitted a large amount of sizing adjustment. Finally, breast cup size has been linked to experiencing excessive bra discomfort, whereby women with larger breasts are more likely to report difficulty finding a well-fitting and comfortable exercise bra compared to women with smaller breasts [125]. By limiting this design to smaller cup sizes, an evaluation of the effectiveness of the bra design with women more likely to report bra discomfort is not possible, and a further limitation to the study.

Part III

Evaluating the Solution of a Better Bra Design

Chapter 7

Evaluation of an Experimental Bra Design: Does a modified exercise bra reduce bra discomfort in women treated for breast cancer?

This chapter is an amended version of the manuscript: S.A. Gho, B.J. Munro, S.C. Jones, and J.R. Steele, "Evaluation of an Experimental Bra Design: Does a modified exercise bra reduce bra discomfort for breast cancer patients during exercise?" *Textile Research Journal*, To be submitted May 2014.

Abstract

Introduction: Bra discomfort has been identified as a barrier to exercise among women treated for breast cancer. A novel experimental exercise bra was designed, based on evidence-based recommendations, to alleviate this bra discomfort. This study aimed to evaluate how well this experimental bra met the exercise bra needs of women

treated for breast cancer. A secondary aim of this study was to evaluate the effect bra fit had on the performance of the bra.

Methods: Twenty female mastectomy patients (mean ± SD; age = 57 ± 9 years; range 40 - 68 years) ran on a treadmill under three bra conditions: their Own bra, the Experimental bra, and a commercially available Crop top. Bra comfort, perceived breast motion, wearability and aesthetics (Visual Analogue Scale); bra fit (professional bra fit criteria), and bra pressure distributions (Pliance, Novel, Germany) were assessed for each bra condition.

Results: Compared to the participants' Own bra, the Experimental bra displayed significantly better bra fit and perceived breast motion control, and performed equally well in the criteria of bra comfort, pressure distribution, wearability and aesthetics. Bra fit played an influential role in bra comfort, perceived breast motion and bra wearability, whereby women who wore a properly fitted bra performed better in each of these criteria than women whom the bra did not fit.

Conclusions: Overall, the Experimental bra design was deemed an improvement on the participants' Own bra, although further design iterations have been recommended to enhance its performance. It is unlikely, however, that any one bra design will fit all breast shapes and sizes, particularly following breast surgery. Achieving correct bra fit through education and improving bra fit knowledge is likely an imperative first step towards improving bra comfort.

7.1 Introduction

Women treated for breast cancer experience numerous barriers to exercise, and these barriers can substantially impact on the ability of these women to maintain sufficiently

healthy exercise levels [123] (see Chapter 3). Bra discomfort is one such significant barrier that is associated with lower exercise levels among women treated for breast cancer [80] (see Chapter 4). Breast cancer treatment side-effects can compound this bra discomfort, and therefore developing exercise bra designs that account for these side-effects is imperative [80] (see Chapters 4 and 5). Evidence-based recommendations for exercise bra designs for women treated for breast cancer have previously been established [124] (see Chapter 5), and based on these recommendations, an experimental exercise bra has been developed (see Chapter 6). An evaluation of whether this novel exercise bra design addressed the needs of women treated for breast cancer, as defined in the literature, is now warranted [124] (see Chapter 5).

Design evaluation, particularly for healthcare or assistive technology, is required to provide a designer with a validation of design decisions [131]. Central to this design evaluation process is the definition of the key evaluation variables to be assessed. Exercise bra design evaluation has traditionally focused on how effective an exercise bra is in limiting vertical breast displacement, and as a secondary notion, how well the bra reduces exercise induced breast discomfort [106, 108–110, 115, 121]. For the purpose of this study, however, bra discomfort was deemed the most appropriate key evaluation variable, as the experimental bra was designed primarily to reduce the bra discomfort reported by these women.

Although reducing excessive breast motion has been identified as a mechanism to reduce exercise induced *breast* discomfort, no study to date has linked excessive *breast* motion with *bra* discomfort. Interestingly, during an analysis of three bras that were designed to provide high levels of breast support, McGhee and Steele [110] found no difference in objectively measured vertical breast motion across all three conditions, but significant condition-dependent differences in breast comfort, bra comfort and perceived breast motion. Therefore, for the purpose of evaluating bra design, these

criteria of bra comfort and perceived breast motion may be more meaningful to the wearer than objectively measured breast motion. Furthermore, among women treated for breast cancer, these criteria appear in two of the top three most important factors sought for in an exercise bra - namely, how comfortable it is (bra comfort) and the amount of support it provides (perceived breast motion; see Chapter 5; Figure 5.3). The third top factor deemed most important by these women is bra fit [124]. Other important factors identified in the literature were that the bra must be easy to put on and take off, in order to account for the limited shoulder range of motion experienced by many women treated for breast cancer; and that the bra looks good on the wearer [124] (see Chapter 5).

The top four causes of bra discomfort among women treated for breast cancer are the bra band and bra straps being either too tight, or too loose [124]. This sensation of 'tightness' may be attributed to higher pressures produced by the bra band on the torso, or the bra straps on the shoulders, whereas being too loose may cause the bra band to ride up, or shoulder straps to slip off [85]. Furthermore, women who have undergone breast removal as part of their treatment for breast cancer may experience this 'tightness' differently on their affected side, when compared to their unaffected side. As this has implications for not only bra design, but bra design evaluation, the pressure of the bra at the band and strap interface with the skin on both the affected and unaffected sides should also be assessed. Only one study was located that assessed the relationship between bra strap pressure and bra strap comfort [130]. This study concluded that although one of two bra strap designs imparted significantly more mean pressure to the wearers' torso, this difference was not reflected in comfort measures. Nevertheless, whether this relationship between bra pressure and comfort holds true for women treated for breast cancer, particularly due to treatment-related skin sensitivity, is yet to be determined.

When developing a better bra design for women treated for breast cancer, the need to address issues unique to this cohort as identified in the literature, assists in forming specific evaluation criteria that should be used when assessing the overall success of the bra. To this end, although bra comfort is the key evaluation variable, assessing how the bra is perceived to limit breast motion, achieves breast comfort, ensures even pressure distributions, is easy to put on and take off (wearability), and looks good on the wearer (aesthetics), all contribute to the overall evaluation of a successful exercise bra design for women treated for breast cancer. Importantly, however, the effect bra fit has on each of these criteria must also be assessed, as bra fit is deemed highly important to these women [124], and is likely to significantly impact each of the afore-mentioned criteria.

The primary aim of this study was to evaluate an experimental exercise bra designed for women treated for breast cancer using specific evaluation criteria of bra comfort, perceived breast motion, pressure distribution, wearability and aesthetics. A secondary aim of this study was to determine the effect bra fit had on each of the above assessment criteria. It was hypothesised that a specifically designed experimental bra would be more comfortable, have less perceived breast motion, have lower pressures, be easier to don and remove, and look better on the wearer, compared to the participant's own current exercise bra, or a commercially available exercise bra. Furthermore, it was hypothesised that bra fit would have a significant effect on each of the assessment criteria such that women who wear a properly fitted bra would display further improvements in each criteria than women who the bra does not fit.

7.2 Participants and Methods

7.2.1 Participants

Twenty female mastectomy patients (mean ± SD; age = 57 ± 9 years; range 40 - 68 years) who were not currently undergoing chemotherapy or radiotherapy for their breast cancer, who had undergone surgery on one breast only, and who wore either a prosthesis or had undergone a breast reconstruction were recruited for the current study. The participants characteristics are provided in Table 7.1.

Participants were recruited via promotion of the study through the Breast Cancer Network Australia Survey and Research group emailing list, and women who met the study criteria and were able to travel to the laboratory to participate were encouraged to contact the research team. All recruiting and testing procedures were approved by the University Human Research and Ethics Committee (HE08/326).

7.2.2 Bra Conditions

Three bra conditions were evaluated: (i) the participant's Own bra; (ii) the Experimental bra, as described in detail in Chapter 6; and (iii) a commercially available compression-style Crop top (Boobytrap, UK) constructed of 68% nylon and 32% spandex, and designed to accommodate a breast prosthesis (see Figure 7.1). Although variations existed in the Own bra condition, this was deemed the most appropriate control condition as it best tests the hypothesis that a specifically designed exercise bra will improve the current bra discomfort experienced by women treated for breast cancer. At the time of testing, 10 participants (50%) wore an everyday mastectomy bra, 5 participants (25%) wore a standard everyday bra, and 5 participants (25%) wore a bra designed for exercise, two of which were exercise crop tops. Ten (50%) of the Own bra conditions were >1 year old, with the other 50% being >3 years old.

Table 7.1: Characteristics of the 20 unilateral mastectomy patients who participated in the study, and their self-selected treadmill running speeds.

ID	Age (years)	Height (m)	Body mass (kg)	Years post treatment	Affected side	Own bra size	Running speed ($km \cdot h^{-1}$)
P01	67	1.66	70.0	6	Right	14C	8
P02	60	1.74	69.2	N/A†	Left	12C	8
P03	40	1.62	57.4	3	Left	12C	8
P04	68	1.60	55.7	20	Right	12B/C	8
P05	64	1.62	60.9	13	Left	12B/C	7.5
P06	61	1.62	74.2	3	Right	XL⋆	5.3
P07	42	1.79	71.0	1	Right	10D	8
P08	52	1.69	68.0	7	Right	12B	6.5
P09	68	1.61	81.5	8	Left	16E	6
P10	53	1.59	66.5	3	Left	12C	6
P11	68	1.56	71.6	37	Right	14D	7
P12	59	1.66	75.8	1	Right	14E	7
P13	46	1.60	62.1	4	Left	12C	8
P14	60	1.58	71.8	15	Right	16C	5.5
P15	59	1.66	70.4	5	Right	14C	8
P16	50	1.55	83.3	5	Left	18D	7.5
P17	67	1.62	73.6	3	Left	XL⋆	7
P18	57	1.64	84.6	7	Left	18D	7
P19	50	1.63	66.0	1	Left	12C	8
P20	N/A†	1.70	65.6	1	Left	Medium⋆	9
Mean	59	1.64	70.0	7.5			7.3
SD	9	0.06	8.0	9.0			1.0

⋆ These women wore a compression style crop top as their Own exercise bra .

† Not Available. These women did not provide this information .

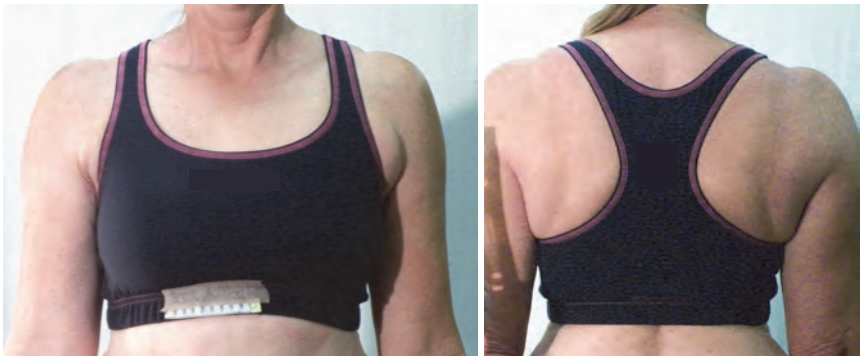


Figure 7.1: Front and back view of the Crop top condition.

7.2.3 Experimental Protocol

7.2.3.1 Anthropometrics and treadmill familarisation

After providing written informed consent and completing a physical activity readiness questionnaire, each participant's anthropometric (height and weight) data were collected. Participants then commenced a treadmill (SportsArt T650ME, Tainan City, Taiwan) familiarisation protocol during which each participant self-selected a treadmill pace to replicate the pace they would use when running for fitness overland, and which they could maintain continuously for at least 3 minutes. Due to the participants' varying fitness levels, and different modes of regular activity, there was wide range of self-selected running speeds (mean ± SD; = 7.3 ± 1.0 km·h^{-1}; range 5.5 - 9.0 km·h^{-1}; see Table 7.1).

7.2.3.2 Bra fit, discomfort, wearability and aesthetics

Following treadmill familiarisation, each participant donned one of the three randomly assigned bra conditions. Using a visual analogue scale (VAS, rated 0-10), participants were asked to rate how much they liked the look of the bra with '0' rated as extremely liking it, and '10' rated as extremely disliking it. The fit of each bra condition was then assessed using professional bra fit criteria [85], in which five components of the bra - band, straps, cups, underwire shape, and front band - were deemed to pass or fail a bra fit test criterion. If one or more of these components were deemed a 'fail' grade, and hooks or straps could not be adjusted to allow correct fit, an overall 'fail' grade was awarded in the fit of that bra condition [84, 85]. Women who were able to achieve bra fit in at least their affected or unaffected breast in the Experimental bra condition were deemed to be in the 'Fitted' group (n = 14) while women who failed the fit criteria in both breasts were deemed to be in the 'Not Fitted' group (n = 6).

Each participant then ran on the treadmill at their self-selected pace for 3 minutes

in the assigned bra condition. Immediately after running, participants were asked to rate their breast and bra discomfort, as well as perceived breast motion, and any associated breast motion discomfort (VAS, rated 0-10) with no discomfort or movement rated as '0' and worst possible discomfort or extreme movement rated as '10' [110]. Using the VAS, participants were also asked to rate how easy it was to put the bra on, and to take it off, with '0' rated as no difficulty, and '10' rated as extremely difficult. Participants then repeated the experimental protocol for the remaining two bra conditions.

7.2.3.3 Pressure data

To quantify the external pressure applied to the participants' chest region by the bra (band pressure), two custom-designed pliance®-x sensor mats (Product ID: S2075, $\text{novel}_{\text{gmbh}}$, Munich, Germany), that consisted of sixty-four 10 mm^2 sensors (0.3-20 $\text{N}\cdot\text{cm}^{-2}$) in a 4 x 16 matrix, were attached directly to each participant's torso using micropore tape. Placement of the pliance®-x sensor mats began at the lateral posterior edge of the breast, and wrapped around the torso towards the back of the participant on both sides, directly under the bra band, to obtain left and right band pressure (see Figure 7.2). To quantify the pressure applied by the bra strap to each participant's shoulder, two pliance®-x low pressure single sensors (Product ID: S2011, $\text{novel}_{\text{gmbh}}$, Munich, Germany), consisting of one 10 mm diameter sensor each (0.05-6 $\text{N}\cdot\text{cm}^{-2}$), were attached directly to each participants' skin using micropore tape where the bra straps crossed over the apex of the shoulder.

Following the bra fit, discomfort, wearability and aesthetics assessment of all three bra conditions, the pliance®-x sensors described above were attached directly to the participants' skin and 'zeroed', before each randomly assigned bra condition was placed on the participant for a second time. Participants then repeated the running trials of 3 minutes duration in each bra condition, during which pressure data were collected

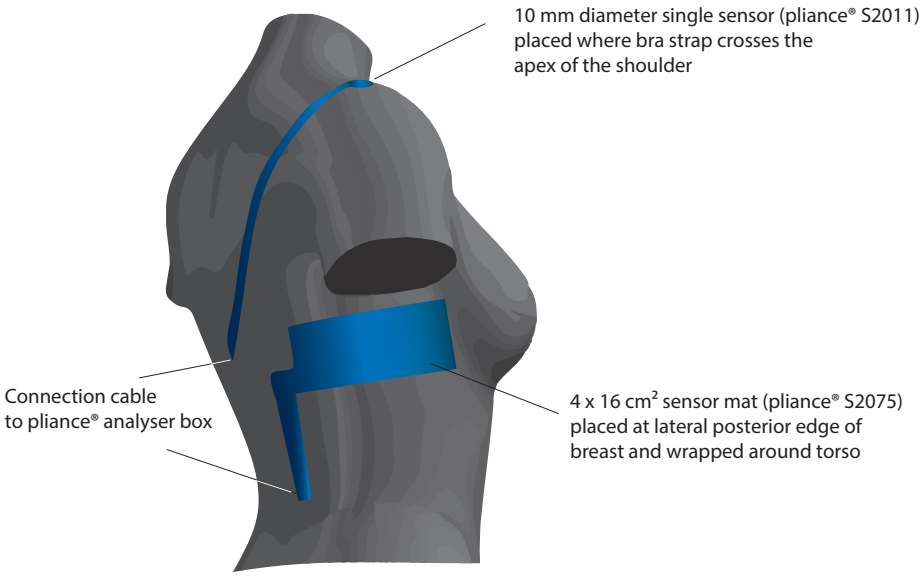


Figure 7.2: Placement of pliance®-x sensor mats and single sensor on participants' torso to measure bra band and strap pressures (image shows right side only).

at 60 Hz using a pliance®-x adapterbox (novel$_{gmbh}$, Munich, Germany) attached to a pliance®-x analyser (novel$_{gmbh}$, Munich, Germany) that was interfaced with a data computer by a fiber optic/USB cable. Pressure data were recorded for six 15 sec intervals once the participant reached a steady running state, using the pliance®-x Recorder 20.1.35 software (novel$_{gmbh}$, Munich, Germany). Once collected, .ascii files of the pressure data were exported to MATLAB® (Mathworks, Natick, U.S.A) and mean pressure (average pressure of all loaded sensors during the time of the trial) was calculated. This protocol was conducted to ensure that the subjective comfort data collected were not affected by placement of the pressure sensors between the bra and skin. Figure 7.3 provides an overview of the experimental protocol.

7.2.4 Statistical Analysis

Bra discomfort, perceived breast motion, bra band pressure, bra strap pressure, wearability scores, and aesthetic scores were each analysed using a one-way repeated-

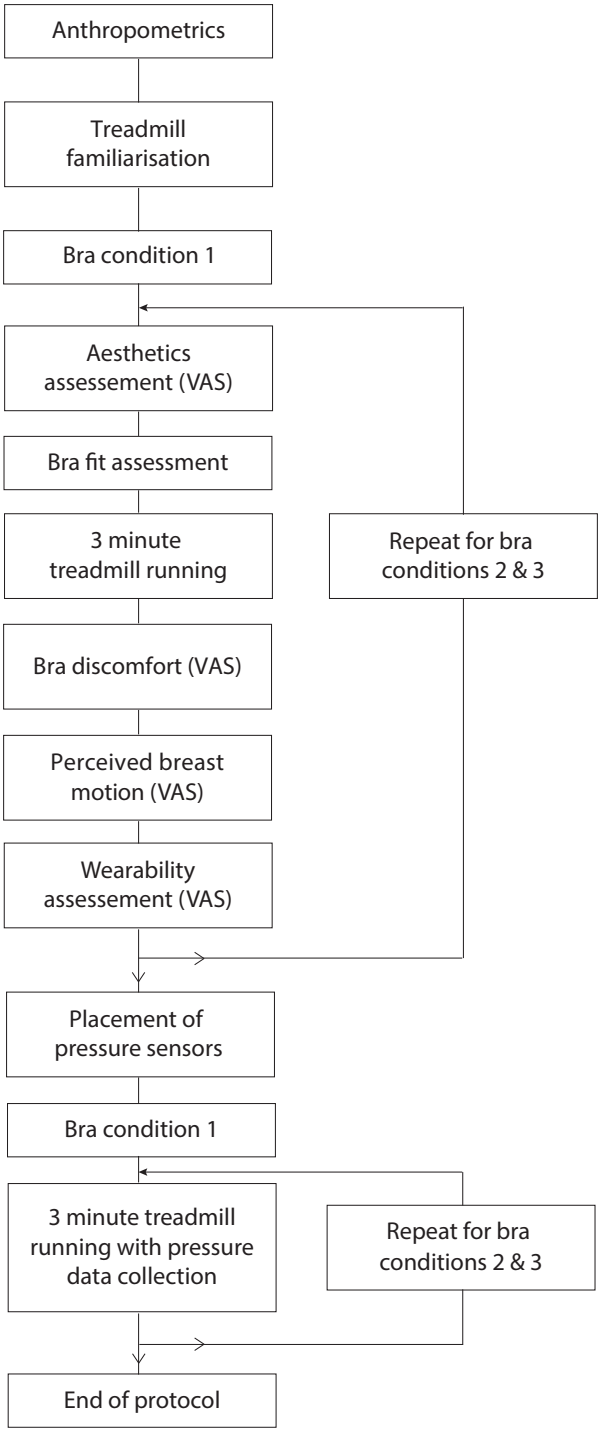


Figure 7.3: Laboratory-based experimental protocol.

measures analysis of variance (ANOVA) design with bra conditions (Own, Experimental and Crop Top) as the independent variable. Where a significant difference was found, paired samples t-tests were conducted to identify where the difference lay, with Holm's sequential Bonferroni procedure used to control for familywise error rates across the three tests at the $\alpha = 0.05$ level. Pressure data for three participants were lost due to technical equipment errors, and data for a further two participants could not be collected in the Crop top condition, as two women could not physically put this bra on. As missing data were treated with listwise deletion, the final sample size for the bra band and strap pressure ANOVA were $n = 15$. Independent-samples t-tests were conducted to evaluate the hypothesis that each of the above-mentioned evaluation criteria would differ in the Fitted group compared to the Not Fitted group. The α-level for all tests were set at 0.05, and tests were conducted using SPSS 17.0 for Windows (IBM® Inc, Armonk, U.S.A).

7.2.5 Evaluation Table

A final evaluation table was designed to consider how well each bra condition performed against each criteria of bra comfort, perceived breast motion, pressure distribution, wearability and aesthetics. The evaluation table applied a weighted value to each of these criterion based on the value ranking identified in earlier sections of this thesis by women treated for breast cancer (see Chapter 5, Figure 5.3). Based on the results of the current paper, each bra condition was ranked on how it performed under each criterion, and this rank was multiplied by the weight of each criterion to provide a relative subscore for that bra condition by that criterion. A ranking value of '3' was provided to a bra that performed significantly better than both the other bras in any given criteria. A ranking value of '2' was provided if there was no significant difference between conditions, and a ranking value of '1' was provided if a bra performed significantly

poorer than both of the other two conditions in any given criteria. Wearability and aesthetics were deemed of equal importance, and thereby provided with the same weighting. All criteria sub-scores were then summed to provide an overall score for the bra. This approach is deemed optimal as it tests the study hypothesis by providing an overall *relative* score for each bra condition.

7.3 Results

7.3.1 Summary of Results

A schematic representation of the overall results of the study, with significant interactions indicated both between bra conditions and between bra fit groups, is provided in Figure 7.4. These interactions are explained in further detail below.

7.3.2 Bra Fit

Figure 7.5 displays the results of the bra fit assessment of the affected and unaffected breast of each participant in each bra condition. Achieving bra fit on both the affected and unaffected breast was a challenge in all three bra conditions. The Own bra condition had the worst fit, with only one participant fitted correctly in this condition on her affected breast, and consequently overall. The Experimental bra achieved reasonable fit for the affected breast, and good fit for the unaffected breast, whereas the Crop top achieved poor fit for the affected breast and good fit for the unaffected breast. When considering overall fit, whereby both the affected and unaffected breast fitted the bra, only seven participants (35%) achieved this level of fit in the Experimental bra, and six participants (30%) in the Crop top.

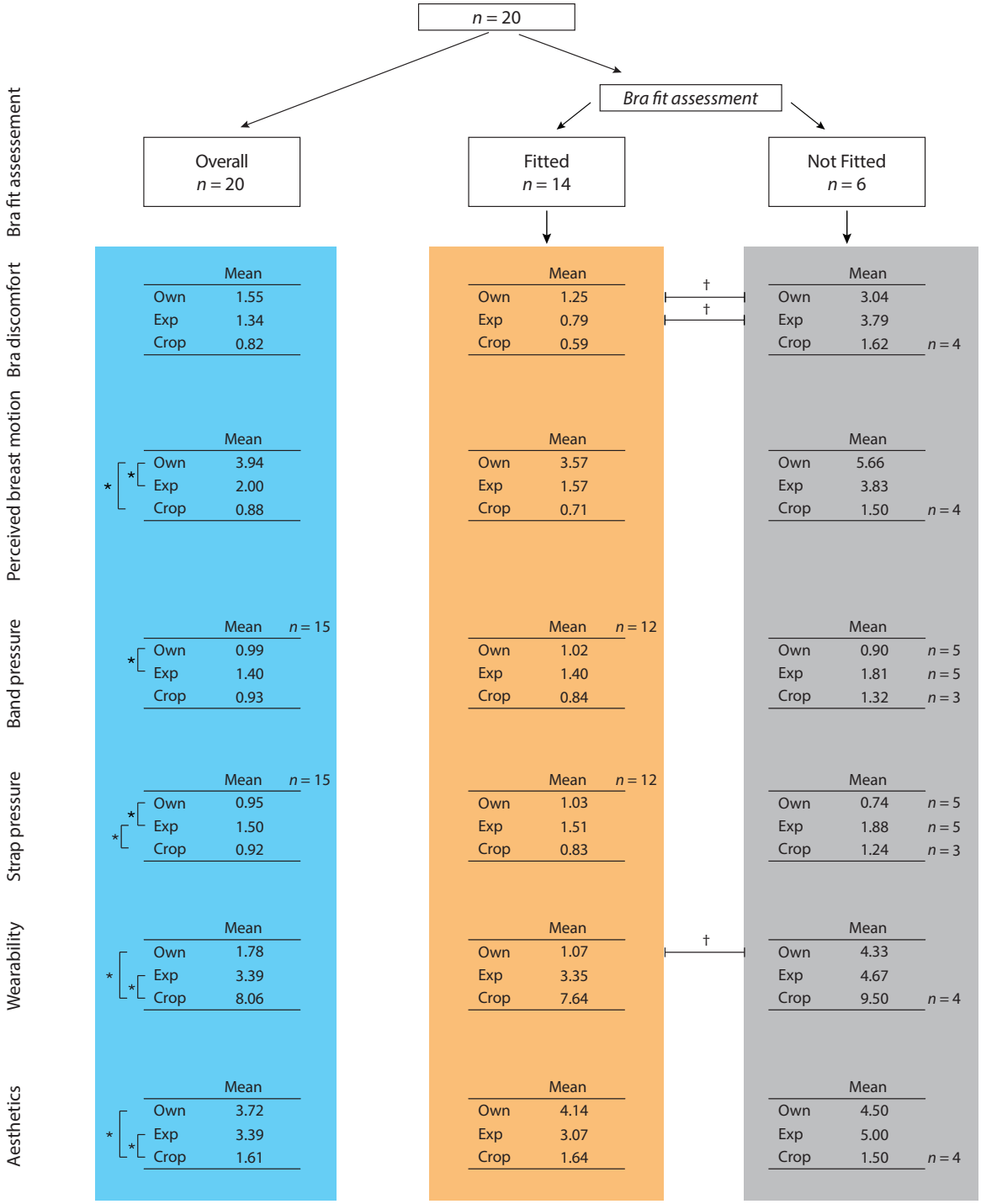


Figure 7.4: Schematic representation of results indicating significant effects of bra conditions, in the Overall sample ($\star$); and significant effects of bra fit, between the Fitted and Not Fitted sub-samples in each bra condition (†).

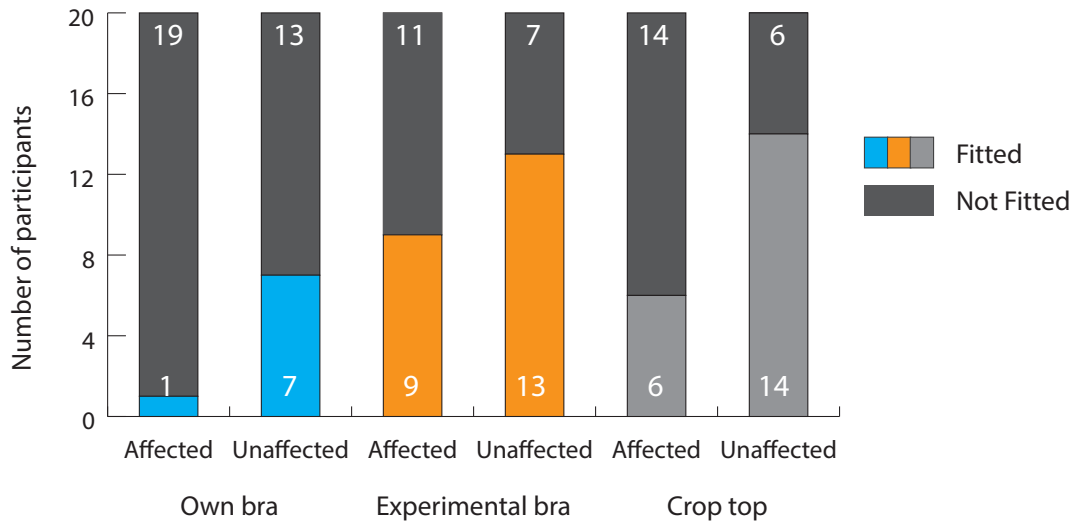


Figure 7.5: Bra fit assessment of the affected and unaffected breast in each bra condition.

7.3.3 Effect of Bra Condition

7.3.3.1 Bra discomfort

Bra discomfort scores varied extensively across all three bra conditions (see Figure 7.6). Therefore, there was no significant difference amongst the mean bra discomfort scores derived for the Own bra (1.55 ± 1.78), the Experimental bra (1.34 ± 1.84), or the Crop top (0.82 ± 1.02) in the total sample (n = 20).

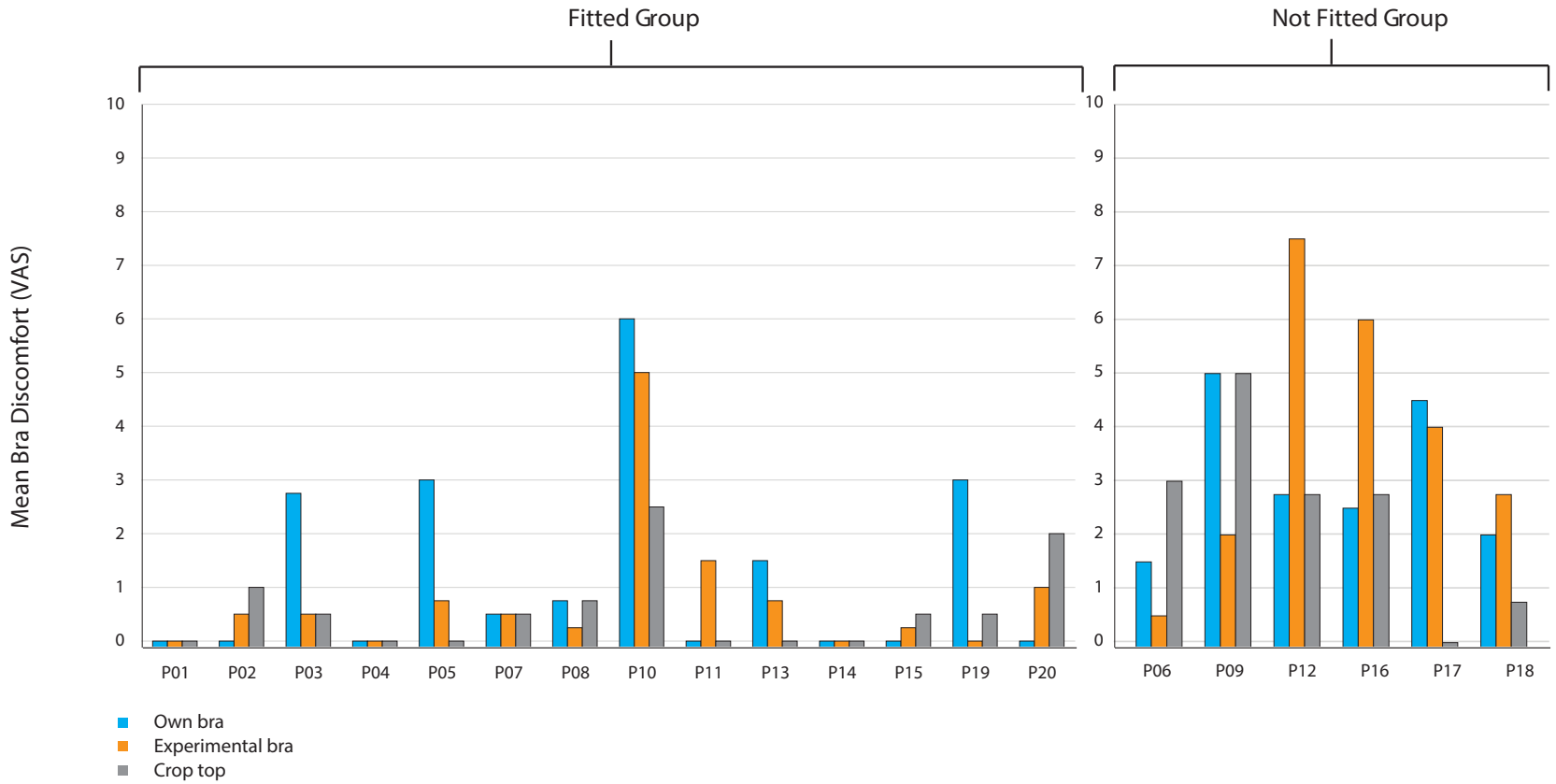


Figure 7.6: Overall mean bra discomfort (VAS) of the Own bra, Experimental bra and Crop top bra conditions, split into the Fitted group and Not Fitted Group. VAS of '0' = no discomfort, and '10' = worst possible discomfort.

7.3.3.2 Perceived breast motion

Figure 7.7 displays the non-ranked distributions of perceived breast motion for the Own bra, Experimental bra, and Crop top conditions in the whole sample. There was a significant main effect of bra condition on perceived breast motion (Wilks' $\Lambda = 0.38$, $F(2, 16) = 12.99$, $p < 0.001$, multivariate $\eta^2 = 0.62$). Paired samples t-tests indicated that the mean perceived breast motion score in the Own bra bra condition (3.94 ± 2.48) was significantly greater than the mean perceived breast motion score in the Experimental bra (2.00 ± 2.22; $p = 0.004$), and the Crop top (0.88 ± 1.23; $p < 0.001$) conditions.

When the perceived breast motion of a participant's affected breast and unaffected breast are considered separately, participants consistently reported lower perceived breast motion in the Experimental bra and Crop top conditions compared to the Own bra condition (see Figure 7.8). Women wearing the Experimental bra who reported their breasts did move a lot (VAS ≥ 5), indicated they experienced this motion equally on the affected and unaffected breasts (VAS score: affected breast, unaffected breast = 8, 8 and 6, 6). Conversely, women wearing the Own bra condition and reporting higher levels of breast motion (VAS ≥ 5), indicated experiencing this motion unequally on either side (VAS score: affected breast, unaffected breast = 0, 9; 2, 6; 5, 6 and 6, 7). For these four women, the Own bra condition was unable to properly control their unaffected breast.

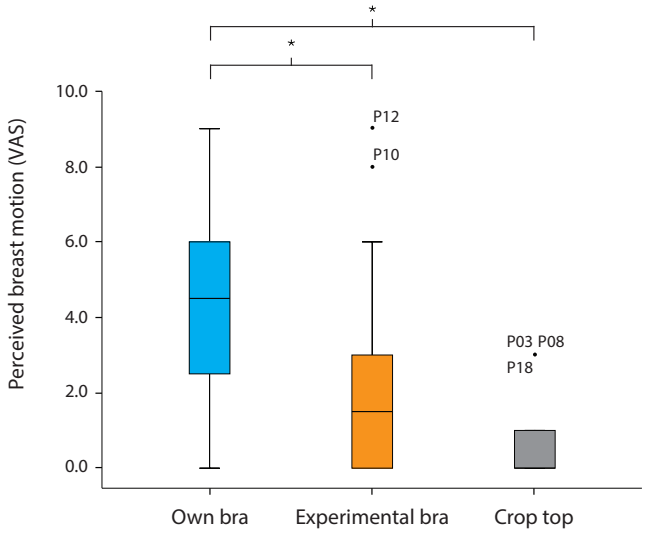


Figure 7.7: Distributions of perceived breast motion in the Own bra, Experimental bra, and Crop top conditions for the entire sample ($n = 18$; $n = 2$ missing cases). The y-axis displays the maximum perceived breast motion of either the affected and unaffected breasts; where '0' = no movement and '10' = extreme movement. The boxplot displays the minimum value (bottom of inverted 'T'), first quartile (bottom of box), median (line in box), third quartile (top of box), and maximum value (top of 'T'), for each bra condition. No 'T' indicates the minimum and maximum values were also the first and third quartiles. Outliers, and their values, are indicated with dots and participant numbers. Asterisk (*) denotes significance (paired samples t-tests; $p < 0.05$).

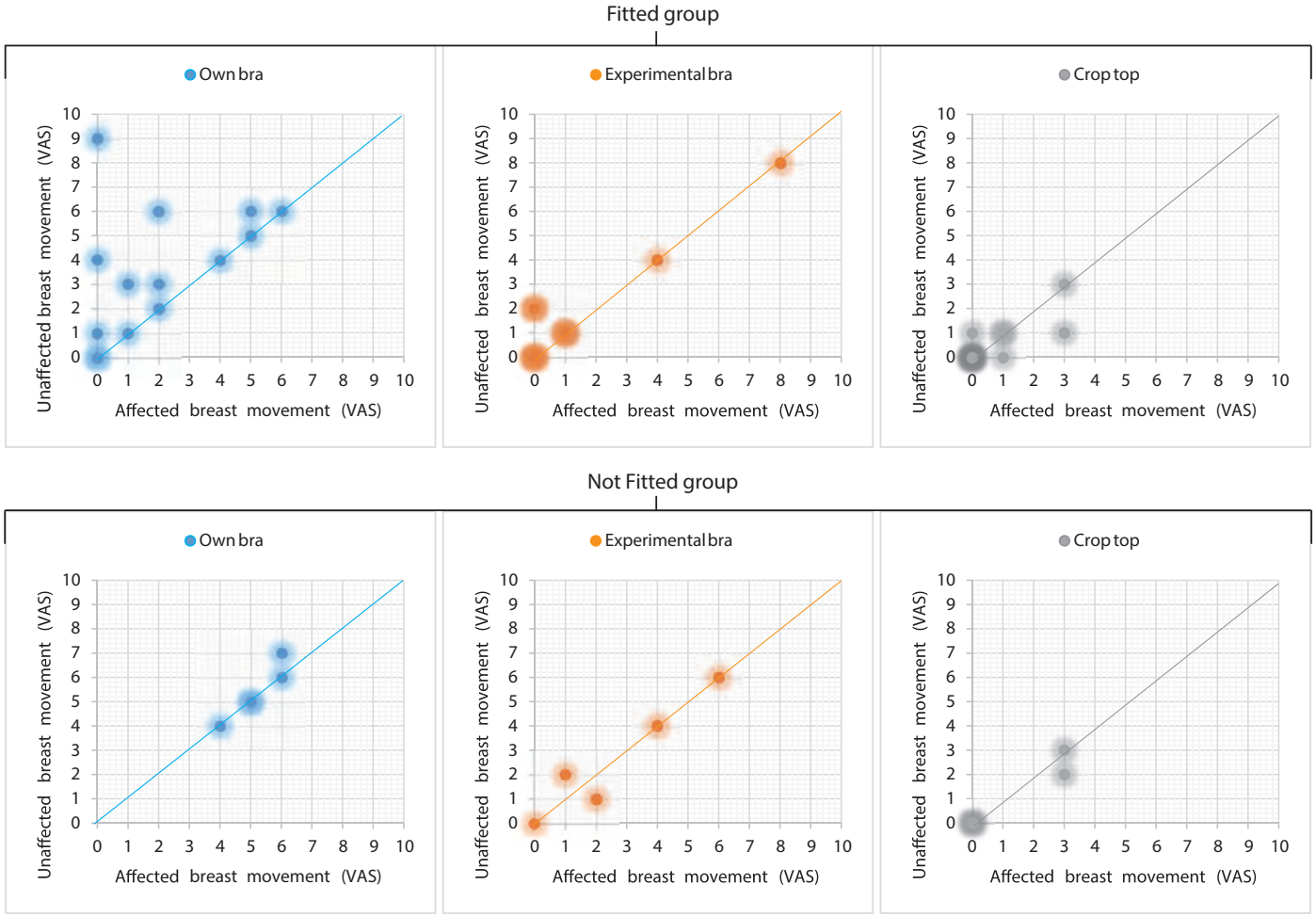


Figure 7.8: Perceived breast motion (VAS) of the affected and unaffected breast of each participant in each bra condition; where '0' = no movement and '10' = extreme movement. Each dot represents a participant, and the intensity of the dot increases as more participants report that level of movement. For symmetrical movement, the dot should fall on the diagonal line (equal perceived movement in the affected and unaffected breast).

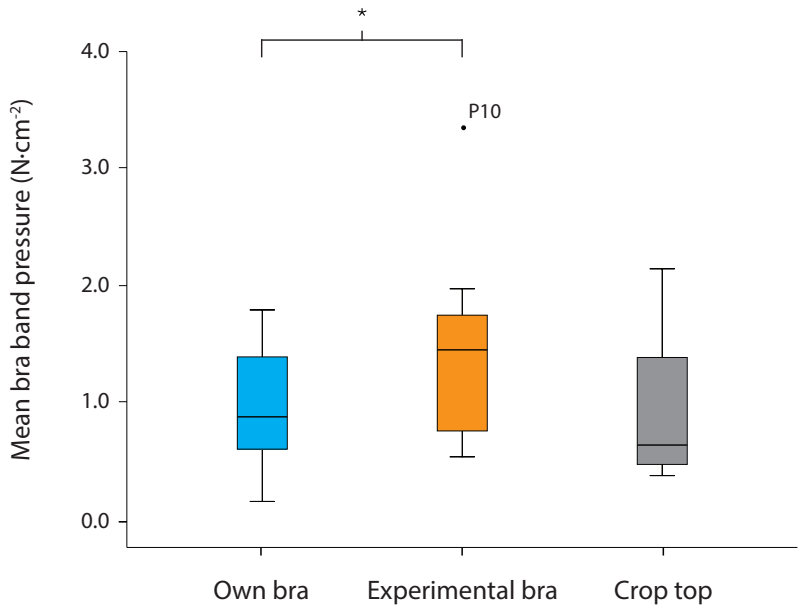


Figure 7.9: Distributions of the bra band pressures between the three bra conditions. Asterisk (*) denotes significance (paired samples t-tests; $p < 0.05$). See Figure 7.7 for boxplot explanation.

7.3.3.3 Bra band pressure

The distributions of mean bra band pressures across bra conditions is displayed in Figure 7.9. In assessing bra band pressure between bra conditions, there was a significant main effect of bra condition on mean bra band pressure (Wilks' $\Lambda = 0.51$, $F(2, 13) = 6.19$, $p = 0.013$, multivariate $\eta^2 = 0.48$). Paired samples t-tests, indicated that the only significant difference was between the Own bra and the Experimental bra ($p = 0.002$), whereby the Experimental bra had a significantly higher mean band pressure (1.40 ± 0.73 N·cm^{-2}) compared to the Own bra (0.99 ± 0.52 N·cm^{-2}).

7.3.3.4 Bra strap pressure

The distributions of mean bra strap pressures across bra conditions is displayed in Figure 7.10. Similar to bra band pressure, there was a significant main effect of bra condition on mean bra strap pressure (Wilks' $\Lambda = 0.50$, $F(2, 13) = 6.43$, $p = 0.011$, multivariate $\eta^2 = 0.50$). Paired samples t-tests, indicated that significant differences

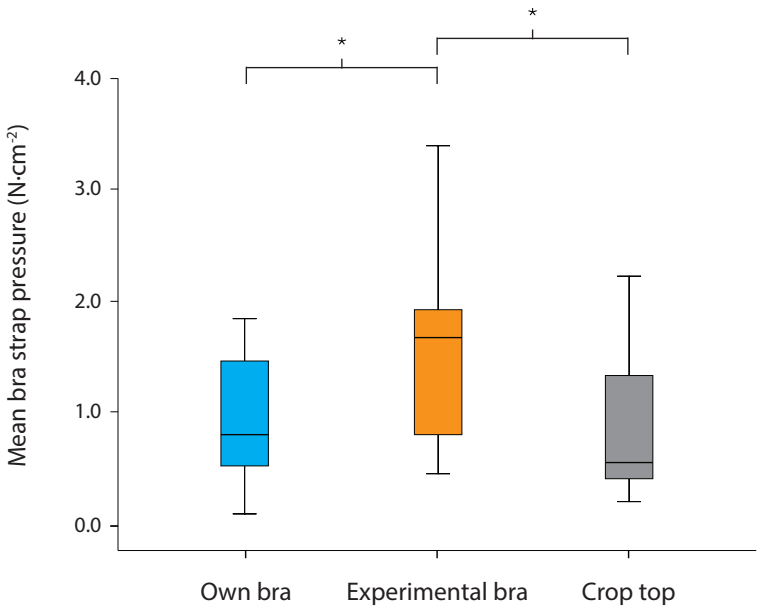


Figure 7.10: Distributions of the bra strap pressures between the three bra conditions. Asterisk (*) denotes significance (paired samples t-tests; $p < 0.05$). See Figure 7.7 for boxplot explanation.

lay between the Own bra and the Experimental bra ($p = 0.001$), and the Crop top and Experimental bra ($p = 0.030$), whereby the Experimental bra had a significantly higher mean strap pressure (1.50 ± 0.79 N·cm^{-2}) compared to both the Own bra (0.95 ± 0.51 N·cm^{-2}), and the Crop top (0.92 ± 0.66 N·cm^{-2}) bra.

7.3.3.5 Wearability score

There was a significant main effect of bra condition on how easily a participant could put a bra on, and take it off (Wilks' $\Lambda = 0.15$, $F(2, 16) = 44.50$, $p < 0.001$, multivariate $\eta^2 = 0.85$). Paired samples t-tests, indicated that the Crop top (mean $= 8.06 \pm 1.95$) was significantly more difficult for participants to put on and take off compared to the Own bra (mean $= 1.78 \pm 2.32$; $p < 0.001$) and compared to the Experimental bra (mean $= 3.39 \pm 3.12$; $p < 0.001$).

7.3.3.6 Aesthetics score

There was a significant main effect of bra condition on how much participants liked the 'look' of the bra, and how they felt they looked in it (Wilks' $\Lambda = 0.61$, $F(2, 16) = 5.07$, $p = 0.02$, multivariate $\eta^2 = 0.39$). Paired samples t-tests, indicated that participants preferred how they looked in the Crop top (mean = 1.61 ± 2.03), compared to their Own bra (mean = 3.72 ± 3.41; $p = 0.007$) and compared to the Experimental bra (mean = 3.39 ± 2.75; $p = 0.019$). However, there was no improvement in aesthetics between the Experimental bra and their Own bra.

7.3.4 Effect of Bra Fit

7.3.4.1 Bra discomfort

Independent-samples t-tests indicated a significant effect of bra fit on bra discomfort in the Own bra and Experimental bra conditions. Compared to the Not Fitted group, the Fitted group reported significantly less mean bra discomfort in the Own bra condition (Fitted = 1.25 ± 1.81; Not Fitted = 3.04 ± 1.40; $p = 0.04$), and in the Experimental bra (Fitted = 0.79 ± 1.29; Not Fitted = 3.79 ± 2.60; $p = 0.04$). There was no significant between-group difference in mean bra discomfort for the Crop top (Fitted = 0.59 ± 0.78; Not Fitted = 1.62 ± 1.48). Figure 7.11 shows the distributions of the bra discomfort scores for the Fitted and Not Fitted Groups in each of the three bra conditions.

7.3.4.2 Perceived breast motion

When examining perceived breast motion, there was no significant effect of bra fit on mean perceived breast motion scores in the Own bra (Fitted = 3.57 ± 2.65; Not Fitted = 5.66 ± 1.21), the Experimental bra (Fitted = 1.57 ± 2.17; Not Fitted = 3.83 ± 3.25) or the Crop top (Fitted = 0.71 ± 1.07; Not Fitted = 1.50 ± 1.73).

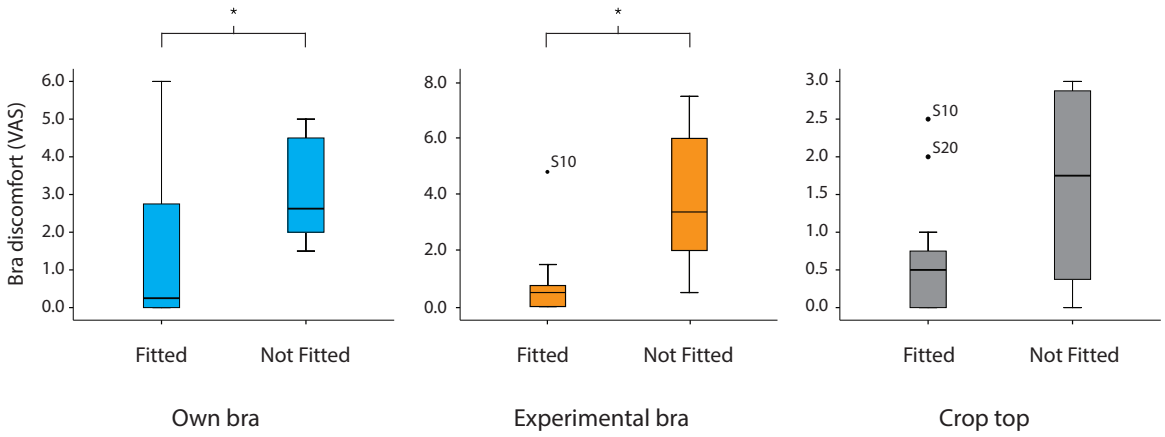


Figure 7.11: Distributions of the bra comfort scores for the Fitted and Not Fitted groups for each bra condition. Asterisk (*) denotes significance (paired samples t-tests; $p < 0.05$). See Figure 7.7 for boxplot explanation.

7.3.4.3 Bra band pressure

There was no significant difference in the mean bra band pressure between the Fitted and Not Fitted groups for the Own bra (Fitted = 1.02 ± 0.50 N·cm^{-2}; Not Fitted = 0.90 ± 0.61 N·cm^{-2}), the Experimental bra (Fitted = 1.40 ± 0.76 N·cm^{-2}; Not Fitted = 1.81 ± 0.97 N·cm^{-2}), or the Crop top (Fitted = 0.84 ± 0.52 N·cm^{-2}; Not Fitted = 1.32 ± 0.83 N·cm^{-2}), suggesting mean bra band pressures were not affected by bra fit for any given bra condition. However, this result must be interpreted with caution as data for three participants were lost due to technical equipment errors. A further two participants could not put on the Crop top, and therefore no Crop top pressure data were collected for these women. This resulted in data missing for three women in the Own bra and Experimental bra conditions (Fitted $n = 12$, Not Fitted $n = 5$), and data missing for five women in the Crop top condition (Fitted $n = 12$, Not Fitted $n = 3$), creating a small Not Fitted sample size in the Crop top condition, that may violate the assumptions underlying t-tests.

7.3.4.4 Bra strap pressure

There was also no significant difference in mean bra strap pressures between the Fitted or Not Fitted groups for the Own bra (Fitted = 1.03 ± 0.50 N·cm^{-2}; Not Fitted = 0.74 ± 0.51 N·cm^{-2}), the Experimental bra (Fitted = 1.51 ± 0.79 N·cm^{-2}; Not Fitted = 1.88 ± 1.06 N·cm^{-2}), or the Crop top (Fitted = 0.83 ± 0.64 N·cm^{-2}; Not Fitted = 1.24 ± 0.73 N·cm^{-2}). Similar to bra band pressure though, this result may be influenced by the small sample size observed in the Not Fitted group in the Crop top condition, as a result of data loss.

7.3.4.5 Wearability score

The Fitted group reported significantly better mean wearability in the Own bra (Fitted = 1.07 ± 1.64; Not Fitted = 4.33 ± 2.25; $p < 0.01$) compared to the Not Fitted group. The test was not significant for the Experimental bra condition (Fitted = 3.35 ± 3.23; Not Fitted = 4.67 ± 3.56) or Crop top (Fitted = 7.64 ± 1.98; Not Fitted = 9.50 ± 1.00) suggesting the ease of putting these bra conditions on or taking it off was not related to having them fit properly. This result must be interpreted with caution, as two participants from the Not Fitted group could not put on the Crop top. The wearability score of these participants, however, was not assumed, and was therefore coded as missing data, even though the Crop top may be considered 'extremely difficult' for these two participants to wear.

7.3.4.6 Aesthetics score

There was no significant difference in the aesthetics mean score between the Fitted or Not Fitted groups for the Own bra (Fitted = 4.14 ± 3.65; Not Fitted = 4.50 ± 3.88), the Experimental bra (Fitted = 3.07 ± 2.50; Not Fitted = 5.00 ± 3.90), or the Crop top (Fitted = 1.64 ± 2.27; Not Fitted = 1.50 ± 1.00). These results suggest that, to

these women, the look of a bra was not affected by bra fit for any given bra condition.

7.3.5 Overall Evaluation Table

The final evaluation table gives an indication of how each bra performed against the criteria, relative to the other bra conditions (see Table 7.2). Overall, the Experimental bra and Crop top both out-performed the Own bra based on these assessment criteria. Although the Crop top condition also appeared to out-perform the Experimental bra, this was affected mainly by the significantly higher strap pressures noted in the Experimental bra.

Table 7.2: Final evaluation table of the three examined bra conditions. A rank value of '3' indicated that a bra performed significantly better than both the other bras in any given criterion. A rank value of '2' indicated there was no significant difference between conditions, and a rank value of '1' indicated a bra performed significantly poorer than both of the other two conditions in any given criteria. The product of ranks and criterion weight values were calculated to provided a criterion score, which were then summed for Total Scores.

Criteria		Bra conditions					
		Own bra		Experimental bra		Crop top	
	Weight	Rank	Score	Rank	Score	Rank	Score
Bra discomfort	7	2	14	2	14	2	14
Bra fit	6	1	6	2	12	2	12
Perceived breast motion	5	1	5	2	10	2	10
Band pressure	4	2	8	2	8	2	8
Strap pressure	4	2	8	1	4	2	8
Wearability	3	2	6	2	6	1	3
Aesthetics	3	2	6	2	6	3	9
Total Score			53		60		64

7.4 Discussion

This study aimed to evaluate an Experimental exercise bra designed for women treated for breast cancer through the specific criteria of bra discomfort, perceived breast motion, pressure distribution, wearability and aesthetics. The secondary aim of this study was to consider the effect bra fit had on each of the above criterion. In agreement with the first hypothesis, a specifically designed Experimental bra performed equally well, or better, in each of these criteria when compared to the participants' Own current exercise bras. This resulted in a better overall final evaluation when compared to the participants' Own bra. In partial agreement with the second hypothesis, bra fit had a significant effect on some of the assessment criteria, such that participants who wore a properly fitted bra reported significant differences in bra discomfort and wearability within bra conditions, compared to participants who the bra did not fit. The details of these findings, and their implications are discussed below.

7.4.1 Bra Discomfort

Unexpectedly, bra discomfort did not differ significantly between bra conditions, indicating no overall effect of bra condition on bra discomfort. Although several studies have examined the effectiveness of bras in limiting breast pain and discomfort associated with exercise [106–108, 110], only one other study could be located in the literature that also considered the effect of experimental bra conditions on overall bra discomfort [110]. Despite this, a recent study reported that bra comfort was the most important factor to women treated for breast cancer, followed by bra fit and breast support [124] (see Chapter 5). Bras that rate high in comfort, however, tend to be less effective at providing breast support [84, 116]. Given the importance of bra comfort to women, and that overall bra comfort is key to encouraging women to wear supportive bras [110], more attention must be focused at improving overall bra comfort with-

out compromising breast support. Interestingly, results from the current study also indicated that when bra fit was considered, there were significant bra discomfort differences between the Own bra and Experimental bra conditions. Specifically, in both these bra conditions, women who could be Fitted reported experiencing less bra discomfort during running than their Not Fitted counterparts. Therefore, the differences noted in bra discomfort were driven by whether the women could be fitted into their bra or not. This finding supports research from a general population suggesting that for a bra to be comfortable and effective, it must fit properly [84, 85], and emphasises the need to ensure correct bra fit among women treated for breast cancer.

7.4.2 Perceived Breast Motion

Breast surgery is the primary mode of treatment for breast cancer, and will inevitably leave marked changes to the breast and surrounding anatomical structures. Controlling breast motion for women treated for breast cancer therefore presents a unique challenge. In the case of women who have undergone a mastectomy, an exercise bra must account for controlling either a prosthesis, or a reconstruction, both of which present as a much 'stiffer' structure than a natural breast. For this reason, women treated for breast cancer have previously reported sensations of asymmetrical breast motion between their affected and unaffected breasts [100, 124]. Unsurprisingly, participants in the present study also reported asymmetrical breast motion, particularly in their Own bra condition (see Figure 7.8). However, wearing bras designed specifically for exercise, such as the Experimental bra and Crop top, appeared to alleviate some of this asymmetrical breast motion, and perceived breast motion overall, compared to the Own bra condition. The ability of these exercise bras to control breast motion may be attributed to both the bra design and fabrics used in the bras' construction. The Experimental bra was an encapsulation bra and supported each breast individually in

its own cup [109, 125]. The straps that connected to each cup of the Experimental bra could be adjusted to facilitate the individual cup fit to each breast, and may therefore be more effective at controlling the motion of each individual breast, and overall breast motion asymmetry. Interestingly, however, the Crop top was equally effective at controlling perceived breast motion overall, and it achieved this motion control by compressing the breasts as a single unit against the chest wall. It appears both strategies are effective, and similar to a general female population, being correctly fitted into a purpose-designed exercise bra may be the key objective when attempting to control breast motion for women treated for breast cancer. Fabrics used in exercise bra construction also play an important role in minimising perceived breast motion. Research suggests that bras constructed of high modulus knit fabrics with low extensibility, and stabilised to allow minimal stretch, scored highest in perceived support [107, 109]. Both the Experimental bra and the Crop top were constructed of firmer fabrics than the Own bra condition, and it is likely that this construction contributed to the lower perceived breast motion reported in these conditions. Conversely, the Own bra condition tended to be either a bra designed for everyday wear, with softer fabrics, or older exercise bras, for which excessive wear had deteriorated the ability of the bra to retract when stretched.

7.4.3 Bra Pressure

The top four causes of bra discomfort in women treated for breast cancer were a bra band being too tight or too loose, and the bra straps being too tight or too loose (see Chapter 5). For this reason, the band and strap pressures of each bra condition were evaluated. A significantly higher mean band pressure was recorded in the Experimental bra condition compared to the Own bra, and a significantly higher mean strap pressure was recorded in the Experimental bra condition compared to both

the Own bra and Crop top. Despite this finding, there was no difference in bra comfort between bra conditions, suggesting this higher overall pressure had no effect on bra comfort. The only two other studies located in the literature examining the effect of bra band and strap pressures on bra comfort found that, although a significant increase in bra pressures existed between examined bra conditions, this did not correlate to an increase in bra discomfort in those conditions [117, 130]. The authors speculate that even the highest mean pressures, which are comparable to those seen in the present study, were not functionally high enough to affect comfort [130]. It is also likely that, in both the present study and the literature [117, 130], the period during which the participants wore the bra condition being evaluated was not long enough to elicit a discomfort response. Importantly, although treated as a poorer outcome in the present study, higher band and strap pressures do not necessarily indicate poorer bra design. Although pressure measurements provide valuable information regarding the 'tightness' of a bra, there are currently no recommendations as to how much pressure is 'too much'. Furthermore, women treated for breast cancer have reported the band and straps of a bra being 'too loose' to be an equally frustrating cause of bra discomfort as being 'too tight' [124] (see Chapter 5). Future studies should therefore evaluate the pressure ranges deemed acceptable for bras designed for exercise, particularly during long term bra wear. These bra band and strap pressure ranges should be used to guide the design of exercise bras that are firm enough to support the breasts, while alleviating the sensation of tightness.

7.4.4 Wearability

The wearability of a bra refers to how women rated the ease of putting the bra on, and the ease of removing the bra. The participants reported great difficulty putting the Crop top on, and taking it off, with some women requiring assistance from the study

team, and two women were unable to put the Crop top on at all. Consequently, the wearability score for the Crop top was significantly higher (indicating greater difficulty) than the Own bra or Experimental bra conditions. Unlike the Experimental bra and most of the Own bra conditions, the Crop top had no fasteners or mechanism to undo the bra, and was donned over the head. For women post breast cancer surgery, shoulder limitations and a reduced shoulder range of motion is a common complaint [33] (see Chapter 2). It is likely that this limited shoulder range of motion is related to the difficulty these women experienced in putting on and taking off the Crop top.

When bra fit was considered, women in the Fitted group found it significantly easier to put on and take off their Own bra than women in the Not Fitted group. Interestingly though, wearability score was not affected by whether or not the bra fitted in the Experimental condition, suggesting the ease of putting this bra on or taking it off was not related to having it fit properly. Some women, however, found it difficult to put on the Experimental bra, although they attributed this difficulty to the 'fiddly' nature of the front eye and hook fasteners, rather than any limited shoulder range of motion. Although no significant effect of bra fit on wearability was found in a Fitted group in the Crop top condition, this result must be interpreted with caution, as two participants from the Not Fitted group could not put on the Crop top. The wearability score of these participants was coded as missing data, even though the Crop top may be considered 'extremely difficult' to wear for these two participants.

7.4.5 Aesthetics

Although not ranked as a top factor in an exercise bra, women treated for breast cancer express a desire to look good in their exercise bra (see Chapter 5). For this reason, how much a women liked the look of the exercise bra formed part of the evaluation criteria. Overall, women preferred how they looked in the Crop top bra

condition compared to the Experimental bra and Own bra conditions. This result was surprisingly, as generally a Crop top is considered unflattering as it compresses the breast tissue against the chest wall, and gives the appearance of 'spreading' rather than shaping the breasts [125]. It is likely that the result was linked to two factors. Firstly, that the Crop top assessed was a commercially available product that was finished well with black and a bright pink trim, that provided a 'sporty' look that the women found attractive. In contrast, the Experimental bra was still a prototype and therefore not finished as well as the Crop top. Secondly, for participants who could not be properly fitted, the Experimental bra was less forgiving aesthetically due to its rigid structure, and breast tissue for these women was bulging over the cups and side band. Interestingly, when only a Fitted group is considered, the Crop top was no longer considered significantly better looking that the Experimental bra.

7.4.6 Final Evaluation Table

The final evaluation table provides a summary of how the bra conditions performed against each criterion, relative to each other (see Table 7.2). Overall, the Experimental bra out-performed the Own bra condition, confirming the first hypothesis that a specifically designed exercise bra would perform better in each of the specific criterion when compared to the participant's Own bra. It is interesting that a commercially-available bra of a completely different design (Crop top) was also able to out-perform the Own bra condition, suggesting that no one bra may provide an entire solution. Instead, designers should create a range of bras to suit all breast shapes and sizes. These bras must also account for symptoms related to breast cancer treatment, such as skin sensitivity, shoulder range of motion limitations and breast asymmetry (see Chapters 4 and 5, Table 5.5).

7.4.7 Design Refinement Recommendations

Although the Experimental bra performed well when evaluated against the specific criteria, observations during the running trials and verbal feedback from participants provided valuable insight into future design refinements. Firstly, the cups of the Experimental bra were cut too low, and future iterations of this design require the cup height to be raised in order to limit breast movement over the superior aspects of the bra cup [118, 132]. Secondly, although sliding fasteners were placed on the front of the straps to allow for easier strap adjustment, these rigid buckles tended to move anteriorly, as the breast was in an upward trajectory when the participants were running. This anterior movement released the tension and therefore support, provided by the straps. Future designs should ensure the front straps stay in contact with the chest wall when women exercise, to maintain support provided by the straps when the breast move [118]. This design iteration may require moving the strap adjusters to the posterior aspect of the bra. Thirdly, although the front opening provided better wearability than a back opening, women found the hook and eye fasteners difficult to manage, and this should be replaced with an option that is easier to manipulate (such as a zip). Finally, Gehlsen and Albohm [106] noted that binding over a supportive exercise bra resulted in a further reduction in breast movement, and McGhee and Steele [110] reported that elevation and compression of the breasts resulted in a lower level of perceived breast motion. Furthermore, women in the present study found the Crop top, which functions by compressing the breasts to the chest wall, provided a high level of breast support. These findings support the notion that creating compression over the breasts may improve breast support in an exercise bra designed for women treated for breast cancer. Designers must remain wary, however, of the increased breast sensitivity these women experience as a result of their breast cancer treatment, and ensure any compression is adjustable to a level deemed acceptable by these woman.

7.4.8 Study Strengths, Limitations and Recommendations

This study relied on subjective discomfort, wearability and aesthetic ratings as primary study outcomes. Although valuable, these subjective ratings are influenced by what the participant is used to wearing, their expectations, their sensitivity to changes in comfort, and their own personal experiences with breast cancer and self-image. An approach that may mitigate subjective influences would be to standardise responses to each individual by reporting the change in subjective scores per individual, rather than raw scores. Furthermore, although perceived breast motion is a valid measure of a bra's performance in controlling breast motion, this study was limited in its lack of an objectively measured breast motion outcome. While there is no substitute for the value of subjective feedback in evaluation studies, this should where possible, be supplemented with objectively collected data such as three-dimensional breast motion. Such data would further strengthen the study, particularly by allowing comparisons to existing literature of high support bras. Due to manufacturing restrictions, the Experimental bra was not available for sizes greater than a D-cup. Although this provides an interesting comparison of a Fitted vs. Not Fitted group, it restricts any comments regarding the performance of this Experimental bra to only women with D-cup sizes or smaller. As women with large breasts tend to more acutely experience the excessive breast and bra discomfort associated with exercise, and are therefore a target population for better bra designs, further research should investigate this population. Finally, women who formed the Not Fitted group were a smaller sub-sample than the Fitted group, and when data were lost in this group due to two women being unable to put on the Crop top, the sub-group sample size became too small for conclusive comments in that bra condition, and results must be interpreted with caution. Specifically, the calculated power in this unpaired sub-sample is reduced to 54%, limiting the ability of this analysis to identify significant relationships, and increasing the likelihood of false

negatives in the data. Despite these limitations, this study provides the first evaluation of an Experimental exercise bra designed specifically for women treated for breast cancer, and is therefore a valuable contribution to the literature. More importantly, this study provides the first steps towards design refinement and future design recommendations for an exercise bra for women treated for breast cancer. Finally, it is clear from the present study results that correct bra fit plays a significant role in overall bra performance and comfort. Therefore, bra fit educational materials that have proven useful in changing bra fit knowledge and practice in a general female population [84] should be adapted for women treated for breast cancer.

7.5 Conclusion

The Experimental bra evaluated in this study was designed to resolve specific bra discomfort and aesthetic issues as reported by women treated for breast cancer. Compared to the participants' Own bras, the Experimental bra displayed better bra fit and perceived breast motion control, and performed equally well in the criteria of bra discomfort, wearability and aesthetics. Further design iterations of a bra designed specifically for women treated for breast cancer should include a higher cup height, easier fastener options, and incorporate an adjustable compression component to the exercise bra design.

Fit played an influential role in bra comfort and bra wearability, and therefore achieving correct fit through bra fit education and improving knowledge is an imperative first step towards improving these outcomes. Furthermore, this study highlighted the challenge presented in fitting a range of breast shapes and sizes, particularly following breast surgery, and it is unlikely that any one design will fit all breast shapes and sizes. Rather, as further information is gathered on breast characteristics, a range of better bras can be designed to enable women, regardless of breast cancer treatment,

to enjoy the benefits of exercise without suffering bra discomfort.

Chapter 8

Summary, Conclusion and Recommendations for Future Work

8.1 Summary

Breast cancer is a highly prevalent and life changing disease, and ensuring the lasting quality of life of women treated for breast cancer is an area demanding research attention. Exercise has been repeatedly shown to be largely beneficial for women treated for breast cancer, and any barriers to exercise should be minimised to encourage such women to reap these benefits. Social cognitive theory indicates that barriers are a key influence on exercise behaviours in women treated for breast cancer, and the identification of these barriers formed the theoretical framework underpinning this thesis investigation. Exercise bra discomfort has been reported as a potential barrier to exercise, and this thesis aimed to evaluate the causes of, and extent to which, bra discomfort was a barrier to exercise; to systematically investigate what women treated for breast cancer required in an exercise bra; and to build a better exercise bra for these women based on this information. This was achieved through a series of studies conducted to establish whether a need to design better bras existed, and

the scope of that need (Part I), to understand what was required to fulfil this need and to build a better exercise bra (Part II), and to evaluate the success of the exercise bra solution through a laboratory-based study (Part III). Specifically, Part I (Chapters 2 - 4) examined the side-effects of breast cancer treatment and the influence of exercise on these side-effects, the main barriers to exercise, and the extent to which bra discomfort is a barrier to exercise for women treated for breast cancer. Part II (Chapters 5 - 6) produced evidence-based recommendations of what women treated for breast cancer want in an exercise bra, and using these recommendations designed and developed an Experimental exercise bra. The third and final Part III of the thesis (Chapter 7) evaluated the success of the Experimental exercise bra design through a set of research-based evaluation criteria, in order to make recommendations on the effectiveness of the novel bra design.

In Chapter 2 the associations between breast cancer treatment side-effects, patient characteristics, and the influence of exercise were investigated. Breast cancer side-effects can have a significant and lasting impact on the woman treated, and understanding characteristics or patients who are most likely to experience treatment side-effects may inform interventions to improve post treatment care. Furthermore, although exercise is an effective intervention in the management of breast cancer treatment side-effects, the effect of exercise on a broad range of breast cancer treatment side-effects was generally unknown. This study concluded that patient characteristics had moderate associative value with breast cancer treatment side-effects, and that exercise was associated with a lesser symptom experience for shoulder limitations, muscular chest wall pain, weight gain, lymphedema and breathlessness. Combined with the growing body of knowledge regarding the positive effects of exercise on quality of life and breast cancer survival, this finding supports the call for further research into the adherence to, and promotion of, exercise for women treated for breast cancer.

Despite the established benefits of exercise, few studies have investigated the perceived barriers to exercise experienced by women treated for breast cancer, and no study could be located that considered these barriers in community-dwelling survivors outside of an exercise intervention. Therefore, the purpose of Chapter 3 was to determine the effect of perceived exercise benefits and barriers on exercise levels among women who have been treated for breast cancer, and who were not part of formal exercise interventions. Sixteen out of a potential 19 exercise barriers had a significant effect on exercise behaviours, whereas only 6 out of 15 exercise benefits had this same effect. It was concluded that perceived barriers explained exercise participation better than perceived benefits, and therefore targeting exercise barriers is more likely to improve exercise participation levels among women treated for breast cancer. The results of Chapter 3 also provided a comprehensive list of the most common benefits of, and barriers to exercise perceived by women treated for breast cancer. When ranked according to mean score, exercise bra discomfort was identified as the third highest perceived barrier to exercise, and the first barrier that could be externally influenced, which makes it an ideal candidate for intervention.

Thus far, the benefits of exercise on treatment side-effects, and that bra discomfort acts as a significant barrier to exercise, has been established. Consequently, Chapter 4 aimed to gain a deeper understanding of the relationship between patient characteristics, treatment side-effects, exercise bra discomfort, and exercise behaviours in women treated for breast cancer. This was the first study in the scientific literature to systematically link the reporting of exercise bra discomfort to not achieving recommended levels of exercise, and this effect was found after controlling for age, surgery type and current treatment among a large cohort of women treated for breast cancer. Furthermore, results from this study indicated that physical side-effects, as a result of treatment associated with breast cancer, are linked to experiencing bra discomfort

during exercise. Based on these findings it was concluded that providing better bra designs, which are specific to the needs of women treated for breast cancer, may eliminate or reduce one of the main barriers to exercise among these women. However, before better bra designs could be developed, an understanding of what women wanted in an exercise bra had to be established.

In Chapter 5, responses from a national, online-based survey were analysed to systematically investigate what breast support options women treated for breast cancer want when they exercise in order to provide recommendations for improving exercise bra designs for these women. This study determined that, similar to the general female population, women treated for breast cancer require an exercise bra that effectively minimises breast motion during physical activity, fits properly, and is comfortable to wear. However, women treated for breast cancer also require an exercise bra that can accommodate their asymmetrical breast sizes, heightened skin sensitivity, increased fluid fluctuations and, if relevant, prosthesis movement. To assist in restoring body image, exercise bras for these women also need to provide a flattering profile, be constructed of soft, breathable, natural materials, and provide complete adjustability. Importantly, the restoration of body image and self-confidence plays a major role in the unique needs of women treated for breast cancer. To this end, if an exercise bra can be designed to look good, and give the wearer shape and confidence, as well as be a functional garment, women may be more likely to use them.

In Chapter 6, an iterative bra design process was followed to develop an Experimental bra based on the recommendations established in Chapter 5. This process, founded on industry practice and educational resources, is outlined in detail in Chapter 6, and culminates in an Experimental bra designed specifically for women treated for breast cancer. The final Experimental bra met most of these key recommendations from Chapter 5, including a wide, seam free band, moulded and padded seam free

cups, a soft inner pocket for a prosthesis, wide straps that did not slip off, sliding fasteners that permitted complete adjustability, and was constructed of a lightweight, breathable fabric. However, an evaluation of how the Experimental bra performed as an exercise bra needed to be undertaken before any conclusive comments regarding functionality could be made.

Chapter 7 evaluated the Experimental bra developed in Chapter 6 against specific evaluation criteria of bra discomfort, perceived breast motion, band and strap pressures, wearability and aesthetics. These criteria were based on responses provided by women treated for breast cancer as the most important factors required in an exercise bra (Chapter 5). Furthermore, due to the importance of bra fit for women treated for breast cancer (Chapter 5), and the established fact that if a bra does not fit, it is not effective, a secondary aim of this study was to consider the effect bra fit had on each of the afore-mentioned evaluation criteria. Compared to the participant's Own bras, the Experimental bra displayed significantly better bra fit and perceived breast motion control, and performed equally well in the criteria of bra comfort, wearability and aesthetics. The Experimental bra was constructed of a firmer material than the Own bra, and displayed higher band and strap pressures, although these higher pressures did not influence bra comfort. Bra fit also played an influential role in bra comfort and bra wearability, whereby women who wore a properly fitted bra reported their bra as being more comfortable in the Experimental and Own bra conditions, and found it easier to put on and take off their Own bra, than women whom the bra did not fit. Overall, the Experimental bra design was deemed an improvement on the participant's Own bras, and further design iterations of a higher cup height, easier fastener options, and providing an adjustable compression component have been recommended to further improve this design. Furthermore, this study highlighted the challenge of fitting a range of breast shapes and sizes, particularly following breast

surgery, and it is unlikely that any one design will suit all breast shapes and sizes. Rather, achieving correct bra fit through bra fit education and improving knowledge may be an imperative first step towards improving bra comfort. Finally, as further information is gathered on breast characteristics, a range of better bras can be designed to enable women, regardless of breast cancer treatment, to enjoy the benefits of exercise without suffering bra discomfort.

8.2 Study Limitations and Considerations

Given the vulnerability of a breast cancer cohort, the study was conducted by working closely with Breast Cancer Network Australia (BCNA), the peak advisory body on breast cancer in Australia, to develop the most professional way to respectfully approach women on this sensitive topic. To ensure research of this nature can be conducted without unnecessarily confronting women who may not wish to be contacted about their breast cancer, BCNA have developed the Review and Survey Group, which is a group of women who have indicated their willingness to be contacted to participate in research regarding their breast cancer. As a result of this approach, the sample may consist of women who are more motivated to participate in the research, than the general Australian breast cancer population. Furthermore, the online nature of the instrument required that respondents had access to a computer, and the internet. This may have skewed the results towards a younger sample population, and limited responses from rural or remote sub-populations - trends that can be seen in comparative population data (see Tables 2.2 and 4.1). In particular, a younger sample is likely to experience a poorer response to emotional functioning outcomes, and treatment-induced menopausal transitions, which may impact on the types of side-effects viewed in the study. With the exception of the Australian Capital Territory (ACT), the geographical sample spread is similar to breast cancer prevalence in Australia (see

Tables 2.2 and 4.1). With a generally higher socio-economic population, the larger representation of ACT residents (9% greater than breast cancer prevalence spread) may reflect respondents with higher education, and better access to health care and services, which may limit the generalisability of this work to the greater Australian breast cancer population.

Although valid and useful, cross-sectional study designs, such as conducted in the present study, are limited by a lack of temporal-based analysis, and the inability to draw any conclusions regarding causality. Specifically, as discussed in Section 3.1 of the thesis, cross-sectional population-based studies have found no significant difference in the exercise behaviours of women treated with breast cancer, and women with no history of breast cancer [69, 70], whereas longitudinal studies have noted significant changes in exercise participation when following the same cohort immediately after a breast cancer diagnosis [71–73]. The lack of temporal data during an experience as transient as breast cancer treatment is a study design limitation. Nevertheless, a cross-sectional design provides large amounts of prevalence data, which can be analysed for risk factors, as required by the present study, and was therefore deemed sufficient to answer the questions posed by this thesis.

8.3 Conclusion

Breast cancer treatment has lasting side-effects which can be positively influenced by participating in regular exercise. However, many perceived barriers to exercise exist, and these barriers negatively influence exercise behaviours, and therefore must be understood and minimised to encourage exercise in this vulnerable population. Exercise bra discomfort is a key barrier to exercise, such that reporting exercise bra discomfort is significantly linked to not achieving the minimum recommended levels of exercise among women treated for breast cancer. It is apparent that several unique issues

surrounding breast cancer treatment side-effects exacerbate the bra discomfort experienced by these women when they attempt to exercise. Understanding these issues, and how they affect what women treated for breast cancer want in an exercise bra is a fundamental first step towards designing better exercise bra solutions. Based on the recommendations provided by women treated for breast cancer, an Experimental bra was designed, developed and evaluated. Although further iterations are required to improve the design, the initial success of the design permits the conclusion that a specifically developed exercise bra can reduce exercise bra discomfort, and has the potential to enable women treated for breast cancer to enjoy the health benefits associated with exercise, without suffering bra-related discomfort.

8.4 Recommendations for Future Work

(1) Bra fit played an influential role in bra comfort, perceived breast motion and bra wearability (Chapter 7). Therefore, achieving correct bra fit is a vital first step towards improving these outcomes. Education has previously proven to be a successful intervention in improving bra fit knowledge and practice in a general female population. Therefore, it is recommended that easily accessed and disseminated educational materials, such as a smart phone application, with bra fit information specifically for women treated for breast cancer, should be developed and evaluated.

(2) The current thesis highlighted the challenge presented in fitting a range of breast shapes and sizes, particularly following breast cancer surgery. It is unlikely that any one bra design will suit all breast shapes and sizes. Therefore, it is recommended that a range of exercise bra designs be developed for women treated for breast cancer, to improve both bra fit and support.

(3) Because breast volume and shape will influence bra design, future research is required to investigate the range of breast volumes and shapes among women treated for breast cancer. It is recommended that information be gathered on the breast characteristics of a large sample of women treated for breast cancer, including objective measures of breast volume and shape.

(4) The effect of breast cancer surgery on breast volume and shape is currently unknown. In order to quantify the physical changes experienced by women treated for breast cancer, a longitudinal study should be conducted whereby the breast shape and volume of women are assessed before surgical treatment, shortly after surgical treatment, and at a final long-term time point. This form of study would provide a clear indication of the physical changes undergone by these women as a result of their surgical treatment, which in turn will provide valuable insight for bra designs for this cohort.

(5) Whether improved exercise bra designs modify exercise behaviours in women treated for breast cancer is still unknown. A prospective cohort study, with an improved exercise bra as an intervention, should be conducted to evaluate whether the provision of a better designed exercise bra improves exercise participation among women treated for breast cancer.

(6) The current study was limited to evaluating breast support based on perceived breast motion. A better understanding of breast motion, particularly of an affected and unaffected breast, may enhance exercise bra designs in women treated for breast cancer. Future research should endeavour to achieve a full three dimensional analysis of the breast in motion, ideally utilising dynamic three dimensional surface scans. This will permit an examination of the breast as a whole segment, rather than reducing it to marker points in a co-ordinate system, as is current practice.

For a thorough understanding of breast motion, future research should also be able to quantify the tissue stress and strain, as well as deformation forces occurring on the breast during exercise.

References

[1] Australian Institute of Health and Welfare and Cancer Australia, "Breast cancer in Australia: an overview." Cancer Series no. 71, Cat. no. CAN67, Canberra, 2012.

[2] M. Martin, R. Meyricke, T. O'Neill, and S. Roberts, "Mastectomy or breast conserving surgery? factors affecting type of surgical treatment for breast cancer - a classification tree approach." *BioMedical Central Cancer*, vol. 6, p. 98, 2006.

[3] D. A. Berry, K. A. Cronin, S. K. Plevritis, D. G. Fryback, L. Clarke, M. Zelen, J. S. Mandelblatt, A. Y. Yakovlev, J. D. Habbema, E. J. Feuer, I. Cancer, and C. Surveillance Modeling Network, "Effect of screening and adjuvant therapy on mortality from breast cancer," *New England Journal of Medicine*, vol. 353, no. 17, pp. 1784–1792, 2005.

[4] S. W. Duffy, L. Tabar, A. H. Olsen, B. Vitak, P. C. Allgood, T. H. Chen, A. M. Yen, and R. A. Smith, "Absolute numbers of lives saved and overdiagnosis in breast cancer screening, from a randomized trial and from the breast screening programme in england," *Journal of Medical Screening*, vol. 17, no. 1, pp. 25–30, 2010.

[5] S. H. Giordano, A. U. Buzdar, T. L. Smith, S. W. Kau, Y. Yang, and G. N.

Hortobagyi, "Is breast cancer survival improving?" *Cancer*, vol. 100, no. 1, pp. 44–52, 2004.

[6] M. Sant, S. Francisci, R. Capocaccia, A. Verdecchia, C. Allemani, and F. Berrino, "Time trends of breast cancer survival in europe in relation to incidence and mortality," *International Journal of Cancer*, vol. 119, no. 10, pp. 2417–2422, 2006.

[7] M. L. Galantino, "Influence of yoga, walking, and mindfulness meditation on fatigue and body mass index in women living with breast cancer," *Seminars in Integrative Medicine*, vol. 1, no. 3, pp. 151–157, 2003.

[8] M. K. Baldwin and K. S. Courneya, "Exercise and self-esteem in breast cancer survivors: An application of the exercise and self-esteem model," *Journal of Sport & Exercise Psychology*, vol. 19, no. 4, pp. 347–358, 1997.

[9] B. S. Cheema and C. A. Gaul, "Full-body exercise training improves fitness and quality of life in survivors of breast cancer," *Journal of Strength and Conditioning Research*, vol. 20, no. 1, pp. 14–21, 2006.

[10] M. L. McNeely, K. L. Campbell, B. H. Rowe, T. P. Klassen, J. R. Mackey, and K. S. Courneya, "Effects of exercise on breast cancer patients and survivors: a systematic review and meta-analysis," *Canadian Medical Association Journal*, vol. 175, no. 1, pp. 34–41, 2006.

[11] T. Ohira, K. H. Schmitz, R. L. Ahmed, and D. Yee, "Effects of weight training on quality of life in recent breast cancer survivors: the weight training for breast cancer survivors (wtbs) study," *Cancer*, vol. 106, no. 9, pp. 2076–2083, 2006.

[12] L. Adamsen, J. Midtgaard, M. Roerth, C. Andersen, M. Quist, and T. Moeller, "Transforming the nature of fatigue through exercise: qualitative findings from a

multidimensional exercise programme in cancer patients undergoing chemotherapy." *European Journal of Cancer Care*, vol. 13, pp. 362–370, 2004.

[13] A. Campbell, N. Mutrie, F. White, F. McGuire, and N. Kearney, "A pilot study of a supervised group exercise programme as a rehabilitation treatment for women with breast cancer receiving adjuvant treatment," *European Journal of Oncology Nursing*, vol. 9, pp. 56–63, 2005.

[14] M. Krishbaum, "Promoting physical exercise in breast cancer care." *Nursing Standard*, vol. 19, no. 41, pp. 41–48, 2005.

[15] V. Mock, M. Pickett, M. E. Ropka, E. Muscari Lin, K. J. Stewart, V. A. Rhodes, R. McDaniel, P. M. Grimm, S. Krumm, and R. McCorkle, "Fatigue and quality of life outcomes of exercise during cancer treatment," *Cancer Practice*, vol. 9, no. 3, pp. 119–127, 2001.

[16] C. Visovsky, "Muscle strength, body composition, and physical activity in women receiving chemptherapy for breast cancer." *Intergrative Cancer Therapies*, vol. 5, no. 3, pp. 183–191, 2006.

[17] J. Midtgaard, A. Tveteras, M. Rorth, R. Stelter, and L. Adamsen, "The impact of supervised exercise intervention on short-term postprogram leisure time physical activity level in cancer patients undergoing chemotherapy: 1- and 3-month follow-up on the body & cancer project," *Palliative & Supportive Care Care*, vol. 4, no. 1, pp. 25–35, 2006.

[25] S. A. Gho, "To what extent are bras an impediment to exercise for breast cancer patients?" Bachelor of Science (Honours) thesis, School of Health Sciences, University of Wollongong, 2007.

[26] N. K. Janz, M. Mujahid, L. K. Chung, P. M. Lantz, S. T. Hawley, M. Morrow, K. Schwartz, and S. J. Katz, "Symptom experience and quality of life of women following breast cancer treatment," *Journal of Womens Health*, vol. 16, no. 9, pp. 1348–1361, 2007.

[27] H. J. Burstein and E. P. Winer, "Primary care for survivors of breast cancer," *New England Journal of Medicine*, vol. 343, no. 15, pp. 1086–1094, 2000.

[28] C. L. Shapiro and A. Recht, "Drug therapy - side effects of adjuvant treatment of breast cancer," *New England Journal of Medicine*, vol. 344, no. 26, pp. 1997–2008, 2001.

[29] D. Cella and L. J. Fallowfield, "Recognition and management of treatment-related side effects for breast cancer patients receiving adjuvant endocrine therapy," *Breast Cancer Research and Treatment*, vol. 107, no. 2, pp. 167–180, 2008.

[30] H. S. Jim, M. A. Andrykowski, P. N. Munster, and P. B. Jacobsen, "Physical symptoms/side effects during breast cancer treatment predict posttreatment distress," *Annals of Behavioural Medicine*, vol. 34, no. 2, pp. 200–208, 2007.

[31] V. Arndt, C. Stegmaier, H. Ziegler, and H. Brenner, "A population-based study of the impact of specific symptoms on quality of life in women with breast cancer 1 year after diagnosis," *Cancer*, vol. 107, no. 10, pp. 2496–2503, 2006.

[32] K. Meeske, A. W. Smith, C. M. Alfano, B. A. McGregor, A. McTiernan, K. B. Baumgartner, K. E. Malone, B. B. Reeve, R. Ballard-Barbash, and L. Bernstein, "Fatigue in breast cancer survivors two to five years post diagnosis: a heal study report," *Quality of Life Research*, vol. 16, no. 6, pp. 947–960, 2007.

[33] S. C. Hayes, S. Rye, D. Battistutta, T. DiSipio, and B. Newman, "Upper-body morbidity following breast cancer treatment is common, may persist longer-term

and adversely influences quality of life," *Health and Quality of Life Outcomes*, vol. 8, pp. 92, 2010.

[34] I. L. Nesvold, K. V. Reinertsen, S. D. Fossa, and A. A. Dahl, "The relation between arm/shoulder problems and quality of life in breast cancer survivors: a cross-sectional and longitudinal study," *Journal of Cancer Survivorship*, vol. 5, no. 1, pp. 62–72, 2011.

[35] C. Buijs, E. G. de Vries, M. J. Mourits, and P. H. Willemse, "The influence of endocrine treatments for breast cancer on health-related quality of life," *Cancer Treatment Reviews*, vol. 34, no. 7, pp. 640–655, 2008.

[36] L. Atkins and L. Fallowfield, "Intentional and non-intentional non-adherence to medication amongst breast cancer patients," *European Journal of Cancer*, vol. 42, no. 14, pp. 2271–2276, 2006.

[18] M. Markes, T. Brockow, and K. L. Resch, "Exercise for women receiving adjuvant therapy for breast cancer," *Cochrane Database of Systematic Reviews*, no. 4, Art no. CD005001, 2006.

[37] K. H. Schmitz and R. M. Speck, "Risks and benefits of physical activity among breast cancer survivors who have completed treatment," *Women's Health*, vol. 6, no. 2, pp. 221–238, 2010.

[38] M. Barbaric, E. Brooks, L. Moore, and O. Cheifetz, "Effects of physical activity on cancer survival: a systematic review," *Physiotherapy Canada*, vol. 62, no. 1, pp. 25–34, 2010.

[39] A. R. Carmichael, A. J. Daley, D. W. Rea, and S. J. Bowden, "Physical activity and breast cancer outcome: a brief review of evidence, current practice and

future direction," *European Journal of Surgical Oncology*, vol. 36, no. 12, pp. 1139–1148, 2010.

[40] K. M. Clough-Gorr, P. A. Ganz, and R. A. Silliman, "Older breast cancer survivors: factors associated with self-reported symptoms of persistent lymphedema over 7 years of follow-up," *The Breast Journal*, vol. 16, no. 2, pp. 147–155, 2010.

[41] P. Servaes, C. Verhagen, and G. Bleijenberg, "Fatigue in cancer patients during and after treatment: prevalence, correlates and interventions," *European Journal of Cancer*, vol. 38, no. 1, pp. 27–43, 2002.

[42] S. A. Gho, J. R. Steele, and B. J. Munro, "Is bra discomfort a barrier to exercise for breast cancer patients?" *Supportive Care in Cancer*, vol. 18, no. 6, pp. 735–741, 2010.

[43] P. Whitney and D. Budd, "Think-aloud protocols and the study of comprehension," *Discourse Processes*, vol. 21, no. 3, pp. 341–351, 1996.

[44] World Health Organisation, "Global physical activity questionaire (GPAQ2)." [Online]. Available: http://www.who.int/chp/steps/resources/GPAQ_Analysis_Guide.pdf, Accessed 3 Feb 2009.

[45] M. A. Warmuth, G. Bowen, L. R. Prosnitz, L. Chu, G. Broadwater, B. Peterson, G. Leight, and E. P. Winer, "Complications of axillary lymph node dissection for carcinoma of the breast: a report based on a patient survey," *Cancer*, vol. 83, no. 7, pp. 1362–1368, 1998.

[46] Australian Institute of Health and Welfare, "Australia's health," Cat no. AUS 122, Canberra, 2010.

[64] Australian Institute of Health and Welfare, Cancer Australia, and Australasian Association of Cancer Registries, "Cancer survival and prevalence in Australia:

Cancers diagnosed from 1982 to 2004," Cancer Series no.42 Cat. no. CAN 38, Canberra, 2008.

[47] C. Rabin and B. Pinto, "Cancer-related beliefs and health behavior change among breast cancer survivors and their first-degree relatives," *Psychooncology*, vol. 15, no. 8, pp. 701–712, 2006.

[48] V. Vance, M. Mourtzakis, L. McCargar, and R. Hanning, "Weight gain in breast cancer survivors: prevalence, pattern and health consequences," *Obesity Reviews*, vol. 12, no. 4, pp. 282–294, 2011.

[49] J. A. McInnes and M. T. Knobf, "Weight gain and quality of life in women treated with adjuvant chemotherapy for early-stage breast cancer," *Oncology Nursing Forum*, vol. 28, no. 4, pp. 675–684, 2001.

[50] H. I. Su, M. D. Sammel, E. Springer, E. W. Freeman, A. DeMichele, and J. J. Mao, "Weight gain is associated with increased risk of hot flashes in breast cancer survivors on aromatase inhibitors," *Breast Cancer Research and Treatment*, vol. 124, no. 1, pp. 205–211, 2010.

[51] C. H. Mom, C. Buijs, P. H. Willemse, M. J. Mourits, and E. G. de Vries, "Hot flushes in breast cancer patients," *Critical Reviews in Oncology/Hematology*, vol. 57, no. 1, pp. 63–77, 2006.

[52] M. H. Savard, J. Savard, C. Quesnel, and H. Ivers, "The influence of breast cancer treatment on the occurrence of hot flashes," *Journal of Pain Symptom Management*, vol. 37, no. 4, pp. 687–697, 2009.

[53] C. L. Rock, S. W. Flatt, V. Newman, B. J. Caan, M. N. Haan, M. L. Stefanick, S. Faerber, and J. P. Pierce, "Factors associated with weight gain in women after diagnosis of breast cancer. women's healthy eating and living study group,"

Journal of the American Dietetic Association, vol. 99, no. 10, pp. 1212–1221, 1999.

[54] W. Demark-Wahnefried, B. L. Peterson, E. P. Winer, L. Marks, N. Aziz, P. K. Marcom, K. Blackwell, and B. K. Rimer, "Changes in weight, body composition, and factors influencing energy balance among premenopausal breast cancer patients receiving adjuvant chemotherapy," *Journal of Clinical Oncology*, vol. 19, no. 9, pp. 2381–2389, 2001.

[55] M. L. McNeely, K. Campbell, M. Ospina, B. H. Rowe, K. Dabbs, T. P. Klassen, J. Mackey, and K. Courncya, "Exercise interventions for upper-limb dysfunction due to breast cancer treatment," *Cochrane Database of Systematic Reviews*, no. 6, Art no. CD005211, 2010.

[56] K. H. Schmitz, R. L. Ahmed, A. Troxel, A. Cheville, R. Smith, L. Lewis-Grant, C. J. Bryan, C. T. Williams-Smith, and Q. P. Greene, "Weight lifting in women with breast-cancer-related lymphedema," *New England Journal of Medicine*, vol. 361, no. 7, pp. 664–673, 2009.

[57] S. C. Hayes, K. Johansson, N. L. Stout, R. Prosnitz, J. M. Armer, S. Gabram, and K. H. Schmitz, "Upper-body morbidity after breast cancer: incidence and evidence for evaluation, prevention, and management within a prospective surveillance model of care," *Cancer*, vol. 118, no. 8 Suppl, pp. 2237–2249, 2012.

[58] B. F. Jung, G. M. Ahrendt, A. L. Oaklander, and R. H. Dworkin, "Neuropathic pain following breast cancer surgery: proposed classification and research update," *Pain*, vol. 104, no. 1-2, pp. 1–13, 2003.

[59] M. S. Wallace, A. M. Wallace, J. Lee, and M. K. Dobke, "Pain after breast surgery: a survey of 282 women," *Pain*, vol. 66, no. 2-3, pp. 195–205, 1996.

[60] T. F. Hack, L. Cohen, J. Katz, L. S. Robson, and P. Goss, "Physical and psychological morbidity after axillary lymph node dissection for breast cancer," *Journal of Clinical Oncology*, vol. 17, no. 1, pp. 143–149, 1999.

[61] D. N. Chan, L. Y. Lui, and W. K. So, "Effectiveness of exercise programmes on shoulder mobility and lymphoedema after axillary lymph node dissection for breast cancer: systematic review," *Journal of Advanced Nursing*, vol. 66, no. 9, pp. 1902–1914, 2010.

[62] K. H. Schmitz, J. Holtzman, K. S. Courneya, L. C. Masse, S. Duval, and R. Kane, "Controlled physical activity trials in cancer survivors: a systematic review and meta-analysis," *Cancer Epidemiology, Eiomarkers & Prevention* , vol. 14, no. 7, pp. 1588–1595, 2005.

[63] G. P. Tolentino, C. L. Battaglini, S. S. Araujo, A. S. Otano, D. M. Conde, E. S. Evans, and R. J. de Oliveira, "Cardiorespiratory fitness and quality-of-life analysis posttreatment in breast cancer survivors," *Journal of Psychosocial Oncology*, vol. 28, no. 4, pp. 381–398, 2010.

[65] W. Demark-Wahnefried and L. W. Jones, "Promoting a healthy lifestyle among cancer survivors," *Hematology-Oncology Clinics of North America*, vol. 22, no. 2, pp. 319–342, 2008.

[66] R. M. Speck, K. S. Courneya, L. C. Masse, S. Duval, and K. H. Schmitz, "An update of controlled physical activity trials in cancer survivors: a systematic review and meta-analysis," *Journal of Cancer Survivorship*, vol. 4, no. 2, pp. 87–100, 2010.

[67] A. L. Schwartz, M. Mori, R. Gao, L. M. Nail, and M. E. King, "Exercise reduces

daily fatigue in women with breast cancer receiving chemotherapy," *Medicine and Science in Sports and Exercise*, vol. 33, no. 5, pp. 718–723, 2001.

[68] A. R. Kendall, M. Mahue-Giangreco, C. L. Carpenter, P. A. Ganz, and L. Bernstein, "Influence of exercise activity on quality of life in long-term breast cancer survivors," *Quality of Life Research*, vol. 14, no. 2, pp. 361–371, 2005.

[69] E. G. Eakin, D. R. Youlden, P. D. Baade, S. P. Lawler, M. M. Reeves, J. S. Heyworth, and L. Fritschi, "Health behaviors of cancer survivors: data from an Australian population-based survey," *Cancer Causes and Control*, vol. 18, no. 8, pp. 881–894, 2007.

[70] S. Kwon, N. Q. Hou, and M. M. Wang, "Comparison of physical activity levels between cancer survivors and non-cancer participants in the 2009 BRFSS," *Journal of Cancer Survivorship - Research and Practice*, vol. 6, no. 1, pp. 54–62, 2012.

[71] M. L. Irwin, D. Crumley, A. McTiernan, L. Bernstein, R. Baumgartner, F. D. Gilliland, A. Kriska, and R. Ballard-Barbash, "Physical activity levels before and after a diagnosis of breast carcinoma - the health, eating, activity, and lifestyle (heal) study," *Cancer*, vol. 97, no. 7, pp. 1746–1757, 2003.

[72] M. L. Irwin, A. Mctiernan, L. Bernstein, F. D. Gilliland, R. Baumgartner, K. Baumgartner, and R. Ballard-Barbash, "Physical activity levels among breast cancer survivors," *Medicine and Science in Sports and Exercise*, vol. 36, no. 9, pp. 1484–1491, 2004.

[73] A. J. Littman, M. T. Tang, and M. A. Rossing, "Longitudinal study of recreational physical activity in breast cancer survivors," *Journal of Cancer Survivorship*, vol. 4, no. 2, pp. 119–127, 2010.

[74] K. S. Courneya, D. C. McKenzie, R. D. Reid, J. R. Mackey, K. Gelmon, C. M. Friedenreich, A. B. Ladha, C. Proulx, K. Lane, J. K. Vallance, and R. J. Segal, "Barriers to supervised exercise training in a randomized controlled trial of breast cancer patients receiving chemotherapy," *Annals of Behavioural Medicine*, vol. 35, no. 1, pp. 116–122, 2008.

[75] A. J. Ottenbacher, R. S. Day, W. C. Taylor, S. V. Sharma, R. Sloane, D. C. Snyder, W. E. Kraus, and W. Demark-Wahnefried, "Exercise among breast and prostate cancer survivors–what are their barriers?" *Journal of Cancer Survivorship*, vol. 5, no. 4, pp. 413–419, 2011.

[76] J. M. Blaney, A. Lowe-Strong, J. Rankin-Watt, A. Campbell, and J. H. Gracey, "Cancer survivors' exercise barriers, facilitators and preferences in the context of fatigue, quality of life and physical activity participation: a questionnaire-survey," *Psycho-Oncology*, vol. 22, no. 1, pp. 186–194, 2013.

[77] L. Q. Rogers, K. S. Courneya, P. Shah, G. Dunnington, and P. Hopkins-Price, "Exercise stage of change, barriers, expectations, values and preferences among breast cancer patients during treatment: a pilot study," *European Journal of Cancer Care*, vol. 16, no. 1, pp. 55–66, 2007.

[81] Australian Bureau of Statistics, "Physical activity in Australia: A snapshot, 2007-08," Canberra, 2011.

[82] Australian Institute for Heath and Welfare, "The Active Australia survey: a guide and manual for implementation, analysis and reporting," Canberra, 2003.

[83] A. P. Sander, J. Wilson, N. Izzo, S. A. Mountford, and K. W. Hayes, "Factors that affect decisions about physical activity and exercise in survivors of breast cancer: a qualitative study," *Physical Therapy*, vol. 92, no. 4, pp. 525–536, 2012.

[19] L. Q. Rogers, P. Shah, G. Dunnington, A. Greive, A. Shanmugham, B. Dawson, and K. S. Courneya, "Social cognitive theory and physical activity during breast cancer treatment," *Oncology Nursing Forum*, vol. 32, no. 4, pp. 807–815, 2005.

[86] L. W. Jones and K. S. Courneya, "Exercise counseling and programming preferences of cancer survivors," *Cancer Practice*, vol. 10, no. 4, pp. 208–215, 2002.

[87] K. S. Courneya, R. J. Segal, K. Gelmon, R. D. Reid, J. R. Mackey, C. M. Friedenreich, C. Proulx, K. Lane, A. B. Ladha, J. K. Vallance, and D. C. McKenzie, "Predictors of supervised exercise adherence during breast cancer chemotherapy," *Medicine and Science in Sports and Exercise*, vol. 40, no. 6, pp. 1180–1187, 2008.

[88] M. Maddocks, S. Mockett, and A. Wilcock, "Is exercise an acceptable and practical therapy for people with or cured of cancer? a systematic review," *Cancer Treatment Reviews*, vol. 35, no. 4, pp. 383–390, 2009.

[89] K. S. Courneya, C. M. Friedenreich, H. A. Quinney, A. L. Fields, L. W. Jones, J. K. Vallance, and A. S. Fairey, "A longitudinal study of exercise barriers in colorectal cancer survivors participating in a randomized controlled trial," *Annals of Behavioural Medicine*, vol. 29, no. 2, pp. 147–153, 2005.

[90] F. M. Perna, L. Craft, C. S. Carver, and M. H. Antoni, "Negative affect and barriers to exercise among early stage breast cancer patients," *Health Psychology*, vol. 27, no. 2, pp. 275–279, 2008.

[24] L. Q. Rogers, S. Markwell, P. Hopkins-Price, S. Vicari, K. S. Courneya, K. Hoelzer, and S. Verhulst, "Reduced barriers mediated physical activity maintenance among breast cancer survivors," *Journal of Sport & Exercise Psychology*, vol. 33, no. 2, pp. 235–254, 2011.

[79] S. A. Gho, J. R. Steele, S. C. Jones, and B. J. Munro, "Self-reported side effects of breast cancer treatment: a cross-sectional study of incidence, associations, and the influence of exercise," *Cancer Causes and Control*, vol. 24, no. 3, pp. 517–528, 2013.

[91] L. Aday, *Designing and conducting health surveys*, 2nd ed. San Francisco, California: Jossey-Bass Inc, 1996.

[78] World Health Organisation, "Global recommendations on physical activity for health," Department of Chronic Diseases and Health Promotion, Surveillance and Population-Based Prevention, Geneva, Switzerland 2010.

[92] U. S. Albert, M. Koller, I. Kopp, W. Lorenz, K. D. Schulz, and U. Wagner, "Early self-reported impairments in arm functioning of primary breast cancer patients predict late side effects of axillary lymph node dissection: results from a population-based cohort study," *Breast Cancer Research and Treatment*, vol. 100, no. 3, pp. 285–292, 2006.

[93] B. Smoot, M. Wampler, and K. S. Topp, "Breast cancer treatments and complications: Implications for rehabilitation," *Rehabilitation Oncology*, vol. 27, no. 3, pp. 16–26, 2009.

[94] K. Holli, M. Pitkanen, R. Jarvenpaa, J. Rajala, S. Lahtela, S. Hyodynmaa, and A. Ojala, "Early skin and lung reactions in breast cancer patients after radiotherapy: prospective study," *Radiotherapy and Oncology*, vol. 64, no. 2, pp. 163–169, 2002.

[95] E. Lopez, R. Guerrero, M. I. Nunez, R. del Moral, M. Villalobos, J. Martinez-Galan, M. T. Valenzuela, J. Munoz-Gamez, F. J. Oliver, D. Martin-Oliva, and J. M. R. de Almodovar, "Early and late skin reactions to radiotherapy for breast

cancer and their correlation with radiation-induced dna damage in lymphocytes," *Breast Cancer Research*, vol. 7, no. 5, pp. R690–R698, 2005.

[96] I. N. Fernando, T. J. Powles, S. Ashley, D. Grafton, C. L. Harmer, and H. T. Ford, "An acute toxicity study on the effects of synchronous chemotherapy and radiotherapy in early stage breast cancer after conservative surgery," *Clinical Oncology*, vol. 8, no. 4, pp. 234–238, 1996.

[97] J. L. Harper, L. E. Franklin, J. M. Jenrette, and E. G. Aguero, "Skin toxicity during breast irradiation: pathophysiology and management," *Southern Medical Journal*, vol. 97, no. 10, pp. 989–993, 2004.

[98] R. R. Chopra and J. A. Bogart, "Radiation therapy-related toxicity (including pneumonitis and fibrosis)," *Hematology/Oncology Clinics of North America*, vol. 24, no. 3, pp. 625–642, 2010.

[99] J. Marinus, C. G. Niel, R. A. de Bie, R. G. Wiggenraad, E. M. Schoppink, and L. H. Beukema, "Measuring radiation fibrosis: the interobserver reliability of two methods of determining the degree of radiation fibrosis," *International Journal of Radiation Oncology, Biology, Physics*, vol. 47, no. 5, pp. 1209–1217, 2000.

[100] S. A. Gho, J. R. Steele, and B. J. Munro, "Breast motion and vertical breast displacement in lumpectomy patients," in *XXIIIrd Congress of the International Society of Biomechanics*, S. Van Sint Jan and V. Feipel, Eds. International Society of Biomechanics, Conference Proceedings, p. 183, 2011.

[101] P. Gallagher, A. Buckmaster, S. O'Carroll, G. Kiernan, and J. Geraghty, "External breast prostheses in post-mastectomy care: women's qualitative accounts," *European Journal of Cancer Care*, vol. 19, no. 1, pp. 61–71, 2010.

[102] S. Roberts, P. Livingston, V. White, and A. Gibbs, "External breast prosthesis use - experiences and views of women with breast cancer, breast care nurses, and prosthesis fitters," *Cancer Nursing*, vol. 26, no. 3, pp. 179–186, 2003.

[85] D. E. McGhee and J. R. Steele, "Optimising breast support in female patients through correct bra fit a cross-sectional study," *Journal of Science and Medicine in Sport*, vol. 13, no. 6, pp. 568–572, 2010.

[103] H. M. Milne, K. E. Wallman, S. Gordon, and K. S. Courneya, "Effects of a combined aerobic and resistance exercise program in breast cancer survivors: a randomized controlled trial," *Breast Cancer Research and Treatment*, vol. 108, no. 2, pp. 279–288, 2008.

[104] C. M. Friedenreich, J. Gregory, K. A. Kopciuk, J. R. Mackey, and K. S. Courneya, "Prospective cohort study of lifetime physical activity and breast cancer survival," *International Journal of Cancer*, vol. 124, no. 8, pp. 1954–1962, 2009.

[105] K. A. Bowles, J. R. Steele, and B. Munro, "What are the breast support choices of Australian women during physical activity?" *British Journal of Sports Medicine*, vol. 42, no. 8, pp. 670–673, 2008.

[106] G. Gehlsen and M. Albohm, "Evaluation of sports bras," *Physician and Sportsmedicine*, vol. 8, no. 10, pp. 89–95, 97, 1980.

[107] D. Lorenzten and L. Lawson, "Selected sports bras: a biomechanical analysis of breast motion while jogging," *Physician and Sportsmedicine*, vol. 15, no. 3, pp. 128–130, 132–134, 136, 139, 1987.

[108] B. R. Mason, K. A. Page, and K. Fallon, "An analysis of movement and discomfort of the female breast during exercise and the effects of breast support

in three cases," *Journal of Science and Medicine in Sport*, vol. 2, no. 2, pp. 134–144, 1999.

[109] C. Starr, D. Branson, R. Shehab, C. Farr, S. Ownbey, and J. Swinney, "Biomechanical analysis of a prototype sport bra," *Journal of Textile and Apparel, Techonology and Management*, vol. 4, no. 3, pp. 1–14, 2005.

[110] D. E. McGhee and J. R. Steele, "Breast elevation and compression decrease exercise-induced breast discomfort," *Medicine and Science in Sports and Exercise*, vol. 42, no. 7, pp. 1333–1338, 2010.

[111] S. Crompvoets, "Comfort, control, or conformity: women who choose breast reconstruction following mastectomy," *Health Care for Women International*, vol. 27, no. 1, pp. 75–93, 2006.

[112] J. Gao and D. S. Dizon, "Preparing for survivorship: quality of life in breast cancer survivors," *Journal of Sexual Medicine*, vol. 10 Suppl 1, pp. 16–20, 2013.

[113] S. M. Mahon and M. Casey, "Patient education for women being fitted for breast prostheses," *Clinical Journal of Oncology Nursing*, vol. 7, no. 2, pp. 194–199, 2003.

[114] A. Losken, I. Fishman, D. D. Denson, H. R. Moyer, and G. W. Carlson, "An objective evaluation of breast symmetry and shape differences using 3-dimensional images," *Annals of Plastic Surgery*, vol. 55, no. 6, pp. 571–575, 2005.

[115] D. E. McGhee, B. M. Power, and J. R. Steele, "Does deep water running reduce exercise-induced breast discomfort?" *British Journal of Sports Medicine*, vol. 41, no. 12, pp. 879–883, 2007.

[116] K. A. Bowles, J. R. Steele, and B. J. Munro, "Features of sports bras that

deter their use by Australian women," *Journal of Science and Medicine in Sport*, vol. 15, no. 3, pp. 195–200, 2012.

[117] K. A. Bowles, J. R. Steele, and R. Chaunchaiyakul, "Do current sports brassiere designs impede respiratory function?" *Medicine and Science in Sports and Exercise*, vol. 37, no. 9, pp. 1633–1640, 2005.

[118] J. Zhou, W. N. Yu, and S. P. Ng, "Identifying effective design features of commercial sports bras," *Textile Research Journal*, vol. 83, no. 14, pp. 1500–1513, 2013.

[119] D. Risius, R. Thelwell, C. Wagstaff, and J. Scurr, "Influential factors of bra purchasing in older women," *Journal of Fashion Marketing and Management*, vol. 16, no. 3, pp. 366–380, 2012.

[120] P. Gallagher, A. Buckmaster, S. O'Carroll, G. Kiernan, and J. Geraghty, "Experiences in the provision, fitting and supply of external breast prostheses: findings from a national survey," *European Journal of Cancer Care*, vol. 18, no. 6, pp. 556–568, 2009.

[121] D. E. McGhee, J. R. Steele, W. J. Zealey, and G. J. Takacs, "Bra-breast forces generated in women with large breasts while standing and during treadmill running: Implications for sports bra design," *Applied Ergonomics*, vol. 44, no. 1, pp. 112–118, 2013.

[122] C. Hardaker and G. Fozzard, "Communications: the bra design process - a study of professional practice," *International Journal of Clothing Science and Technology*, vol. 9, no. 4, pp. 311–325, 1997.

[80] S. A. Gho, B. J. Munro, S. C. Jones, and J. R. Steele, "Exercise bra discomfort

is associated with insufficient exercise levels among Australian women treated for breast cancer," *Supportive Care in Cancer*, vol. 22, no. 3, pp. 712–729, 2014.

[123] S. A. Gho, B. J. Munro, S. C. Jones, and J. R. Steele, "Benefits and barriers of exercise for women living with a breast cancer diagnosis: A cross-sectional survey of 432 Australian breast cancer survivors," *Physical Therapy*, Accepted April 2014.

[124] S. A. Gho, B. J. Munro, S. C. Jones, and J. R. Steele, "Evidence based recommendations for building better bras for women treated for breast cancer," *Ergonomics*, DOI:10.1080/00140139.2014.897377, 2014.

[125] G. Krenzer, C. Starr, and D. Branson, "Development of a sports bra prototype," *International Textile and Apparel Association*, vol. 23, pp. 131–134, 2005.

[126] E. Mass, "Bamboo textiles: Luxurious and practical," *NaturalLifeMagazine.com*, pp. 36–39, March 2009.

[127] R. Mishra, B. K. Behera, and B. P. Pal, "Novelty of bamboo fabric," *Journal of the Textile Institute*, vol. 103, no. 3, pp. 320–329, 2012.

[128] T. Afrin, T. Tsuzuki, R. K. Kanwar, and X. Wang, "The origin of the antibacterial property of bamboo," *Journal of the Textile Institute*, vol. 103, no. 8, pp. 844–849, 2012.

[129] K. Shin, *Patternmaking for Underwear Design*. Shin Woo Kyung, 2010.

[131] G. E. Torrens and N. C. Smith, "Evaluation of an assistive technology product design using a paired comparisons method within a mixed methods approach: a case study evaluating preferences for four types of cutlery with 34 upper limb impaired participants," *Disability and Rehabilitation Assistive Technology*, vol. 8, no. 4, pp. 340–347, 2013.

[130] K. A. Bowles and J. R. Steele, "Effects of strap cushions and strap orientation on comfort and sports bra performance," *Medicine and Science in Sports and Exercise*, vol. 45, no. 6, pp. 1113–1119, 2013.

[84] D. E. McGhee, J. R. Steele, and B. J. Munro, "Education improves bra knowledge and fit, and level of breast support in adolescent female athletes: a cluster-randomised trial," *Journal of Physiotherapy*, vol. 56, no. 1, pp. 19–24, 2010.

[133] P. Buckle and A. Fernandes, "Mattress evaluation–assessment of contact pressure, comfort and discomfort," *Applied Ergonomics*, vol. 29, no. 1, pp. 35–39, 1998.

[134] J. Cohen, *Statisical power analysis for the behaviorial sciences (2nd ed.)*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.

[132] K. A. Page and J. R. Steele, "Breast motion and sports brassiere design. implications for future research," *Sports Medicine*, vol. 27, no. 4, pp. 205–11, 1999.

[21] S. M. Phillips and E. McAuley, "Social cognitive influences on physical activity participation in long-term breast cancer survivors," *Psycho-Oncology*, vol. 22, no. 4, pp. 783–791, 2013.

[20] L. Q. Rogers, P. Hopkins-Price, S. Vicari, R. Pamenter, K. S. Courneya, S. Markwell, S. Verhulst, K. Hoelzer, C. Naritoku, L. Jones, G. Dunnington, V. Lanzotti, J. Wynstra, L. Shah, B. Edson, A. Graff, and M. Lowy, "A randomized trial to increase physical activity in breast cancer survivors," *Medicine and Science in Sports and Exercise*, vol. 41, no. 4, pp. 935–946, 2009.

[23] L. Q. Rogers, E. McAuley, P. M. Anton, K. S. Courneya, S. Vicari, P. Hopkins-Price, S. Verhulst, R. Mocharnuk, and K. Hoelzer, "Better exercise adherence

after treatment for cancer (beat cancer) study: Rationale, design, and methods," *Contemporary Clinical Trials*, vol. 33, no. 1, pp. 124–137, 2012.

[22] L. Q. Rogers, E. McAuley, K. S. Courneya, and S. J. Verhulst, "Correlates of physical activity self-efficacy among breast cancer survivors," *American Journal of Health Behavior*, vol. 32, no. 6, pp. 594–603, 2008.