

Utah State University

DigitalCommons@USU

---

All Graduate Theses and Dissertations

Graduate Studies

---

5-1985

## A Comparison of Eight Selected Sports Bras: Biomechanical Support, Overall Comfort Ratings and Overall Support Ratings

LaJean R. Lawson  
*Utah State University*

Follow this and additional works at: <https://digitalcommons.usu.edu/etd>



Part of the [Medicine and Health Sciences Commons](#)

---

### Recommended Citation

Lawson, LaJean R., "A Comparison of Eight Selected Sports Bras: Biomechanical Support, Overall Comfort Ratings and Overall Support Ratings" (1985). *All Graduate Theses and Dissertations*. 4039.

<https://digitalcommons.usu.edu/etd/4039>

This Thesis is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Theses and Dissertations by an authorized administrator of DigitalCommons@USU. For more information, please contact [digitalcommons@usu.edu](mailto:digitalcommons@usu.edu).



A COMPARISON OF EIGHT SELECTED SPORTS BRAS:  
BIOMECHANICAL SUPPORT, OVERALL COMFORT RATINGS  
AND OVERALL SUPPORT RATINGS

by

LaJean R. Lawson

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

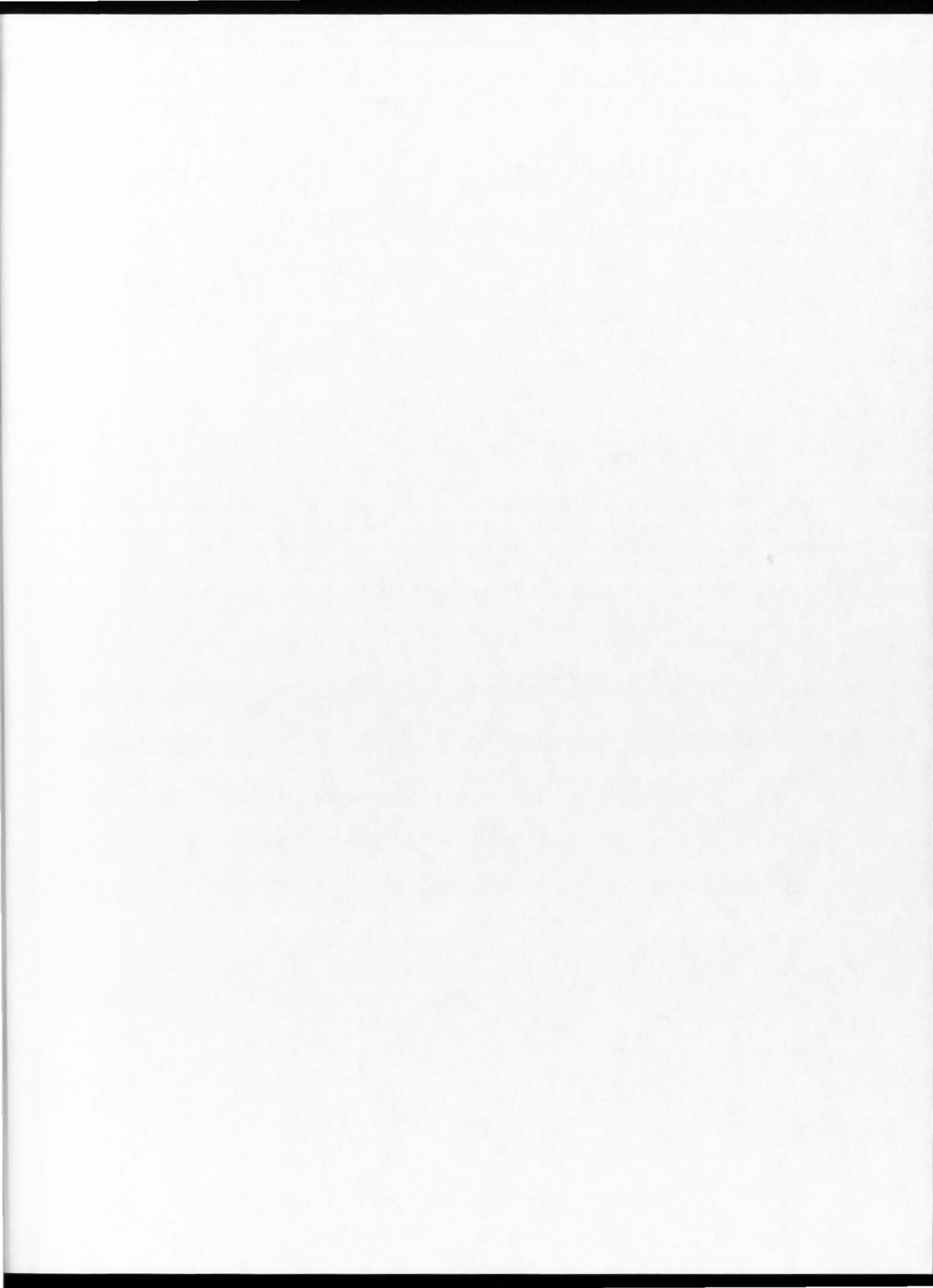
in

Home Economics and Consumer Education

Approved:

UTAH STATE UNIVERSITY  
Logan, Utah

1985



## ACKNOWLEDGEMENTS

Utah State University, under the direction of Bartell Jensen, offered a Faculty Research Grant to Dr. Deana Lorentzen in the spring of 1984 for the support of a study on breast motion and sports bras. I would like to express my appreciation to Dr. Lorentzen for her help and encouragement, both during the funding process and during the actual research.

I would also like to thank Dr. Tom C. Peterson, my advisor, for his unflagging encouragement, support and understanding during my tenure at Utah State University; and Ruth V. Clayton for her inspiration, help and professional example. Maria Norton deserves a great deal of credit and thanks for her assistance with the statistical analysis.

I owe a particular debt to my subjects, 59 dedicated women who lent their time, energy and feedback to the research process. They performed a difficult task with a great deal of enthusiasm.

Finally, I must say thank you to a wonderful group of friends who encouraged me every step of the way: Don Frohlich, Tom Greider, Dennis Hinkamp, and Ron Ryel (and his washing machine).

LaJean R. Lawson

## TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS . . . . .	ii
LIST OF TABLES . . . . .	v
ABSTRACT . . . . .	viii
Chapter	
I. STATEMENT OF THE PROBLEM . . . . .	1
Introduction . . . . .	1
Significance of the Study . . . . .	2
Objective of the Study . . . . .	3
Hypotheses . . . . .	3
Limitations . . . . .	4
Definitions . . . . .	5
II. REVIEW OF LITERATURE . . . . .	7
Sports Bra Controversy . . . . .	7
Biomechanical Studies . . . . .	11
Summary . . . . .	13
III. METHODOLOGY AND ANALYSIS . . . . .	14
Data Source . . . . .	14
Design of the Study . . . . .	14
Procedures and Materials . . . . .	15
Operational Definition of Dependent and Independent Variables . . . . .	19
Data Analysis . . . . .	20
IV. FINDINGS . . . . .	23
Demographic and Anthropometric Data . . . . .	25
Results of Testing Hypotheses . . . . .	29
Summary . . . . .	65
V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS . . . . .	66
Summary . . . . .	66
Discussion of the Findings . . . . .	73

## TABLE OF CONTENTS, CONTINUED

Conclusions . . . . .	80
Recommendations . . . . .	81
REFERENCES . . . . .	87
APPENDICES . . . . .	89
Appendix A. Features of Bras . . . . .	90
Appendix B. Bra Evaluation Form . . . . .	93

## LIST OF TABLES

Table	Page
1. Anthropometric Characteristics of Subjects . . .	26
2. Frequencies for Incidence of Breast Injuries, Breast Pain and Sports Bra Usage . . . . .	30
3. ANOVA Summary Table for Nude Breast Displacement . . . . .	32
4. Analysis of Pairwise Differences for Nude Breast Displacement (LSD Method) . . . . .	32
5. ANOVA Summary Table for Vertical Displacement for the Combined A, B, C and D Cup Size Groups Wearing Seven Selected Styles . . . . .	34
6. ANOVA Summary Table for Vertical Displacement for the Combined B, C and D Cup Size Groups Wearing Eight Selected Styles . . . . .	35
7. Analysis of Pairwise Differences for Vertical Displacement for the Combined A, B, C and D Cup Size Groups in Seven Selected Styles . . . . .	36
8. Analysis of Pairwise Differences for Vertical Displacement for the Combined B, C and D Cup Size Groups in Eight Selected Styles . . . . .	37
9. Analysis of Pairwise Differences For Vertical Displacement for the A Cup Size Group in Seven Selected Styles . . . . .	39
10. Analysis of Pairwise Differences for Vertical Displacement for the B Cup Size Group in Eight Selected Styles . . . . .	40
11. Analysis of Pairwise Differences for Vertical Displacement for the C Cup Size Group in Eight Selected Styles . . . . .	42

12.	Analysis of Pairwise Differences for Vertical Displacement for the D Cup Size Groups in Eight Selected Styles . . . . .	43
13.	ANOVA Summary Table for Overall Comfort Scores for the Combined A, B, C and D Cup Size Groups Wearing Seven Selected Styles . . . . .	45
14.	ANOVA Summary Table for Overall Comfort Scores for the Combined B, C and D Cup Size Groups Wearing Eight Selected Styles . . . . .	46
15.	Analysis of Pairwise Differences for Overall Comfort Scores for the Combined A, B, C and D Cup Size Groups in Seven Selected Styles . . . .	47
16.	Analysis of Pairwise Differences for Overall Comfort Scores for the Combined B, C and D Cup Size Groups in Eight Selected Styles . . . .	48
17.	Analysis of Pairwise Differences for Overall Comfort for the A Cup Size Group in Seven Selected Styles . . . . .	50
18.	Analysis of Pairwise Differences for Overall Comfort for the B Cup Size Group in Eight Selected Styles . . . . .	51
19.	Analysis of Pairwise Differences for Overall Comfort for the C Cup Size Group in Eight Selected Styles . . . . .	53
20.	Analysis of Pairwise Differences for Overall Comfort for the D Cup Size Group in Eight Selected Styles . . . . .	54
21.	ANOVA Summary Table for Overall Support Scores for the Combined A, B, C and D Cup Size Groups Wearing Seven Selected Styles . . . . .	55
22.	ANOVA Summary Table for Overall Support Scores for the Combined B, C and D Cup Size Groups Wearing Eight Selected Styles . . . . .	56
23.	Analysis of Pairwise Differences for Overall Support Scores for the Combined A, B, C and D Cup Size Groups in Seven Selected Styles . . . .	58

24.	Analysis of Pairwise Differences for Overall Support Scores for the Combined B, C and D Cup Size Groups in Eight Selected Styles . . . .	59
25.	Analysis of Pairwise Differences for Overall Support Scores for the A Cup Size Group in Seven Selected Styles . . . . .	60
26.	Analysis of Pairwise Differences for Overall Support Scores for the B Cup Size Group in Eight Selected Styles . . . . .	62
27.	Analysis of Pairwise Differences for Overall Support Scores for the C Cup Size Group in Eight Selected Styles . . . . .	63
28.	Analysis of Pairwise Differences for Overall Support Scores for the D Cup Size Group in Eight Selected Styles . . . . .	64
29.	Hypotheses Summary Table . . . . .	69

ABSTRACT

A Comparison of Eight Selected Sports Bras:  
Biomechanical Support, Overall Comfort Ratings  
and Overall Support Ratings

by

LaJean R. Lawson, Master of Science  
Utah State University, 1985

Major Professor: Dr. Tom C. Peterson  
Department: Home Economics and Consumer Education

The purpose of this paper was to evaluate eight currently marketed sports bras for differences in control of vertical displacement of the breast, overall comfort scores, and overall support scores for A, B, C and D cup sizes. An additional goal was to determine and compare differences in the vertical displacement of the nude breast among the four cup size groups. To determine differences in vertical displacement, subjects were filmed while jogging on a treadmill, and film data were analyzed frame by frame. To determine differences in overall comfort and support ratings, subjects tested each of the eight bra styles under actual exercise conditions and subsequently completed an evaluation form. Significant differences in vertical displacement in the nude condition were found between the D cup size group

and the other 3 cup sizes. Significant differences in the eight styles' abilities to control vertical displacement, and in overall comfort and support scores were found, both within the group as a whole and within each bra cup size group. Specific suggestions for further sports bra development and for individualized bra style selection are included.

(97 pages)

## CHAPTER I

### STATEMENT OF THE PROBLEM

#### Introduction

Since the advent of the women's movement in the 1960's and the accompanying federal legislation in the 1970's, which mandated equal access to athletic opportunities for women, female participation in sports has increased dramatically (Oglesby, 1978). In addition, increasing numbers of non-athletes--members of the general population--are engaging in regular non-competitive but strenuous exercise (Gerber, Felshin, Berlin & Wyrick, 1974).

Paralleling this trend has been the development of sports equipment designed especially for women, of which the sports bra is an example. Foundation garment manufacturers have tried to capitalize on the sports bra market, and a number of bras are currently marketed as sports bras. However, few bras have been designed using data from empirical studies of the biomechanics of breast motion. Moreover, most existing research on sports bras has been conducted on athletes, which constitute only

a small percentage of active women, and whose breast sizes tend to be smaller and whose problems with bras may be less significant. The needs of the large breasted, active women have not yet been seriously addressed.

The current leadership in women's sports advocates involvement of all women in an active lifestyle, regardless of their size, shape or age. The emphasis is on fitness, positive self-image and enjoyment rather than weight loss, which has often been the focus of many recreation programs ("Text of Draft Resolutions," 1983). In order to encourage women of all sizes to become involved in a healthier, more active lifestyle, barriers related to physical discomfort, self-consciousness or humiliation by others need to be lowered. More adequate means of controlling breast motion through better bra design may be an important part of this effort.

#### Significance of the Study

While informal polls of active women indicate that there is a need for better designed bras for sports, few studies have attempted to approach the problem of excessive breast motion in any sort of empirical fashion. No studies have attempted to compare empirical data on biomechanical support with subjective evaluations of comfort and support, nor have they taken into serious account how these needs may vary among women with different sizes of breasts.

Because this study will examine both objective and subjective evaluations of sports bra performance as well as examine differences within cup size groups, it is an important step in the development of better sports bra designs for women of all sizes and ages.

#### Objective of the Study

The objective of the study was to evaluate currently marketed sports bras, and to further develop empirically based guidelines for the development and design of sports bras for small, medium and large-breasted women. Specific suggestions relating to physical comfort and support that may emerge during this study will be included.

#### Hypotheses

Based on a review of related research findings and literature, the following null hypotheses were formulated:

1. There will be no difference in the amount of vertical displacement of the breast among A, B, C, and D cup size groups while jogging in the nude condition.
2. There will be no difference in the amount of vertical displacement allowed by each of the eight selected sports bras relative to the nude condition while jogging:

- a. within the entire group.
  - b. within the A cup size group.
  - c. within the B cup size group.
  - d. within the C cup size group.
  - e. within the D cup size group.
3. There will be no difference in the overall comfort rating for each of the eight selected models of sports bras:
- a. within the entire group.
  - b. within the A cup size group.
  - c. within the B cup size group.
  - d. within the C cup size group.
  - e. within the D cup size group.
4. There will be no difference in the overall support rating for each of the eight selected models of sports bras:
- a. within the entire group.
  - b. within the A cup size group.
  - c. within the B cup size group.
  - d. within the C cup size group.
  - e. within the D cup size group.

#### Limitations

The following limitations in the design of this research need to be recognized:

1. The body of existing knowledge about breast motion and sports bra design is limited.
2. The subjects' previous experiences with and possible favoritism toward specific sports bras may influence their responses to the subjective portions of the evaluations.
3. Differences between subjects in athletic ability, intensity of performance, and stride length may affect both the objective and subjective portions of the research.

#### Definitions

Several terms which have been used within the context of this paper are defined as follows to provide a clear understanding of their use.

Biomechanics: The application of physical laws of motion to the study of biological systems.

Biomechanical support: The degree to which a sports bra limits vertical displacement of the breast relative to the body during exercise.

Comfort: Freedom from distress that can be caused by a bra's irritating seams or parts, cutting or chafing, stiff or itchy fabric, and hot or bulky fabric.

Sports bra: A bra designed and marketed specifically for use during sports and exercise.

Support: The nature and extent of breast motion restriction afforded by a sports bra; additionally, freedom from soreness and distress that can be caused by a bra allowing excessive breast motion.

## CHAPTER II

### REVIEW OF LITERATURE

The limited body of literature pertaining to breast motion and sports bra design generally falls into two categories: 1) Debate over whether specially designed sports bras are necessary, and 2) Biomechanical studies.

#### Sports Bra Controversy

Recommendations that female athletes ought to wear special sports bras to minimize breast injury and soreness during strenuous activity and to prevent sagging later in life are common in the literature, and are summarized below. Some findings appear in conflict with that proposal. For example, Hunter and Torgan (1982) questioned 85 intercollegiate athletes about breast pain during sports and about the kinds of bras they used. Only 20 percent reported occasional breast pain, usually associated with cold weather or menstrual periods. Only 10 percent of the athletes wore a sports bra. However, a survey of 115 U.S. college and university physical education departments and trainers of four women's football teams by Haycock, Shierman, and Gillette (1978) appeared to contradict Hunter

and Torgan's findings. They found that 72 percent of female athletes reported sore or tender breasts after running, basketball, and weight training. Respondents concurred that a better bra was needed for women athletes.

Breast soreness was not the only concern. Some injuries to the breasts in sports where contact occurs have been reported. Haycock et al (1978) found that only 17 percent of the respondents in her study reported breast injuries. However, it was noted that several trainers--some of whom were men--thought that female athletes may have been reluctant to report injuries for fear of being labelled "babies," or losing their scholarships. Bayne (1968) has also suggested that women ought to wear a protective bra in contact sports, feeling that even if serious breast injuries occurring during sports activities are rare, there should be protection against the painful blows to the breasts which are common. And, Haycock (1978) theorized that sagging of the breasts occurs later in women from countries where a specific supportive garment for the breasts is worn. She also noted that although there are few top competitive runners who are large breasted (a conclusion supported by the Haycock et al (1978) study), the condition poses a problem in all sports.

All citations agree on the importance of wearing bras

when exercising and some research has addressed women's needs in sports bras. For example, the complaints about bras registered in the Haycock et al (1978) study pertained to abrasive metallic or plastic parts, or to allergic reactions to the materials in the bras. All-elastic bras were found to irritate the skin, and basketball and volleyball players noted slipping shoulder straps and bras that "rode up." Based on research compiled from three different studies, Haycock (1978) indicated that a good sports bra should meet the following criteria: 1) provides good upward support; 2) limits motion of the breast relative to the body; 3) is made of a material that is absorptive, non-allergenic, non-abrasive, and mostly elastic; 4) has fasteners well covered to prevent abrasion to the skin or to other players; 5) utilizes straps that are wide, non-elastic, and designed so that they do not slip off the shoulders; 6) makes provision at the base of the bra to prevent "riding up" of the bra over the breast; and 7) provides a pocket inside the bra for placement of protective padding. In a poll conducted by Sportsmedicine ("Women marathoners describe bra needs," 1977), 27 national marathon finalists indicated the following requirements: firm support on the side; no lace, padding or underwires; lots of support; an all-elastic back; and a wide variety of

sizes. The women in the Hunter and Torgan (1982) study stated that sports bras should be inexpensive, easy to care for, available in many sizes, made of absorbent fabric, and constructed with seamless cups and non-irritating straps.

While most studies have examined only problems and needs related to physical support and comfort, Haycock (1978) suggests that women have psychological needs relating to bra design and breast support. The female breast has one primary biological function, the production of milk to support the growing infant; but society has attached to the female breast various sexual connotations as to size and attractiveness. In some cases, severe psychological problems have resulted when breast surgery is necessary or when breasts are unusually small. Haycock has theorized that women who believe their breast size and motion are excessive may restrict their athletic participation due to self-consciousness about appearance, and believes that sports bra features (amount of support and silhouette) should work to minimize psychological discomfort.

The majority of researchers who have polled athletes about breast pain and soreness, injury, and the types of bras used have concluded that wearing a specially designed bra while exercising is important, especially for moderate to heavy breasted women. According to Schuster (1979),

bras designed for athletic women have long been needed, but manufacturers are only now racing to capture the sports bra market. While available bras are all designed to minimize breast motion during activity, the models vary considerably. Research conducted on existing models clearly indicates that few bras on the market meet the standards specified by athletes. Furthermore, the existing data have been collected on competitive collegiate athletes, most of whom are small to moderate breasted and less likely to experience breast discomfort than large breasted women, or the female population at large. Similar data are missing for members of the general population who engage in regular non-competitive but strenuous exercise, and who vary more in age and breast size.

#### Biomechanical Studies

Biomechanical studies apply the physical laws of motion to the study of biological systems. Sports equipment design has been strongly influenced by applications of biomechanical research, resulting in beneficial changes (Burdett, 1983). To date, however, only two studies have used biomechanical techniques to investigate breast motion with and without breast support. In a pioneer study, Haycock et al (1978) filmed five athletes (at 100 frames per second) walking at three miles

per hour and running at six miles per hour on a treadmill. Close-up front and side view were obtained of the subjects nude, wearing their own bras, and finally wearing specially fitted bras. It was observed that with no bra the breasts, especially large or pendulous ones, rose up and then slapped down against the chest wall with considerable force at each complete step. Motion was moderately restricted by their ordinary bras, and the fitted bras markedly restricted both vertical and lateral motion. A frame-by-frame analysis delineated the range of motion as traced by small markers placed over the nipple. Haycock concluded that there is still a great need to develop better designed sports bras for women athletes.

Because bra design may influence breast discomfort, Gehlsen and Albohm (1980) used biomechanical procedures to determine: 1) whether there is a difference in support provided by selected bras, 2) the normal, acceptable range of breast motion for comfort, and 3) the effects of additional binding of the breasts over a bra during jogging. An analysis of variance showed that there was a statistically significant difference in the vertical displacement of the breast in relation to the body during one running stride allowed by the eight selected sports bras. Gehlsen and Albohm also concluded that the mass of the breast in conjunction with the velocity of movement may

be related to discomfort while jogging, and that binding over a bra prevents over 45 percent of the movement.

#### Summary

Studies of sports bras are needed that combine biomechanical and field-testing approaches, and that utilize both objective and subjective assessments. The data thus gained will be valuable in the design of bras for athletes and active women of all ages, but particularly the heavily "endowed" individual.

## CHAPTER III

### METHODOLOGY AND ANALYSIS

#### Data Source

The data from which this research is derived was collected at Utah State University by Deana Lorentzen, Ph.D., principal investigator, and LaJean Lawson during fall quarter, 1984. Research design and implementation, and construction of all data-gathering instruments were products of their joint collaboration.

#### Design of the Study

The following specific objectives determined the research design:

1. To determine and compare the normal range of vertical biomechanical movement of the nude breast occurring in small, medium and large breasted women during jogging (i.e., vertical displacement of the breast relative to the body during one average running stride).
2. To compare the differences in the biomechanical support provided by eight selected sports bras presently on the market (i.e., amount of vertical displacement of the

breast relative to the body allowed in small, medium and large breasted women while wearing each of the bras during jogging).

3. To compare subjective responses about the comfort and support features of each of the selected sports bras.

#### Procedures and Materials

##### Preliminary Procedures

1. Identify the sample: The subjects were volunteer female students and employees of Utah State University, and female residents of Cache and Salt Lake Counties, Utah. The 59 subjects were divided into four experimental groups of approximately 15 according to bra cup size (A cup=small; B cup=medium; C cup=medium/large; and D cup=large). The main criterion, in addition to willingness to participate, was that a subject be in adequate physical condition to be able to complete both the treadmill and field-testing portions of the study.

2. Selection of sports bras to be tested: Eight bras were selected on the basis of their use in previous sports bra research, innovativeness in design, and their availability in a wide range of sizes (Gehlsen & Albohm, 1980). They include:

- Elegant Support by Creative Support Systems (CS)
- Jogbra by Jogbra, Inc. (JB)
- The Lady Duke by Royal Textile Mills (LD)

- Sportsbra by Cupid (CU)
- Actively Yours by Actively Yours (AY)
- The Sportsbra by Olga's Christina (OC)
- Freedom Frontrunner by Olga (OF)
- Sport Bra by Lily of France (LF)

A more complete description of each sports bra style appears in Appendix A. Because the Freedom Frontrunner by Olga was available in B, C, and D cup sizes only, the A cup group did not test this style. For purposes of brevity and convenience, all styles will subsequently be referred to by their two-letter identification code.

3. Prior to filming and field-testing, the following demographic and anthropometric data were collected: subject's age, height, weight, percent body fat, chest and breast circumference, chest depth and width, bra size, number of children, and number breastfed. Percent body fat was determined by hydrostatic weighing in the Human Performance Lab. The chest circumference measurement was taken around the rib cage just below the breasts. Breast circumference was measured around the the rib cage at the fullest part of the breast. Chest depth and width measurements were established using two T-squares to form a rectangle around the chest at the level of the fullest part of the breast. Subjects were also asked questions relating to previous sports-related breast injuries,

exercise-related breast pain and discomfort, and prior usage of specially designed sports bras.

#### Collection of Biomechanical Support Data

To determine and compare the normal range of biomechanical breast excursion and to compare the differences in the biomechanical support provided by the eight selected sports bras (specific objectives #1 and #2), the vertical displacement of the breast relative to the body during one average running stride was calculated. The subjects jogged indoors on a treadmill at six miles per hour on a flat grade in nine different conditions--first wearing each of the eight selected sports bras, and then nude from the waist up. The order of wearing the various brands of bra was systematically varied among subjects. A body reference mark was placed on the lower sternum to determine vertical displacement of the body. The vertical motion of the breast was derived from a second mark placed over the bra at the center of the breast (or over the nipple when nude). The difference between the body displacement and the breast displacement was calculated and considered to be the net vertical displacement of the nude or supported breast. Three rises and falls of the breast were studied, and the average of the three consecutive vertical displacement values used for analysis.

A 16 mm Photosonics Action Master camera with an internal timing device set at 100 frames per second was used to film the subjects as they jogged on the treadmill. The film was analyzed frame-by-frame on a Lafayette Motion Analyzer. By filming a ruler of known length, it was possible to convert film distance values to real distance values.

Collection of Data Regarding  
Subjective Evaluation of Comfort,  
Support, and Overall Ratings

The field-testing portion of the study was an attempt to evaluate and rank the eight sports bras, during actual exercise conditions, on specific factors other than biomechanical support that may affect comfort, support and acceptability of a sports bra.

In order to construct an instrument for data gathering, criteria related to comfort and support were first established from the review of literature. A questionnaire was developed to include features found desirable or objectionable by female athletes in previous sports bra research (See Appendix B). Questionnaire items called for rating on a five point Likert-type scale.

Subjects were asked to test each bra while engaging in some form of vigorous exercise that would produce vertical body movement and breast motion. Acceptable activities included running or jogging, brisk walking, aerobic dance,

racquet sports, soccer or football, basketball or volleyball, and horseback riding. Swimming and cycling were not acceptable activities for this research. Subjects were encouraged to engage in the same type, duration and intensity of exercise for all eight bras.

After familiarizing herself with the questionnaire and the design features to be evaluated, each subject exercised in each type of bra for a minimum of twenty minutes. Subjects were instructed to fill out the form immediately after the exercise session to assure accuracy.

During this phase of the study, all bras were laundered by the researchers in a uniform manner (cold water wash, line dry) so as to minimize possible damage to the elasticity, resiliency and supportiveness of the bras.

#### Operational Definitions of Dependent and Independent Variables

For determination and comparison of the degree of vertical displacement occurring among the four cup sizes in the nude condition, the dependent variable was the actual amount of vertical motion in centimeters, as derived from taking an average of three consecutive rises and falls of the breast. The independent variable was cup size.

For determination of differences in the amount of vertical displacement allowed by each of the eight selected

sports bras for the whole group and for a given size, the dependent variable was the actual amount of vertical motion in centimeters (derived from taking an average of three consecutive rises and falls of the breast). The independent variable was style of bra. The amount of vertical displacement in the nude condition was used as a covariate to minimize differences due to stride frequency, running style and age.

For determination of differences in comfort and support ratings between each of the eight selected sports bras for the entire group of subjects, the dependent variable was the sum of the actual rating scores from the Likert-type scale given in each category and the independent variable was style of bra. To determine differences in these ratings within a given cup size group, the independent variable was also style of bra.

#### Data Analysis

Descriptive statistics were used to summarize and report the demographic and anthropometric data.

To compare the differences in vertical displacement between the A, B, C and D cup size groups in the nude condition, a one-way analysis of variance was used, and if a significant F value was found, the Least Squares Difference (LSD) method was used to determine specifically which differences between the means were significant.

To compare differences in the amount of biomechanical support provided by the eight sports bras for each cup size group, a repeated measures analysis of variance with covariance was utilized. If a significant F value was found, the LSD method was used to make pairwise comparisons between styles. Vertical displacement was compared across eight conditions (each subject wearing each of the eight selected bras) for the whole group and for each of the cup size groups. Because the Olga Freedom Frontrunner bra was not available in an A cup size, this group was only compared across seven conditions.

To compare subjective responses about the comfort, support and overall satisfaction with each of the selected sports bras, aggregate comfort and support scores for each bra were determined by summing the scores of questionnaire items in each category. Questionnaire items were recoded where necessary so that the highest numbered response coincided with the most desirable characteristic. A two-way repeated measures analysis of variance was used to compare differences in these ratings across eight conditions (each of the eight selected sports bras) for the whole group of subjects, and also within each cup size group. If a significant F value was found, the LSD method was used to identify differences between specific styles. Again, because of a lack of availability of an A cup size

in the Olga Freedom Frontrunner style, this cup size group only evaluated seven styles.

## CHAPTER IV

## FINDINGS

The primary purpose of this study was to evaluate currently marketed sports bras on objective measures of vertical displacement, and on subjective measures of overall comfort and support. An additional purpose was to compare differences in vertical displacement of the nude breast among A, B, C, and D cup size groups.

The findings from the study include a report of the demographic and anthropometric data and the results of the statistical analyses used to test each hypothesis. The hypotheses tested, broken down into their individual parts, are listed below:

H<sub>0</sub> 1. There will be no difference in the amount of vertical displacement of the breast among A, B, C, and D cup size groups in the nude condition.

H<sub>0</sub> 2. There will be no difference in the amount of vertical displacement allowed by each of the eight selected sports bras during jogging:  
a. within the entire group.

- b. within the A cup size group.
- c. within the B cup size group.
- d. within the C cup size group.
- e. within the D cup size group.

H<sub>0</sub> 3. There will be no difference in the overall comfort rating for each of the eight selected sports bras:

- a. within the entire group.
- b. within the A cup size group.
- c. within the B cup size group.
- d. within the C cup size group.
- e. within the D cup size group.

H<sub>0</sub> 4. There will be no difference in the overall support rating for each of the eight selected sports bras:

- a. within the entire group.
- b. within the A cup size group.
- c. within the B cup size group.
- d. within the C cup size group.
- e. within the D cup size group.

Each portion of the hypotheses was tested individually and will be addressed following a report of demographic and anthropometric data describing the sample used in this study.

## Demographic and Anthropometric Data

The subjects who participated were volunteer female students and employees of Utah State University, and female residents of Cache and Salt Lake Counties, Utah. The 59 subjects were divided into four experimental groups according to bra cup size (A cup=small; B cup=medium; C cup=medium/large; and D cup=large).

The mean age of the entire group of subjects was 31.3 years  $\pm$  10.40 years. Forty-two of the 59 subjects had no children, and the remaining 17 subjects had from one to six children. Of this group of 17 mothers, 11 (18.6% of the total sample) had breastfed their children.

The mean physical characteristics of the entire group of subjects, and of each cupsize group (A, B, C, and D) are summarized in Table 1. The mean height for the entire group was 164.80 cm  $\pm$  6.96 cm (64.90 inches  $\pm$  2.74 inches).

The mean body weight of the total group was 59.55 kg  $\pm$  7.01 kg. The A cup and B cup size groups were lighter than the total group's mean weight, and the C cup and D cup size groups were heavier than the total group's mean weight.

The mean percent body fat for the 59 subjects was 24.46%  $\pm$  6.54%, which places them within the average range for females (Pollock, Laughridge, Coleman, Linnerud & Jackson, 1975). The A cup and B cup size groups had body fat percentages less than the total group's mean

Table 1

Anthropometric Characteristics of Subjects

	Entire Group	A Cup	B Cup	C Cup	D Cup
Height (cm)					
Mean	164.80	163.98	166.37	164.69	164.34
SD	6.96	4.57	7.72	7.45	7.77
Weight (kg)					
Mean	59.55	56.74	59.03	60.46	61.99
SD	7.01	6.14	6.89	7.19	7.41
Body Fat (%)					
Mean	24.46	22.01	24.01	26.36	25.39
SD	6.54	5.68	8.04	4.52	7.06
Chest Circ. (cm)					
Mean	78.21	77.34	78.13	77.04	80.40
SD	4.81	4.18	5.55	4.11	4.93
Breast Circ. (cm)					
Mean	88.48	84.93	87.09	87.99	94.16
SD	6.07	4.28	4.16	5.89	6.13

Table 1, Cont.

Anthropometric Characteristics of Subjects

	Entire Group	A Cup	B Cup	C Cup	D Cup
<hr/>					
Chest Width (cm)					
Mean	28.62	27.69	28.36	28.44	30.03
SD	1.90	1.96	1.72	1.32	1.94
Chest Depth (cm)					
Mean	22.78	21.86	22.31	23.07	23.92
SD	2.13	2.76	1.64	1.83	1.81

percentage, while the C cup and D cup size groups had mean percentages larger than the total group's mean percentage. This pattern confirms previous research (Pollock et al, 1975) that showed breast volume to be positively correlated with, and a predictor of, body fat percentage.

The mean chest circumference (as measured around the chest just below the bottom of the breast) for the total group was  $78.21 \text{ cm} \pm 4.81 \text{ cm}$ . Only the D cup size group fell above the total group mean on this measurement.

The mean breast circumference (as measured around the chest at the nipple level around the fullest part of the breast) for the entire group was  $88.48 \text{ cm} \pm 6.07 \text{ cm}$ . The three smallest cup size groups, A, B, and C, were all smaller than the total group mean, while the D cup size group was larger than the total group.

The mean chest width and chest depth for the total group were  $28.62 \text{ cm} \pm 1.90 \text{ cm}$  and  $22.78 \text{ cm} \pm 2.13 \text{ cm}$ , respectively. As may be expected, the A cup and B cup size groups showed smaller chest width and depth values than the total group mean. The C cup size group was slightly smaller in chest width and slightly larger in chest depth than the total group mean for these characteristics. The D cup size group was larger than the total group mean on both measures.

The 59 women were asked three questions concerning

sports-related breast injury, sports-related breast pain, and current use of specially designed sports bras. The responses both for the entire group and for each cup size group are shown in Table 2.

Nine of the 59 women (15.3%) had suffered sports-related injuries to the breast. The most common injuries were blows to the breast from equipment or other players, and abrasions from bras.

For the entire group, more than half (55.9%) of the women had experienced sports-related breast pain. Among the 33 women in the entire group who had experienced pain, the most common causes were pain due to excessive breast motion (27.3%), and pain due to pre-menstrual syndrome (51.5%). Although the cup size groups were reasonably similar in incidence of pain, the smaller cup size groups complained primarily of pain related to pre-menstrual syndrome, and the larger cup size groups complained of mostly of pain resulting from excessive motion.

Out of the 59 women in the study, 18 (30.5%) had used a bra designed specifically for sports and exercise prior to the start of the study. Of this group of 18, nine (50%) used the Jogbra brand sports bra.

#### Results of Testing Hypotheses

Analysis of variance methods were used to test the

Table 2

Frequencies for Incidence of Breast Injuries,  
Breast Pain and Sports Bra Usage

	Whole				
	Group	A	B	C	D
Sports-related					
Breast Injury	9	3	4	0	2
Exercise-related Breast					
Pain or Discomfort	33	9	9	4	11
Previous Sports Bra					
Usage	18	6	5	6	1

null hypotheses. A one-way ANOVA was used to test Hypothesis 1. Hypothesis 2 was tested using a repeated-measures analysis of variance and covariance, and a repeated-measures analysis of variance (with no covariates) was used to test Hypothesis 3. The level of significance acceptable for this study was set at .05.

Hypothesis 1--Vertical Displacement  
in the Nude Condition

H<sub>0</sub>1. There will be no difference in the amount of vertical displacement of the breast among the A, B, C and D cup size groups in the nude condition.

Analysis of variance for data measuring differences in the amount of vertical displacement of the nude breast among the four cup sizes is summarized in Table 3. Inspection of this table reveals that there was a significant difference between the groups (  $F = 4.73$ ,  $p \leq .05$ ). Because a significant F was found, pairwise differences were investigated using the LSD method. The results, shown in Table 4, identified significant differences in vertical displacement of the nude breast between the A and D cup sizes, between the B and D cup sizes, and between the C and D cup sizes.

On the basis of these findings, H<sub>0</sub>1 was rejected.

Hypothesis 2--Vertical Displacement  
Allowed by Bra Styles

A repeated-measures analysis of variance with

Table 3

One-Way ANOVA Summary Table for Nude Breast Displacement

Source of Variation	SS	df	<u>F</u>	P level
Between Cupsize				
Groups	42.17	3	4.73	0.005
Within Groups				
(Error)	163.44	55		
Total	205.61	58		

Table 4

Analysis of Pairwise Differences for Nude Breast  
Displacement (LSD Method)

Mean	Cup Size Group	A	B	C	D
5.76	A				
5.99	B				
6.55	C				
7.98	D		*	*	*

\*Denotes pairs of groups significantly different,  $p < .05$

covariance was used to test all parts of Hypothesis 2. The nude condition vertical displacement was used as the covariate to establish a baseline of breast motion for each subject and to correct for individual differences in running style and stride frequency. Because the OF bra was not available in the A cup size, two analyses were performed--one on the data for the A, B, C and D cup size groups wearing the other seven styles, and one on the data for the B, C, and D cup size groups wearing all eight styles. The summaries of these analyses are presented in Tables 5 and 6.

Inspection of Tables 5 and 6 reveals that there were significant differences in the amount of vertical displacement allowed by the eight different styles of sports bras ( $F = 18.96$ ,  $F = 22.42$ ,  $p \leq .05$ ). Because a significant  $F$  was found, pairwise differences relating to the five separate parts of Hypothesis 2 were investigated with the LSD method, and are presented below.

$H_{02-a}$ . There will be no difference in the amount of vertical displacement allowed by each of the eight selected sports bras while jogging, within the entire group.

The following significant differences between eight bra styles were found, and are presented in Tables 7 and 8. The CS and LD bras allowed less vertical displacement than the JB, CU, AY, OC, OF and LF bras. The OF bra allowed

Table 5

ANOVA Summary Table for Vertical Displacement for the  
Combined A, B, C and D Cup Size Groups Wearing Seven  
Selected Styles

Source of Variation	df	MS	F	p Level
<u>Covariate</u>				
Nude Displacement	1	46.81	34.59	0.000
<u>Main Effect</u>				
Cupsize (S)	3	16.06	2.53	0.067
Person/Cupsize (P)				
[Error A]	55	6.36	4.70	0.000
Style of Bra (B)	6	25.66	18.96	0.000
<u>Interaction</u>				
Cupsize x Style	18	1.79	1.32	0.170
Style x Person/				
Cupsize [Error B]	330	1.35		

Table 6

ANOVA Summary Table for Vertical Displacement for the  
Combined B, C and D Cup Size Groups Wearing Eight  
Selected Styles

Source of Variation	df	MS	<u>F</u>	p Level
<u>Covariate</u>				
Nude Displacement	1	53.29	56.43	0.000
<u>Main Effect</u>				
Cupsize (S)	2	13.49	1.82	0.175
Person/Cupsize (P)				
[Error A]	55	7.41	7.84	0.000
Style of Bra (B)	7	21.17	22.42	0.000
<u>Interaction</u>				
Cupsize x Style	14	1.26	1.33	0.189
Style x Person/ Cupsize [Error B]	294	0.94		

Table 7

Analysis of Pairwise Differences for Vertical Displacement  
for the Combined A, B, C and D Cup Size Groups in Seven  
Selected Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	LF
1.67	CS		*		*	*	*	*
3.02	JB							
1.99	LD		*		*	*	*	*
3.30	CU							
3.11	AY							
3.30	OC							
3.05	LF							

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

Table 8

Analysis of Pairwise Differences for Vertical Displacement  
for the Combined B, C and D Cup Size Groups in Eight  
Selected Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
1.67	CS		*		*	*	*	*	*
3.02	JB								
1.99	LD		*		*	*	*	*	*
3.30	CU								
3.11	AY								
3.30	OC								
2.77	OF		*		*	*	*		*
3.05	LF						*		

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

less motion than the JB, CU, AY, OC and LF bras. The LF bra was lower in vertical displacement than the OC bra. On the basis of these findings,  $H_{O2-a}$  was rejected.

$H_{O2-b}$ . There will be no difference in the amount of vertical displacement allowed by each of the eight selected sports bras while jogging, within the A cup size group.

The significant differences found within the A cup size group are shown in Table 9. Because the OF bra was not available in an A cup size, no comparisons were made with it. The CS bra allowed less vertical displacement than the CU and LF bras, and the LD bra allowed less displacement than the CU, OC and LF bras. Hence,  $H_{O2-b}$  was rejected.

$H_{O2-c}$ . There will be no difference in the amount of vertical displacement allowed by each of the eight selected sports bras while jogging, within the B cup size group.

The following significant differences between the eight styles of bras were found, and are presented in Table 10. The CS bra allowed less vertical displacement than the JB, CU, AY, OC, OF and LF bras. The LD bra allowed less movement than the CU, AY and OC bras. Based on these findings,  $H_{O2-c}$  was rejected.

$H_{O2-d}$ . There will be no difference in the amount

Table 9

Analysis of Pairwise Differences for Vertical Displacement  
for the A Cup Size Group in Seven Selected Styles

(LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	LF
1.70	CS				*			*
2.19	JB							
1.34	LD				*	*		*
2.96	CU							
2.14	AY							
2.33	OC							
2.63	LF							

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

Table 10

Analysis of Pairwise Differences for Vertical Displacement  
for the B Cup Size Group in Eight Selected Styles

(LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
1.38	CS		*		*	*	*	*	*
2.41	JB								
1.93	LD				*	*	*		
2.89	CU								
2.77	AY								
2.77	OC								
2.31	OF								
2.46	LF								

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

of vertical displacement allowed by each of the eight selected sports bras while jogging, within the C cup size group.

For the C cup size group, the following significant differences were identified. They are summarized in Table 11. The CS and LD bras allowed less vertical displacement than the JB, CU, AY, OC, OF and LF bras. Additionally, the OF bra allowed less displacement than the AY, OC and LF bras. Because of these differences,  $H_{O2-d}$  was rejected.

$H_{O2-e}$ . There will be no difference in the amount of vertical displacement allowed by each of the eight selected sports bras while jogging, within the D cup size group.

The significant differences found within the D cup size group are shown in Table 12. The CS bra allowed less vertical displacement than all seven of the other bras (JB, LD, CU, AY, OC, OF and LF). The LD bra showed less vertical displacement than the JB, CU, AY, OC and LF bras. The OF bra allowed less displacement than the JB, CU, AY and OC bras, and the LF bra allowed less than the JB and OC bras. Hence,  $H_{O2-e}$  was rejected.

#### Hypothesis 3--Overall Comfort Ratings

A repeated-measures analysis of variance was used to test all parts of Hypothesis 3. Again, because the OF bra

Table 11

Analysis of Pairwise Differences for Vertical Displacement  
for the C Cup Size Group in Eight Selected Styles

(LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
1.53	CS		*		*	*	*	*	*
2.99	JB								
1.87	LD		*		*	*	*	*	*
3.07	CU								
3.35	AY								
3.51	OC								
2.57	OF					*	*		*
3.47	LF								

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

Table 12

Analysis of Pairwise Differences for Vertical Displacement  
for the D Cup Size Group in Eight Selected Styles

(LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
2.08	CS		*	*	*	*	*	*	*
4.49	JB								
2.85	LD		*		*	*	*		*
4.27	CU								
4.16	AY								
4.62	OC								
3.42	OF		*		*	*	*		
3.64	LF		*				*		

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

was not manufactured in the A cup size, two analyses were performed--one on the data for the A, B, C and D cup size groups wearing the other seven styles, and one on the data for the B, C and D cup size groups wearing all eight styles. The summaries of these analyses are presented in Tables 13 and 14.

An examination of Tables 13 and 14 shows that there were significant differences in overall comfort scores between the eight styles of bras ( $F = 13.28$ ,  $F = 8.51$ ,  $p \leq .05$ ). Because a significant  $F$  was found, pairwise differences relating to each separate part of Hypothesis 3 were investigated with the LSD method, and are presented below.

$H_{03-a}$ . There will be no difference in the overall comfort rating for each of the eight selected sports bras within the entire group.

The following significant differences between the eight bra styles were found, and are presented in Tables 15 and 16. The overall comfort score for the JB and CU bras were higher than the scores for the CS, LD and AY bras. The OC bra scored higher on comfort than the CS, LD, CU and AY bras. The OF bra received higher scores than the CS bra, while the LF bra scored better than the CS, LD, CU, AY, and OF bras. On the basis of these findings,  $H_{03-a}$  was rejected.

Table 13

ANOVA Summary Table for Overall Comfort Scores for the  
Combined A, B, C and D Cup Size Groups Wearing Seven  
Selected Styles

Source of Variation	df	MS	<u>F</u>	p Level
<u>Main Effect</u>				
Cupsize (S)	3	266.80	2.85	0.046
Person/Cupsize (P)				
[Error A]	54	93.62	3.83	0.000
Style of Bra (B)	6	324.34	13.28	0.000
<u>Interaction</u>				
Cupsize x Style	18	46.77	1.91	0.015
Style x Person/				
Cupsize [Error B]	291	24.43		

Table 14

ANOVA Summary Table for Overall Comfort Scores for the  
Combined B, C and D Cup Size Groups Wearing Eight  
Selected Styles

Source of Variation	df	MS	<u>F</u>	p Level
<u>Main Effect</u>				
Cupsize (S)	2	390.24	3.72	0.033
Person/Cupsize (P)				
[Error A]	41	104.87	4.73	0.000
Style of Bra (B)	7	188.42	8.51	0.000
<u>Interaction</u>				
Cupsize x Style	14	25.21	1.14	0.324
Style x Person/				
Cupsize [Error B]	257	22.13		

Table 15

Analysis of Pairwise Differences for Overall Comfort  
Scores for the Combined A, B, C and D Cup Size Groups  
in Seven Selected Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	LF
54.55	CS							
54.18	JB	*		*		*		
54.37	LD							
58.05	CU	*		*		*		
55.84	AY							
60.12	OC	*		*	*	*		
57.47	LF	*		*	*	*		

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall comfort than the style in the column.

Table 16

Analysis of Pairwise Differences for Overall Comfort  
Scores for the Combined B, C and D Cup Size Groups in  
Eight Selected Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
54.55	CS								
54.18	JB	*		*		*			
54.37	LD								
58.05	CU	*		*		*			
55.84	AY								
60.12	OC	*		*		*			
57.47	OF	*							
60.02	LF	*		*		*		*	

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall comfort than the style in the column.

H<sub>O</sub>3-b. There will be no difference in the overall comfort rating for each of the eight selected sports bras within the A cup size group.

The significant differences found within the A cup size group are shown in Table 17. Because the OF bra was not available in an A cup size, no comparisons were made with it. The CS, JB, CU, AY, OC and LF bras all scored higher than the LD bra on overall comfort. Additionally, the OC bra also scored higher on comfort than the CS, CU and AY bras. Hence, H<sub>O</sub>3-b was rejected.

H<sub>O</sub>3-c. There will be no difference in the overall comfort rating for each of the eight selected sports bras within the B cup size group.

The following significant differences between the eight styles of bras were found, and are presented in Table 18. The JB and CU bras scored higher on overall comfort than the CS bra. The OC bra received higher comfort scores than the CS, LD and AY bras. The OF bra scored higher than the CS bra, and the LF bra scored significantly higher on comfort than the CS, LD and AY bras. Based on these differences, H<sub>O</sub>3-c was rejected.

H<sub>O</sub>3-d. There will be no difference in the overall comfort rating for each of the eight selected sports bras within the C cup size group.

For the C cup size group, the following significant

Table 17

Analysis of Pairwise Differences for Overall Comfort  
Scores for the A Cup Size Group in Seven Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	LF
55.14	CS			*				
58.40	JB			*				
49.38	LD							
56.86	CU			*				
56.96	AY			*				
61.08	OC	*		*	*	*		
58.63	LF			*				

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall comfort than the style in the column.

Table 18

Analysis of Pairwise Differences for Overall Comfort  
Scores for the B Cup Size Group in Eight Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
53.05	CS								
58.42	JB	*							
56.13	LD								
58.63	CU	*							
56.01	AY								
59.81	OC	*		*		*			
58.00	OF	*							
60.40	LF	*		*		*			

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall comfort than the style in the column.

differences were observed. They are illustrated in Table 19. The JB, LD, CU, OC, OF and LF bras all scored higher than the CS bra on overall comfort. These were the only significant differences observed. Because of these findings,  $H_{O3-d}$  was rejected.

$H_{O3-e}$ . There will be no difference in the overall comfort rating for each of the eight selected sports bras within the D cup size group.

The significant differences found within the D cup group are shown in Table 20. The JB bra scored higher on overall comfort than the LD and AY bras. The OC bra received higher comfort scores than the LD and AY bras. The OF bra was rated higher on comfort than the AY bra, and the LF bra scored higher than the CS, LD, CU, and OF bras. Hence,  $H_{O3-e}$  was rejected.

#### Hypothesis 4--Overall Support Ratings

A repeated measures analysis of variance was used to test all parts of Hypothesis 4 in the same manner as Hypothesis 3. The summaries of the analyses of the A, B, C and D cup sizes in seven styles, and the B, C and D cup sizes in eight styles are presented in Tables 21 and 22.

An examination of Tables 21 and 22 reveals that there were significant differences in the overall support scores for the eight different styles of bras (  $\underline{F} = 7.19$ ,  $\underline{F} = 4.90$ ,

Table 19

Analysis of Pairwise Differences for Overall Comfort  
Scores for the C Cup Size Group in Eight Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
54.91	CS								
61.62	JB	*							
58.73	LD	*							
61.80	CU	*							
58.60	AY								
61.12	OC	*							
59.48	OF	*							
60.67	LF	*							

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall comfort than the style in the column.

Table 20

Analysis of Pairwise Differences for Overall Comfort  
Scores for the D Cup Size Group in Eight Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
55.10	CS								
58.29	JB			*		*			
53.27	LD								
54.94	CU								
51.78	AY								
58.47	OC			*		*			
54.93	OF					*			
60.37	LF	*		*	*			*	

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall comfort than the style in the column.

Table 21

ANOVA Summary Table for Overall Support Scores for the  
Combined A, B, C and D Cup Size Groups Wearing Seven  
Selected Styles

Source of Variation	df	MS	<u>F</u>	p Level
<u>Main Effect</u>				
Cupsize (S)	3	184.04	5.69	0.002
Person/Cupsize (P)				
[Error A]	54	32.32	2.69	0.000
Style of Bra (B)	6	86.44	7.19	0.000
<u>Interaction</u>				
Cupsize x Style	18	32.08	2.68	0.000
Style x Person/				
Cupsize [Error B]	291	12.03		

Table 22

ANOVA Summary Table for Overall Support Scores for the  
Combined A, B, C and D Cup Size Groups Wearing Eight  
Selected Styles

Source of Variation	df	MS	F	p Level
<u>Main Effect</u>				
Cupsize (S)	2	180.75	4.59	0.016
Person/Cupsize (P)				
[Error A]	41	39.41	3.07	0.000
Style of Bra (B)	7	62.94	4.90	0.000
<u>Interaction</u>				
Cupsize x Style	14	44.21	3.44	0.000
Style x Person/				
Cupsize [Error B]	257	12.85		

$p \leq .05$ ). Because a significant F was found, pairwise differences relating to each part of Hypothesis 4 were investigated with the LSD method, and are presented below.

H<sub>O</sub>4-a. There will be no difference in the overall support rating for each of the eight selected sports bras within the entire group.

The following significant differences between the eight bra styles were found, and are presented in Tables 23 and 24. The CS bra scored higher on overall support than the OC bra. The LD bra received higher scores than the CS, JB, CU, AY, OC, OF and LF bra styles. The CU bra scored higher on support than the CS and OC bras, and the LF bra scored higher than the OC bra. On the basis of these findings, H<sub>O</sub>4-a was rejected.

H<sub>O</sub>4-b. There will be no difference in the overall support rating for each of the eight selected sports bras within the A cup size group.

The significant differences found within the A cup size group are summarized in Table 25. Because the OF bra was not manufactured in an A cup size, no comparisons were made with it. The LD bra scored higher on overall support than the JB, AY and OC bras. Hence, H<sub>O</sub>4-b was rejected.

H<sub>O</sub>4-c. There will be no difference in the overall support rating for each of the eight selected

Table 23

Analysis of Pairwise Differences for Overall Support  
Scores for the Combined A, B, C and D Cup Size Groups  
in Seven Selected Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	LF
29.36	CS						*	
29.63	JB							
32.68	LD	*	*		*	*	*	*
30.94	CU	*					*	
30.14	AY							
28.85	OC							
30.76	LF						*	

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall support than the style in the column.

Table 24

Analysis of Pairwise Differences for Overall Support  
Scores for the Combined B, C and D Cup Size Groups in  
Eight Selected Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
29.36	CS								
29.63	JB								
32.68	LD	*	*		*	*	*	*	*
30.94	CU	*					*		
30.14	AY								
28.85	OC								
30.32	OF	*					*		
30.76	LF						*		

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall support than the style in the column.

Table 25

Analysis of Pairwise Differences for Overall Support  
Scores for the A Cup Size Group in Seven Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	LF
31.21	CS							
29.67	JB							
33.50	LD		*			*	*	
32.14	CU							
30.47	AY							
30.48	OC							
32.29	LF							

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall support than the style in the column.

sports bras within the B cup size group.

The following significant differences between the eight styles of bras were found, and are presented in Table 26. The JB bra scored higher on overall support than the AY bra. The LD bra received higher support scores than the CS, AY and OF bras. Based on these findings,  $H_{O4-c}$  was rejected.

$H_{O4-d}$ . There will be no difference in the overall support rating for each of the eight selected sports bras within the C cup size group.

For the C cup size group, the following significant differences were identified, and are summarized in Table 27. The JB, LD and CU bras all scored higher on overall support than the CS bra style. Because of these differences,  $H_{O4-d}$  was rejected.

$H_{O4-e}$ . There will be no difference in the overall support rating for each of the eight selected sports bras within the D cup size group.

The significant differences found within the D cup size group are shown in Table 28. The CS bra scored higher on overall support than the JB, OC and OF bras. The LD bra received higher overall support scores than the CS, JB, CU and OC bras. The CU, AY, OF and LF bras all scored higher on overall support than the JB and OC bras. Therefore,  $H_{O4-e}$  was rejected.

Table 26

Analysis of Pairwise Differences for Overall Support  
Scores for the B Cup Size Group in Eight Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
30.14	CS								
32.41	JB					*			
32.94	LD	*				*		*	
31.75	CU								
29.71	AY								
30.63	OC								
29.94	OF								
31.05	LF								

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall support than the style in the column.

Table 27

Analysis of Pairwise Differences for Overall Support  
Scores for the C Cup Size Group in Eight Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
28.31	CS								
31.81	JB	*							
32.00	LD	*							
31.11	CU	*							
30.07	AY								
30.49	OC								
30.27	OF								
29.68	LF								

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall support than the style in the column.

Table 28

Analysis of Pairwise Differences for Overall Support  
Scores for the D Cup Size Group in Eight Selected  
Styles (LSD Method)

Mean	Style	CS	JB	LD	CU	AY	OC	OF	LF
27.76	CS		*				*	*	
24.64	JB								
32.28	LD	*	*		*		*		
28.75	CU		*				*		
30.33	AY		*				*		
23.80	OC								
30.76	OF		*				*		
30.06	LF		*				*		

\*Denotes pairs of groups significantly different,  $p < .05$

Note. In each pairwise case, the style in the horizontal row scored significantly higher on overall support than the style in the column.

### Summary

This chapter has reported differences among eight selected sports bras in vertical displacement, overall comfort ratings, and overall support ratings. Additionally, differences in vertical displacement between cup size groups in the nude condition were examined. Four null hypotheses and their individual parts were stated. The pre-determined level of significance was .05.

A one-way analysis of variance was used to test the null Hypothesis 1, a repeated-measures analysis of variance and covariance was used for the null Hypothesis 2, and a repeated-measures analysis of variance was used for null Hypotheses 3 and 4. All significant F values were subsequently tested for pairwise differences using the LSD method.

Significant differences in vertical displacement, overall comfort ratings, and overall support ratings were found among the group as a whole, and among each of the individual cup size groups. This resulted in the rejection of all null hypotheses.

## CHAPTER V

### SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A summary of the study and findings, a discussion of those findings, and conclusions derived from the findings follow. Recommendations for sports bra design, further research and individual sports bra selection are included.

#### Summary

##### Purpose of the Study

The purpose of the study was to evaluate currently marketed sports bras for differences in control of vertical displacement of the breast, overall comfort and overall support. Determination of differences in vertical displacement in the nude condition among the four cup sizes studied was an additional objective. Further, results of the study were to be used to develop guidelines for the improvement of sports bra designs for women of all breast sizes.

##### Sample and Methodology

The 59 subjects were volunteer female students and employees of Utah State University, and female residents of Cache and Salt Lake Counties, Utah. The subjects were

divided into four experimental groups of approximately equal size according to bra cup size (A, B, C and D). Subjects needed to be in adequate physical condition to be able to complete all exercise-related portions of the testing. Prior to participation in filming and field-testing, demographic and anthropometric data were collected from the subjects.

Eight sports bras were selected for testing on the basis on their use in previous research, innovativeness and diversity of design, and their availability in a wide range of sizes.

To determine and compare differences in the vertical displacement of the nude breast, and to compare differences in the biomechanical support provided by the eight sports bras, subjects were filmed while jogging on a treadmill. Film data were analyzed frame by frame on a Lafayette Motion Analyzer. Reference marks placed on the body and breast enabled the researchers to calculate the net vertical movement of the breast relative to the body.

To determine differences in overall comfort and support ratings, subjects tested each of the eight styles of bras under actual exercise conditions. Data on comfort and support were gathered using a questionnaire developed by the researchers from the review of literature. Questionnaire items called for rating on a 5-point Likert-type scale. Subjects exercised in each bra for at

least twenty minutes duration just prior to completing the evaluation form. Overall scores were determined by summing responses to the questions relating to comfort, and summing responses to those questions relating to support.

#### Statistical Procedures

Four null hypotheses with a total of sixteen individual parts were developed for purposes of statistical analysis. The null hypotheses were tested using one-way analysis of variance, repeated-measures analysis of variance and covariance, and repeated-measures analysis of variance. The significance level for all tests was established at .05. Table 29 provides a summary of the hypotheses and brief findings. A discussion of the findings follows.

#### Findings of the Study

Vertical displacement of the nude breast. Testing of Hypothesis 1 revealed that there is significantly more vertical displacement for the D cup size group than for the A, B or C cup size groups. There were no other significant differences in displacement between cupsize groups.

Vertical displacement allowed by the eight selected sports bras. Testing of the five individual parts of Hypothesis 2 revealed significant differences in the eight styles' abilities to control breast motion during exercise.

Table 29

Hypotheses Summary Table

Hypothesis	<u>F</u>	Conclusion
$H_0 1$ :		
There will be no difference in the amount of vertical displacement of the breast among A, B, C and D cup size groups in the nude condition.	4.73**	Rejected
$H_0 2$ :		
There will be no difference	18.96**a	
in the amount of vertical	22.42**b	
displacement allowed by		Rejected
of the eight selected sports bras relative to the nude condition while jogging.		
$H_0 3$ :		
There will be no difference	13.28**a	
in the overall comfort	8.51**b	
rating for each of the		Rejected
eight selected models of sports bras.		

Table 29, Continued

Hypotheses Summary Table

Hypothesis	<u>F</u>	Conclusion
H <sub>0</sub> 4:		
There will be no difference	7.19** a	
in the overall support	4.90** b	
rating for each of the		Rejected
eight selected models of		
sports bras.		

\*\*Significant,  $p < .05$

<sup>a</sup>Combined A, B, C and D cup size groups wearing eight styles.

<sup>b</sup>Combined B, C and D cup size groups wearing seven styles.

-For the whole group, both the CS and LD bras allowed significantly less vertical displacement than the other six bras (JB, CU, AY, OC, OF and LF). Among the B, C and D cup size groups (the A cup size group did not test the OF bra), the OF bra allowed less motion than the JB, CU, AY, OC and LF bras, and the LF allowed significantly less motion than the OC bra.

-Within the A and B cup size groups, only the CS and LD bras allowed significantly less vertical displacement than any other bras.

-Within the C cup size group, the CS and LD bras allowed significantly less displacement than all of the other 6 bra styles, and the OF bra allowed less motion than the AY, OC and LF bras.

-Within the D cup size group, the CS bra allowed significantly less vertical displacement than each of the other seven styles. The LD bra allowed less motion than the JB, CU, AY, OC and LF bras. The OF bra allowed less displacement than the JB, CU, AY and OC bras, while the LF bra did a better job of controlling motion than the JB and OC bras.

Overall comfort scores. Testing of the five individual parts of Hypothesis 3a established the following differences in overall comfort ratings.

-Within the entire group, the JB and CU bras were rated significantly higher on overall comfort than the CS,

LD and AY bras. The OC and LF bras were scored higher than the CS, LD, CU and AY bras. Among the combined B, C and D cup size groups, the OF bra scored significantly higher on comfort than the CS bra, and the LF bra scored higher than the CS, LD, AY and OF bra.

-Within the A cup size group, every other bra scored significantly higher on overall comfort than the LD bra, and the OC bra additionally scored higher than the CS, CU and AY bras.

-Within the B cup size group, the JB, CU and OF bras all achieved significantly higher scores on overall comfort than the CS bra. The OC and LF bras were rated significantly better than the CS, LD and AY bras.

-Within the C cup size group, the JB, LD, CU, OC, OF and LF bras all scored significantly higher on overall comfort than the CS bra.

-Within the D cup size group, the JB and OC bras were rated significantly higher on overall comfort than the LD and AY bras. The OF bra outscored the AY bra, and the LF bra scored higher than the CS, LD, CU and OF bras.

Overall support scores. Testing of each of the individual part of Hypothesis 3b established the following significant differences in overall support scores between the eight styles.

-For the entire group, the LD bra scored significantly higher on support than all of the other seven bras. The CS

and LF bras were rated higher on support than the OC bra. The CU and OF bras scored higher than both the CS and OC bras.

-Within the A cup size group, the LD bra scored significantly higher on overall support than the JB, AY and OC bras.

-Within the B cup size group, the JB bra scored higher than the AY bra, and the LD was rated higher than the CS, AY and OF bras.

-For the C cup size group, the JB, LD and CU bras all scored significantly higher on support than the CS bra.

-Within the D cup size group, all six other bras were rated higher than the JB and OC bras on overall support. The CS bra also scored better than the OF bra, and the LD outsourced the CS and CU bras on this measure.

#### Discussion of the Findings

##### Vertical Displacement in the Nude Condition

The D cup size group displayed significantly more vertical displacement in the nude condition than either the A, B or C cup size groups. Because there were no significant differences between any other groups, this finding would seem to indicate that excessive breast motion is an especially serious problem for active women in the D cup size group, and that sports bra research needs to be

slanted toward the needs of this cup size group.

Differences in Vertical  
Displacement Allowed by  
the Eight Bra Styles

The CS and LD bras demonstrated excellent low ratings for vertical displacement within all cup sizes. The OF bra also performed well. It is helpful to look at specific design features of these and other bras to examine reasons for good performance on this criterion.

First, The fabric of the CS bra is very firm and only slightly stretchy. The straps also allow very little stretch. The waist-length design of the bra allows the bra to fit firmly around the torso without cutting in below the breasts, and provides support from both above and below the breasts. The design produces a rather flattened, rounded silhouette, which serves to hold the breasts close to the body.

The LD bra is also constructed of a very firm, barely stretchy fabric, and the double layer of material in the cup area provides additional support. Since the band below the breasts and the binding around the armholes are non-elastic, the only stretch comes from a small elastic insert at the back of the bra and at the back ends of the straps. The LD bra is a firmer, even less "giving" design than the CS bra, and probably only scored slightly less well on displacement because its rather pointed cup silhouette allows the tips of the breasts to move more.

The OF bra's design features that help control motion include molded, non-stretch cups, non-elastic straps which are connected almost directly to the cup, and a rounded contour that keeps the breasts relatively close to the body. The LF bra has similar design characteristics, except that the cups are set into a surrounding stretchy frame, and this may keep the LF bra from controlling motion more effectively.

Two of the bras that did not perform well--the JB and the OC bras--are constructed of all-elastic fabric and straps. The CU bra fabric is also somewhat stretchy, the straps are quite elastic, and the cups are surrounded by stretchy insets. This degree of elasticity does not appear to provide the needed support, particularly for larger breasted women. The AY bra, while being constructed of rather firm fabric, may offer too little support below the breasts, and has an excessively pointed silhouette which does not hold the breasts close to the body and allows unnecessary motion.

It is of interest to note that fewer significant differences in displacement occurred within the A and B cup size groups, and that the most differences occurred within the D cup size group. Evidently, the mass and volume of the larger sized breast put the supportive capabilities of a sports bra to a more serious test.

During the process of analyzing the film, it became evident that there is a fair amount of lateral breast displacement occurring during exercise. In some cases, this lateral motion appeared to add significantly to the total length of the excursion of the breast with each stride, so that vertical displacement alone was perhaps not an accurate measure of total breast motion. The extent of lateral motion seemed to be dependent upon the amount of shoulder rotation and the running style exhibited by each subject, as well as on breast size. Because of difficulties in distinguishing lateral breast displacement from shoulder rotation while observing from a single camera angle, no attempts were made to measure lateral displacement or total breast excursion.

Another observation that resulted from viewing the film during the analysis procedure is that stride frequency seems to affect the amount of vertical displacement. Even though all subjects ran on the treadmill at a given speed and grade during filming, the frequency of their steps determined how far in the air they rose and fell with every stride. Large bounding strides appeared to increase the distance, speed and momentum of breast motion, and increase the force with which the breast slapped against the chest wall. Quicker, smaller steps seemed to minimize the up and down movements of the breast. Informal observation of the

differences in stride frequencies for the various cup size groups suggest that perhaps larger breasted women have adapted a shorter stride so as to minimize breast motion and run more comfortably.

#### Differences in Overall Comfort Ratings

Two of the bras rating very well on overall comfort were the JB bra and the OC bra. These two bras share the characteristics of being all-elastic, of having no fasteners, of being constructed of a soft, cotton-blend knit fabric and of having a cross-back or Y-back strap configuration that minimizes slipping of straps during exercise. These qualities were all found to be desirable in previous sports bra research.

Two other more conventionally styled bras which scored well on comfort, the CU and the LF, are both made of a light, comfortable cotton-blend fabric, and incorporate stretchy areas and inserts around the cup to allow for freedom of movement. The OF bra, in addition to having light cotton-blend fabric cups, also features a front opening between the cups for ease of movement and ventilation, and well-cushioned back hooks.

Of the bras that did not rate well on comfort, the CS and LD bras present the problems of being constructed of firm, bulky, overly hot fabric, and of perhaps not allowing

easy expansion of the ribs in the chest area. Subjects registered complaints about tightness and cutting in the armhole area, and about difficulties in getting in and out of these two bras. This last problem is probably due to a lack of hooks on the part of the CS bra, and to an excess of hooks (5) on the LD bra.

Subjects complained of the AY bra being too "pointy," of its rough seams on the inside of the cups, of the scratchiness of the mesh surrounding the cup, and of a silhouette design fault that causes excessive pressure across the upper part of the breast but allows the lower part to sag.

The A cup size group scored the LD bra lower on comfort than any other bra. They may have found that five hooks and total lack of elasticity excessively supportive for someone who may barely even need a bra for exercise. The B and C cup size groups' low scores for the CS bra were probably related to the hotness and heaviness of this bra, along with the difficulty inherent in getting it on and off the body.

#### Differences in Overall Support Ratings

The first finding of note is that the subjective ratings of support were not always consistent with the more objective observations of vertical displacement. This

would suggest that there is more to the concept of support than simple restriction of vertical motion.

The LD bra, which allowed significantly less motion than all other styles except the CS bra, probably owes its high scores on overall support to its non-elastic fabric and straps, and to how well it separates the breasts and holds them close to the body. It provides support from both the chest area and the shoulder strap area. The OF bra, which also rated well at controlling motion, offers molded, non-stretch cups and straps, and a rounded silhouette. There seems to be no reasonable explanation for the CU bra's high scores, as it did not rate well at controlling displacement in the biomechanical portion of the study.

The low overall support rating assigned the CS bra by the A, B and C cup size groups was surprising, since the CS bra allowed less vertical displacement than any other style. This rating may be partially explained by the unconventionality of the design. The CS bra does not separate and uplift the breasts in the conventional manner--it compresses them close to the body. Perhaps the subjects did not perceive this style as supportive for this reason. It may not "feel" like a supportive bra usually feels. Another possible explanation may relate to many subjects' general dislike of this style. Many did not like the black color, the flat silhouette, the hotness of the

fabric and the difficulty of putting it on and off. Because they found it uncomfortable or unacceptable in other ways, they may have been reluctant to give it high marks on any characteristic.

It is again notable that there were less significant differences between styles among the A, B and C cup size groups. Because their need for support is less, their bras may not be stressed to the same extent as bras worn by the D cup size group, and differences in supportiveness may not be as apparent to them.

The results of the overall comfort and overall support ratings pose a difficult dilemma for the sports bra designer. The styles that were highly rated on comfort tended to be rated low on support, and vice versa. Some styles seem to have reached a compromise between comfort and support, but may not have rated particularly well on either criterion. This suggests that the choice of style for a particular person should be somewhat dependent upon the size and needs of that person, and her preference for a particular silhouette. This also suggests that sports bra designers and manufacturers may need to move away from their present practice of designing all sizes--A, B, C and D--of one style exactly alike.

#### Conclusions

Based on the findings from this study, the following

conclusions were drawn:

1. Women in the D cup size group experience significantly more vertical displacement of the nude breast during exercise than women of A, B and C cup sizes.

2. The eight selected sports bras tested in this study differ significantly in their capacity to control breast motion during exercise. This effect is seen within the group as a whole, and in all cup size groups, A, B, C and D.

3. There are significant differences between the eight selected sports bras in subjectively determined overall comfort and support ratings, within the group as a whole, and within each cup size group.

#### Recommendations

##### Recommendations for Sports Bra Selection

The results of the study indicate that there is no clear winner among the eight styles of sports bras that rated high on all three criteria: control of objectively measured vertical displacement, overall comfort rating, and overall support rating. To the question of which sports bra is best, one must answer that it depends upon consideration of a number of individual variables.

Cup size. Perhaps the most important factor in determining bra style selection is cup size. For a larger

breasted woman, control of vertical displacement is essential for pain-free exercise. Since she is probably willing to sacrifice some comfort in return for more adequate support, she should consider non-stretchy cup fabrics and straps. A smaller breasted woman, on the other hand, needs little in the way of support, and should consider bras that are more elastic and comfortable.

Sport engaged in. Different sports require varying amounts of arm involvement and range of motion. Sports such as aerobic dance, basketball, volleyball, tennis and racquetball involve considerable shoulder rotation and reaching above the head. An appropriate bra for these sports should have enough stretch in the straps that the shoulders are not chafed and cut into, and should have a strap configuration that does not slip off the shoulders. For sports that require a lot of leg action but little overhead arm motion, such as running, walking and soccer, strap comfort is less important while control of vertical displacement is more crucial. For these sports, a non-stretch strap provides more support.

Individual breast configuration. Sports bras and individuals vary considerably in cup shape and separation. An active woman will be able to exercise most comfortably in a bra configuration that is complementary to her own breasts, and that does not either press her breasts

together unduly in the center or pull them apart toward the armpits. It is generally helpful to try several different styles prior to making a purchase decision.

Silhouette preference. Sports bras come in a number of silhouettes, from very flat to very pointed. Again, it is helpful for a woman to try several styles in order to find a profile that is pleasing to her individual taste. If the bra is to be used exclusively for sports activities, a flatter silhouette may be acceptable. If the bra is also intended for all-purpose use, a more conventional silhouette may be more appealing.

Fabric preferences and sensitivities. Sports bras are available in cotton fabrics, synthetic fabrics, and blends of the two. There is also a wide range of fabric weights, from thick and heavy to thin and light. Fabric choice should be based upon one's intensity of activity, climatic and seasonal conditions, support requirements, and possible allergic reactions to a particular type of fiber.

#### Recommendations for Sports Bra Design

Based upon this research and the valuable opportunities it afforded to talk with active women about their sports bra needs and preferences, the following recommendation are set forth:

1. Sports bras should be designed for the needs of a particular cup size. In this study, all sizes of a given

bra style were exactly the same, i.e., both the 32A and the 36D LD bra had non-elastic construction and five hooks down the back. Manufacturers should not be afraid to segment their style designs to fit the requirements of the various cup size groups.

2. A survey of participants in this study indicates that many larger women would prefer a sports bra design that incorporates an underwire, since they feel that the underwire provides better separation and support. Underwires are now being developed that are actually made of plastic and that are flat and non-irritating. It seems that an underwire design incorporating other features desirable in a sports bra would meet the needs of large breasted women better than existing styles of sports bras.

3. Sports bra manufacturers need to re-evaluate the silhouettes of their bras and make design changes that will lessen both breast motion and psychological discomfort. Ideally, a sports bra will provide some separation between the breasts, but at the same time, the contour should be as non-pointed as possible so that the breast is held closer to the body's center of gravity.

4. One serious, limiting problem in sports bra design at the present time is a lack of specially designed fabrics that can provide firm support but still be thin, cool and comfortable enough to wear during vigorous exercise.

Adequate fiber and fabric technology certainly exists, but it has not been directed toward this specific end. Sports bra manufacturers need to invest time and effort into developing fabrics more appropriate for sports bra use.

5. Manufacturers need to reconsider strap design and configurations, and how they relate to the neckline and armhole designs of other athletic apparel such as leotards and running singlets. More effort could be applied to coordinating strap position with necklines so that neither functionality or attractive appearance is lost.

#### Recommendations for Further Research

Because this area of study is still somewhat undeveloped, the research process established valuable information about the sports bras tested, as well as insights into the development of appropriate research methodologies. The following recommendations reflect the researcher's special concern for methodological advancements:

1. In future research stride frequency during the filming process needs to be standardized through use of a metronome. This would assure greater accuracy in comparing both style and cupsize differences.
2. There is a need to develop more objective means of determining comfort and support. This could be partially

accomplished through the use of pressure point analysis, and the utilization of heat and temperature sensors to measure how effectively heat and moisture are allowed to leave the breast surface during exercise.

3. The distance of total breast excursion during exercise, rather than simply the amount of vertical displacement, needs to be examined. Access to computer interfaced video equipment and software for digitizing the information would make this type of analysis fairly straightforward. The use of two camera angles would enable the researcher to separate true lateral displacement due to breast motion from shoulder rotation.

4. Since all clothing creates a microenvironment around the body, there is a need for more research on how clothing affects the body's thermo-regulatory capacities, and for development of fibers and fabrics that enhance the body's capabilities to accomplish thermo-regulation during exercise.

5. Sports bra research efforts should concentrate on the needs of larger breasted women in an effort to remove barriers to exercise that may presently exist for these women.

## REFERENCES

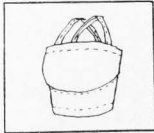
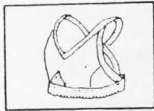
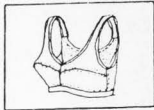
- Bayne, J. (1968). Pro + tec protective bra. Journal of Sports Medicine, 8, 34-35.
- Burdett, R. (1983). Status of biomechanical research in sports and physical education, Research Newsletter Consortium, 7 (1).
- Gehlsen, G., & Albohm, M. (1980). Evaluation of sports bras, The Physician and Sports Medicine, 8 (10), 89-96.
- Gerber, E., Felshin, J., Berlin, P., & Wyrick, W. (1974). The american woman in sport. Reading, Mass.: Addison-Wesley Publishing Co.
- Haycock, C. (1978). Breast support and protection in the female athlete, AAHPERD Consortium Symposium Papers. 1 (2), 50-53.
- Haycock, C., Shierman, G., & Gillette, J. (1978). The female athlete--does her anatomy pose problems?, American Medical Association 19th conference on the medical aspects of sports, Monroe, Wisconsin: AMA Press, 1-9.
- Hunter, L., & Torgan, C. (1982). The Physician and Sports Medicine, 10 (11), 75-76.
- Oglesby, C. (1978). Women and sport: From myth to reality. Lea & Febiger.
- Pollock, M., Laughridge, E., Coleman, B., Linnerud, A., & Jackson, A. (1975). A water displacement method for determination of body density in young and middle-aged women. Journal of Applied Physiology, 38, 745-749.
- Schuster, K. (1979). Equipment update: jogging bras hit the streets, The Physician and Sports Medicine, 7 (4), 125-128.
- Text of draft resolutions drawn up at conference on women and sports. (1983, November 16). The Chronicle of Higher Education, p. 26.

Women marathoners describe bra needs. (1977). The Physician and Sports Medicine, 5 (4), 12-13.

## APPENDICES

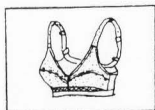
## Appendix A

## Features of Bras

<u>Style &amp; Price</u>	<u>Fabric</u>	<u>Features</u>
Elegant Support \$29.95	94% nylon, 6% spandex	No rigid fasteners Non-stretch cross straps Boned support from above the breast Snug fit to the waist Firm, thick fabric Custom sizes available from 30 A to 42 DD
		
Jogbra \$18.95	Cups: 46% cotton, 8% Lycra, 46% polyester Elastic: Lycra, nylon, polyester	No rigid fasteners Seams away from body Elastic cross straps Flat cut to compress breasts Wide elastic band below breasts Salt-resistant elastic Ventilation panel below breasts
		
Lady Duke Unknown	Cups: 55% cotton, 45% polyester Elastic: 82% nylon, 18% spandex	Firm fabric Non-stretch straps Seams away from body Non-elastic band below breasts Wide camisole back with 5 hooks Optional protective Ensolite pad inserts
		

## Cupid

Unknown



## Body:

Cotton,  
polyester,  
spandex

## Elastic:

Nylon,  
spandexLight mesh cup  
fabric

Adjustable straps

Stretch mesh

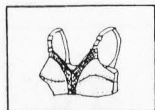
inserts under

breasts to keep

bra in place

Actively  
Yours

\$25.00



## Cups &amp; straps:

80% polyester,  
20% cotton

## Mesh inserts:

100% nylon

## Back: 42% nylon,

33% cotton,  
25% LycraAdjustable,  
non-stretch  
straps

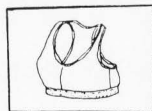
Lowcut armholes

Mesh inserts above

and between cups

Polyester/cotton  
blend cupsOlga's Christina  
Sportsbra

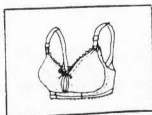
\$20.00

92% cotton,  
8% Lycra"Y-back" stretch  
strapsInner molded  
stretch cupCotton encased  
elastic band  
below breasts

No rigid fasteners

Olga's Freedom  
Frontrunner

\$15.00

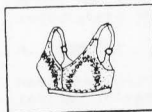


Cups:  
65% cotton,  
35% polyester  
Back:  
78% nylon,  
22% spandex

Molded, poly-cotton  
mesh non-stretch  
cups  
Adjustable  
non-stretch  
straps  
Ventilation slit  
between cups  
Covered inside  
seams

Lily of France

\$15.00



Cups:  
82% polyester,  
12% cotton,  
6% spandex  
Elastic:  
83% nylon,  
17% spandex

Smooth, molded cups  
Lace inserts around  
cups for  
ventilation  
Adjustable  
non-stretch strap  
Covered inside  
seams  
Strap placement set  
close in back to  
keep straps up on  
shoulders

## Appendix B

## Bra Evaluation Form

## BRA EVALUATION SHEET

Your Name \_\_\_\_\_ Date \_\_\_\_\_  
 Name of Bra Tested \_\_\_\_\_ Size (chest) \_\_\_\_\_ (cup) \_\_\_\_\_  
 Type of Exercise (running, racquetball, etc.) \_\_\_\_\_  
 Length of Exercise Session (minimum of 20 minutes) \_\_\_\_\_  
 Weather conditions (if done outside) \_\_\_\_\_

PLEASE READ OVER THE FOLLOWING QUESTIONNAIRE BEFORE TESTING THE BRA

Please answer the following questions regarding the physical comfort and support, and the "psychological fit" of the bra you have just tested. In order for your evaluation to be valid, you should fill in this form immediately after exercising in the bra. This is VERY IMPORTANT.

## A. COMFORT

Here are some questions concerning the comfort of the bra you have just tested. Please circle the appropriate response after each question.

1. Metallic or plastic parts or fasteners rub and irritate the skin:
  - A. On the back.
 

not at all	a little	somewhat	a lot	excessively
------------	----------	----------	-------	-------------
  - B. Under or between the breasts.
 

not at all	a little	somewhat	a lot	excessively
------------	----------	----------	-------	-------------
  - C. On the straps.
 

not at all	a little	somewhat	a lot	excessively
------------	----------	----------	-------	-------------
2. The shoulder straps slip down and do not stay in place.
 

not at all	a little	somewhat	a lot	excessively
------------	----------	----------	-------	-------------
3. Seams on the bra (across the nipple or any other spot) are bulky or irritating.
 

not at all	a little	somewhat	a lot	excessively
------------	----------	----------	-------	-------------

4. The bra "rides up" and does not stay in place.

not at all      a little      somewhat      a lot      excessively

5. There is a feeling of tightness or pressure around the ribcage or across the back.

not at all      a little      somewhat      a lot      excessively

6. The bra cuts into the arm or armpit and causes chafing.

not at all      a little      somewhat      a lot      excessively

7. The straps cause pressure and chafing on the shoulders or back.

not at all      a little      somewhat      a lot      excessively

8. The bra cup fabric is stiff or itchy.

not at all      a little      somewhat      a lot      excessively

9. The trim on the bra is stiff or itchy.

not at all      a little      somewhat      a lot      excessively

10. The bra fabric is hot or bulky.

not at all      a little      somewhat      a lot      excessively

11. The bra fabric gets damp and uncomfortable during exercise.

not at all      a little      somewhat      a lot      excessively

12. How would you rate this bra on overall comfort on a scale of 1 to 5, with 1 representing very uncomfortable, and 5 representing very comfortable?

1	2	3	4	5
Very uncomfortable				Very comfortable

13. Based on COMFORT alone, would you purchase this bra for use as a sports bra?

a. Yes      b. No

## B. SUPPORT

This group of questions concerns the way this sports bra supports your breasts. Again, simply circle the appropriate response following each question.

1. This bra's support seems to come mainly from the shoulder straps.  
not at all      a little      somewhat      a lot      excessively
2. This bra's support seems to come mainly from the chest or breast area of the bra.  
not at all      a little      somewhat      a lot      excessively
3. The bra holds my breasts close to the body.  
not at all      a little      somewhat      a lot      excessively
4. The bra separates my breasts.  
not at all      a little      somewhat      a lot      excessively
5. The bra allows my breasts to move or bounce.  
not at all      a little      somewhat      a lot      excessively
6. The bra straps stretch during exercise.  
not at all      a little      somewhat      a lot      excessively
7. The bra cup fabric stretches during exercise.  
not at all      a little      somewhat      a lot      excessively
8. I feel pain or discomfort in my breasts while running with this bra.  
not at all      a little      somewhat      a lot      excessively
9. If you experienced breast pain or discomfort, is this discomfort due in any way to pre-menstrual breast swelling?  
a. Yes                      b. No                      c. Not applicable



6. Would the amount of dissatisfaction with the femininity of the bra keep you from buying or wearing this sports bra for exercise?

a. Yes                      b. No

7. On a scale of 1 to 5, with 1 representing no self-consciousness at all and 5 representing very self-conscious, consider the amount of bounce or jiggle this bra allows and rate how self-conscious you feel exercising in this sports bra:

a. in front of other women

1	2	3	4	5
Not at all self-conscious			Very self-conscious	

b. in front of men

1	2	3	4	5
Not at all self-conscious			Very self-conscious	

8. Would the amount of self-consciousness about exercising in this bra keep you from buying this sports bra for exercise?

a. Yes                      b. No

#### D. FINAL SCORE

1. All things considered, on a scale of 1 to 5, with 1 representing the worst rating and 5 representing the best rating you would give a sports bra, what overall rating would you give this bra?

1	2	3	4	5
Worst				Best

2. All things considered, would you purchase this bra for use as a sports bra?

a. Yes                      b. No

Please feel free to add any other observations or comments you may have about this bra: