

Influence Factors of Sports Bra Evaluation and Design Based on Large Size

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Abstract. The purpose of this paper was to find the main influence factors of sports bra evaluation by the subjective assessment of different styles commercial sports bra, and to summarize the design elements of sports bra for large size. 10 women in large size (>C80) were chosen to evaluate 9 different sports bras. The main influence factors were extracted by factor analysis and all the product samples were classified by Q-cluster analysis. The conclusions show that breast stability, wearing comfort and bust modelling are the three key factors for sports bra evaluation. And a classification-positioning model of sports bra products was established. The findings can provide theoretical basis and guidance for the research and design of sports bras both for academic and sports or underwear enterprises, and also provide reference value for women customers.

1 Introduction

The demand of sports bra is increasing due to the popularity of sports and the enhancement of the consciousness of bodybuilding. At the same time, more and more women begin to realize the importance of breast health protection during exercise, and they also give a higher demand to the comfort and functionality of sports bra. The researches on the comfort and evaluation of sports bra were mainly focused on two aspects: pressure comfort and breast displacement. Sports bra is more effective in reducing breast pain and breast displacement than other bra [1]. This protection effect is more obvious in the women with large breast sizes [2]. Zhou et al. [3] evaluated the reduction degree of breast displacement during exercise. The study concluded that the most effective bras had the following features: compression type, short vest style, high neckline, slings, cross back, bound neckline, no center gore, no wire, no cradle, no pad and a non-adjustable wide strap. Although there are many researches on the breast displacement and pressure comfort of sports bra [4-7], however, there is little published information on sports bra evaluation and its influence factors.

Given the lack of research about sports bra evaluation, the purpose of this paper was to find the main influence factors, as well as the design elements of sports bra evaluation by the subjective assessment of different styles commercial sports bra from large size women. A classification-positioning model of sports bra products was established afterwards. It can provide theoretical basis and guidance for the research and development, as well as the products design and evaluation of sports bra both for academic and sports or underwear enterprises, and also provide reference value for women customers.

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2 Methods

2.1 Experiment samples

9 different styles commercial sports bras were chosen as the experiment samples. The detailed information was shown in Table 1. The 9 chosen samples are from different sports or underwear brands with high awareness.

Table 1. Information of experiment samples.

No.	Components (Body)	Style characteristic	Figure
1	Nylon 90.0% Spandex 10.0%	Light support, inserted pads, adjustable elastic straps	
2	Nylon 79.0% Spandex 21.0%	Molded cups, air holes in pads, adjustable elastic straps	
3	Polyester 43.0% Nylon 38.0% Spandex 19.0%	Molded cups, air holes in pads, racerback	
4	Polyester 88.0% Spandex 12.0%	Medium support, molded cups for large size, racerback	
6	Nylon 82.0% Spandex 18.0%	Double layer fabric, with wires, adjustable elastic straps	
7	Nylon 73.0% Spandex 27.0%	Molded cups, with wires, adjustable elastic straps	
8	Polyester 82.0% Spandex 18.0%	Light support, double layer fabric, molded cups, racerback	
10	Polyester 75.0% Polyurethane 10.0% Nylon 5.0% Spandex 10.0%	High support, inserted pad, racerback	
11	Nylon 58.0% Cotton 24.0% Spandex 18.0%	Light support, adjustable elastic straps	

2.2 Participants

Subjects were 10 female (C80, D80, E80) who did sports regularly and were familiar with sports bra, with the age range of 18-30 years. The sizes of sports bra samples corresponded with each breast size.

2.3 Subjective assessment

The experiment was taken by means of subjective assessment. Firstly, a pre-experiment was done to sum up the high mentioned evaluation items and focus points when the subjects were fitting. The

results show that the large size pays more attention to the cup inclusiveness and bust gather. The subjects were asked to rate the samples on a scale of 1-5 (1 refers to very uncomfortable, 5 refers to very comfortable), including four stages (before fitting, after fitting, after sports and comprehensive assessment). Table 2 showed the detailed subjective evaluation items.

Every bra would be evaluated by each subject, without time limitation and in a quiet room maintained at a temperature of 20°C and a relative humidity of 60%. Before fitting, the subjects started to rate the thickness of fabric (1 refers to very thick, 5 refers to very thin) and fabric preference. Then, the subjects began to fit the sample bras in no particular order and were asked to rate the corresponding evaluation items. Afterwards, according to the experiment set, the subjects were required to do five motions under three different exercises intensity (light, medium and high), including arm lifting, body twisting, stand and reach, high knee stepping and jump jack. Each movement repeated three times. After all the motions finishing, the subjects started to rate corresponding evaluation items on a scale of 1 to 5. Finally, the subjects gave a comprehensive preference evaluation for each sample bra.

Table 2. Subjective evaluation items.

Stages	Evaluation items
Before fitting	Thickness of fabric, fabric preference
After fitting	Tightness of under bust, tightness of shoulder straps, cup inclusiveness) , bust modelling (up, protrusion, gather) , outwear, easy to wear
After sports	Breast stability, under bust stability, shoulder straps stability, shoulder straps comfort
Comprehensive assessment	Overall preference

3 Results

3.1 Correlation between products preference and other evaluation items

Pearson correlation was taken. Before fitting was set as state I. After fitting was set as state II. And after sports was set as state III.

As shown in Table 3, before fitting, products preference has a negative correlation with thickness of fabric ($P=0.003$), while it has a positive correlation with fabric preference ($P=0.000$). After fitting, products preference is significantly correlated with bust modelling (including protrusion, gather and up) and cup inclusiveness ($P=0.000, 0.006, 0.000, 0.004, 0.001$). It shows that the large size is more sensitive to cup inclusiveness. After sports, products preference has a positive correlation with breast stability and under bust stability ($P=0.000, 0.001$).

Table 3. Correlation coefficients of sensory values for each evaluation item.

State	Correlation				
	Correlation	Thickness	Fabric		
I	Preference	-.310**	.380**		
	Correlation	Under bust tightness	Shoulder straps tightness	Cup inclusiveness	Bust modelling
II	Preference	-0.112	0.026	.353**	.597**
	Correlation	Protrusion	Gather	Up	Easy to wear
	Preference	.287**	.463**	.303**	0.182
	Correlation	Breast stability	Under bust stability	Shoulder straps stability	Shoulder straps comfort
III	Preference	.440**	.348**	0.149	0.105

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

3.2 Factor analysis of evaluation items

Based on the results of correlation, factor analysis of evaluation items was done by means of principal component analysis.

In terms of large size, three factors were sufficient to describe the data, given in Table 4. Factor one is highly related to bust modelling (including up, gather and protrusion), defined as modelling factor. Factor two is highly related to breast and under bust stability, defined as stability factor. Factor three is highly related to fabric and cup inclusiveness, defined as inclusiveness and comfort factor.

Table 4. Rotated component matrix^a.

Factors	Items	Component		
		1	2	3
Modelling	Breast modeling	0.779	0.261	0.104
	Protrusion	0.735	-0.245	0.259
	Gather	0.756	0.301	-0.015
	Up	0.816	0.253	-0.074
Stability	Breast stability	0.147	0.88	-0.125
	Acceptance degree of breast motion	-0.268	-0.816	-0.041
	Under bust stability	0.046	0.628	0.407
Inclusiveness and comfort	Fabric	-0.017	-0.06	0.889
	Cup inclusiveness	0.292	0.291	0.408

3.3 Cluster analysis of products based on evaluation factors

Based on the results of factor analysis, factor assignment was done for each product sample before cluster analysis. This paper aims to sum up the classification positioning of sports bra. The method used Q-cluster in hierarchical cluster analysis.

Nine products of the large size were divided into three groups (Table 5). Taking reference to average score of evaluation items (Table 6), key findings show that products no.1, 6, 8, 11 with high scores in cup inclusiveness, along with shoulder strap pressure comfort and easy to wear, belong to the product with good inclusiveness and high comfort; Class two are products no.3 and 7, which gets high scores in breast modelling (including protrusion, gather and up), defined as the product with good modelling; Products no.2, 4, 10 with good performance on breast and under bust stability belong to the product with good motion stability. However, these products get low scores in breast modelling, especially no.10. Product no.4 shows poor performance on shoulder strap pressure comfort. Many subjects felt uncomfortable on the shoulder points.

Table 5. Agglomeration Schedule.

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	8	11	0.052	0	0	2
2	1	8	0.322	0	1	6
3	2	10	0.419	0	0	5
4	3	7	0.567	0	0	7
5	2	4	0.661	3	0	8
6	1	6	1.132	2	0	7
7	1	3	1.664	6	4	8
8	1	2	2.739	7	5	0

Table 6. Average score of evaluation items.

Class	No.	Fabric	Cup inclusiveness	Breast modelling	Protrusion	Gather
Inclusiveness and comfort	1	3.5	3.8	2.8	2.9	2.1
	6	4.1	3.4	3	4.4	2.9
	8	3.5	4.1	3.2	3.2	2.7
	11	3.8	4.2	2.9	3.6	2.4
Modelling	3	4.2	4.7	4.1	4	3.9
	7	3.6	4.2	3.6	3.9	3.4
Stability	2	3.6	4.1	3.2	3.7	2.7
	4	3.8	4.4	3.1	2.3	3.1
	10	3.2	3.1	2.7	2.8	3.4
Class	No.	Up	Breast Stability	Under bust stability	Shoulder strap comfort	Easy to wear
Inclusiveness and comfort	1	2.6	1.8	2.9	4.1	4.5
	6	3.6	1.5	3.3	4.4	4.2
	8	3	2.2	3.6	4.2	3.1
	11	3	2.4	3.4	4.8	4.7
Modelling	3	4.1	3.4	4.6	3.9	3.5
	7	4	2.4	4.4	4.2	4.7
Stability	2	3.9	4.4	4.3	4.3	4.5
	4	2.9	3.8	4.7	2.6	2.8
	10	3.4	3.7	4.7	3.4	2.8

4 Discussions

4.1 Influence factors of sports bra evaluation

The focus of large size women is relatively concentrated. Taken together, the main evaluation factors are breast modelling, motion stability and comfort and inclusiveness.

Related research [8,9] showed that 56% of the women had breast pain and discomfort during exercise. The prime reason is that the breast is doing long-term reciprocating motion during exercise, resulting in breast tissue stretching deformation, even breast ligament injury. Therefore, good breast stability in movement process is one of the key factors in the evaluation of sports bra.

Pressure comfort has been one of the focuses on sports bra comfort. Bowles et al. [10] found that cross-back shoulder strap produced more pressure than traditional shoulder strap, but the difference in pressure produced of two shoulder straps did not reflect on the difference of shoulder comfort. In this evaluation experiment, the results demonstrate that the pressure comfort of cross-back shoulder strap is lower than that of traditional one.

Although sports bra is used in sports, most experimenters put forward the requirement of breast modelling in the evaluation process. Breast modelling effect directly affects the final results of the evaluation. The sports bra with wires had better breast modelling, but the wearing comfort was reduced instead. Therefore, not only the motion function and wearing comfort need to be improved, breast modelling should also be taken into account in sports bra design and research.

4.2 Establishment of classification-positioning model of sports bra products

This paper summed up the key evaluation factors of sports bra products by factor analysis. Namely, modelling factor, stability factor, inclusiveness and comfort factor for large size. Combined with the factor value assignment results of products, a three-dimensional classification-positioning model of sports bra products was established, as shown in Figure 1. From the coordinate model, the

classification positioning of different products and the features of each classification group can be seen directly, providing reference for enterprises in the future commercial positioning.

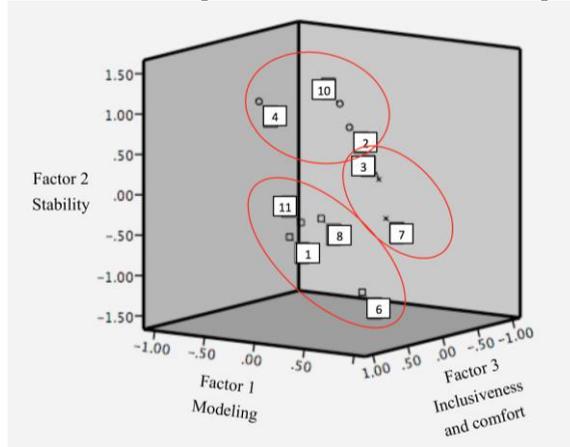


Figure 1. Classification-positioning model of sports bra products.

5 Conclusion

This paper summed up the main influence factors of sports bra evaluation by the subjective assessment of different styles commercial sports bra based on large size, and summarized the design elements of sports bra for large size. Breast stability, wearing comfort and bust modelling are the three important factors for sports bra evaluation. Wearing comfort refers to fabric comfort and pressure comfort. And pressure comfort mostly reflects on the shoulder strap pressure. A three-dimensional classification-positioning model of sports bra products was established based on the influence factors, providing a guiding value in the future commercial positioning and design of sports bra for enterprises.

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