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METHODS

The design and analysis of the bra fit on V-Stitcher 3D software

Mong Hien Thi Nguyen*

Faculty of Mechanical Engineering, University of Information Technology – VNUHCM, Ho Chi Minh City, Vietnam

***Correspondence:**
Mong Hien Thi Nguyen,
ntmhien14719@hcmut.edu.vn

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This paper presents the results of research and design of women's bras and analysis of the product's fit on three-dimensional (3D) simulation software, V-Stitcher. The study was conducted on 130 females aged 25–35 years old. The research results were divided into four body shape groups from the sample based on classification criteria for FFIT body shape, as measured by principal component analysis, factor cluster analysis, and an analysis of variance test on SPSS software. Group 1 has 51 people, group 2 has 24 people, group 3 has 51 people, and the last has four people. In each of the four groups, choose the one with the highest percentage by sample number to design the base pattern. The products are evaluated on the model to check if the bra is comfortable when people wear it. Besides that, products are simulated through 3D V-Stitcher software to check the fit through the display of different colors on the tension and pressure charts. These evaluation results are checked for reliability by Cronbach's alpha coefficient. The results of this study provide a way to assess the fit of clothes in accordance with the current 4.0 trend.

Keywords: bra, simulation, fit clothes, body shape, principal component, V-Stitcher

Introduction

Underwear general and the bra in particular are indispensable in women's daily lives. The function of a bra is to support the volume of the breast while helping to improve its appearance, usually by increasing breast size (1). Therefore, the shaping of the bra is very high to achieve the technique for a well-balanced natural fit (2). Wearing a bra is just as important as wearing outerwear because it comes into direct contact with the skin of the body. However, it has been reported that 70% of the female population in the United Kingdom, especially large-breasted women, wear the wrong bra size (3–6). One study surveyed 100 women and found that they were wearing the wrong bra size 77% of the time (7). What's particularly sad is that women who need bras with the most support are the least likely to get bras that fit and feel comfortable. This can significantly affect their physical health and quality of life (8, 9). A well-fitting bra is suggested to be important in providing adequate support for the breasts and for comfort (10), as bras are often worn when in direct contact with the skin for more than 12 h a day (11, 12). There are many kinds of underwear for body shapes such as triangle, rectangle, hourglass, and spoon shape (13), and they are created by smart fabrics (14). Therefore, it is necessary to research and design women's daily bras and simulate them with V-Stitcher software to check the fit in the design of the sample quickly and save money because of the trial sewing. This study will show different body shapes in the upper bodies of Vietnamese females when measured. These physiques are simulated through the avatar's images of V-Stitcher software. This research direction is a sample testing method that minimizes sample sewing time and raw material costs. Furthermore, customers can see the product in the shortest time to meet the urgent needs of consumers and producers.

Material and methodology

Material

Vietnamese females between the ages of 25 and 35. Determine the sample size according to the following formula (1):

$$n = \frac{t^2 \times \sigma^2}{m^2} = \frac{1.96^2 \times 2.91^2}{0.5^2} = 130 \text{ (people)} \quad (1) \ (15)$$

In Equation (1), n is the sample (people); t is the Student coefficient (t = 1.96); m is error (m = 0.05); and σ is standard deviation (σ = 2.91 cm). Thus, the sample size selected for this study has an accuracy of 95% and requires 130 people.

The research uses Gerber Accumark two-dimensional (2D) and V-Stitcher 3D software. Besides that, lace fabric is used to sew bras.

Methodology

The method of data collection: directly measuring 24 anthropometric dimensions, including one height, three body length dimensions, 14 body circumference dimensions, and six bust-related dimensions. Body shape analysis techniques: Using SPSS 21.0 software to perform principal component analysis of a set of dimensions to reduce large amounts of data into a small number of subgroups with common features. It uses analytical subgroups of subjects by *K*-means and discriminant analysis to find the differences between groups of research subjects (16, 17). Finally, it is used to test analysis of variance (ANOVA) for the mean of independent sample groups. Based on this test result and FFIT's criteria to classify body shape, the bras are created using a 2D pattern from the basic block (18) and the bra design formula system (19). The results of the study are tested for fit on a 3D simulated method through the tension map and pressure map. They are checked for reliability according to Cronbach's alpha coefficient.

Results and discussion

Analysis of the body shape

Through a survey of 24 body sizes of 130 women in the study age group to analyze the body shapes by the *K*-mean cluster method. The results show the mean and standard deviation

TABLE 1 | The result of body shape analysis.

STT	Dimensions	Positions	Sample		Group 1	Group 2	Group 3	Group 4	*F*	Sig
			N = 130 (100%)		*N* = 51	*N* = 24	*N* = 51	*N* = 4		
			Average	SD	Average	Average	Average	Average		
1	Height	A	155.65	4.18	156.51	158.71	153.78	150.0	14.13	0.000
2	Side length	B	97.32	1.42	97.2	97.3	97.4	97.4	4.38	0.000
3	Waist length	C	38.27	2.17	38.78	38.06	37.96	36.75	2.08	0.011
4	Bust depth	D	23.27	1.50	24.13	22.75	22.79	21.50	12.94	0.000
5	Arm length	E	54.96	3.61	55.89	55.92	53.83	51.70	4.83	0.003
6	Across shoulder	F	35.80	2.16	36.47	36.08	35.18	33.50	5.16	0.002
7	Across back	G	33.98	2.27	35.04	33.83	33.34	29.50	13.13	0.000
8	Across chest	H	31.50	2.14	32.46	30.75	31.14	28.50	8.95	0.000
9	Chest	I	82.09	4.25	85.57	77.58	81.34	74.25	60.65	0.000
10	Bust	K	85.13	4.18	88.63	80.23	84.53	77.50	75.82	0.000
11	Lower bust	L	73.85	4.43	77.00	68.63	73.67	67.50	46.10	0.000
12	Waist	M	70.87	5.15	75.00	64.27	70.45	63.00	73.23	0.000
13	Abdomen	N	85.71	5.27	89.56	81.79	84.66	73.50	41.40	0.000
14	Hip	O	90.67	4.95	94.39	86.88	89.62	79.50	43.34	0.000
15	Armhole	P	36.92	3.46	37.83	35.02	36.82	37.88	3.96	0.010
16	Bicep	Q	26.65	2.78	28.03	24.21	26.33	27.63	14.04	0.000
17	Thigh	R	52.36	3.86	55.04	48.94	51.73	46.75	29.66	0.000
18	Calf	S	33.23	2.49	34.36	31.79	32.74	33.70	8.07	0.000
19	1/2 bust gap	T	17.06	0.77	17.22	16.79	17.08	16.50	2.48	0.064
20	Bust slope	U	18.63	1.25	19.04	18.42	18.42	17.25	4.49	0.005
21	Bust height	Pu-PB.P	7.77	0.97	8.04	8.06	7.42	7.00	5.58	0.001
22	Side bust arc	Po-PB.P	9.50	1.21	9.64	9.48	9.39	9.13	0.48	0.698
23	Center bust arc	Pi-PB.P	8.45	0.91	8.64	8.35	8.36	7.63	2.10	0.104
24	Middle of bust	V	1.72	0.26	1.69	1.60	1.80	1.75	4.08	0.008

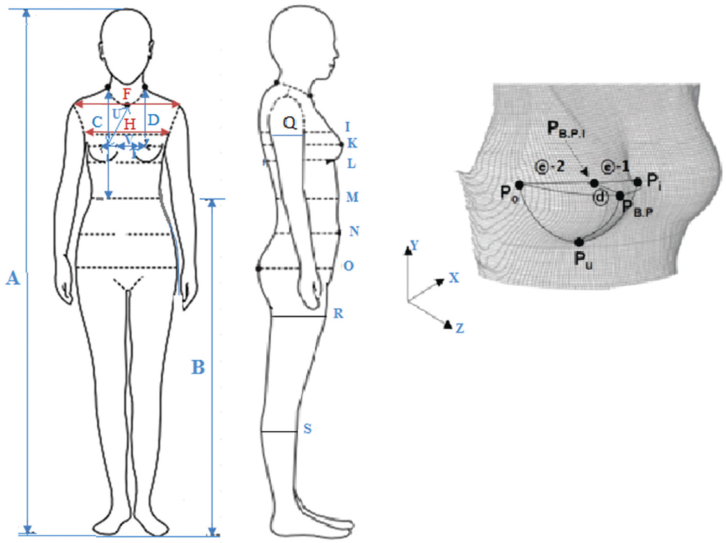


FIGURE 1 | Positions to measurements of the body.

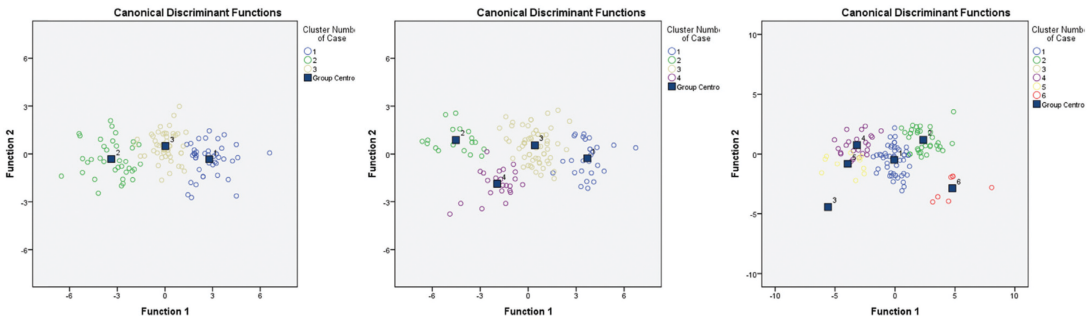


FIGURE 2 | The distribution of samples (three group, four group, and five group).

(SD) of the four body groups as follows (**Table 1**). The body's dimensions are measured as in **Figure 1**.

The results of the classification of 130 samples into three kinds of groups are as follows: there are three groups, four groups, and five groups. Besides that, *K*-mean cluster analysis allows the analyst to proactively impose the number of groups to be classified. Based on the results of *K*-mean cluster analysis, initially choosing the solution divided into three groups, four groups are the most suitable because the distribution chart of these groups has no overlap between the groups (**Figure 2**). Combining the ANOVA test, describing the data dispersion, the solution divided into four groups was selected. In the solution for four groups, the difference between variables is the highest compared to the three group solution. The solution of dividing into four groups with 23/27 variables with a Sig < 0.05 value shows that there is a quantitative difference between the groups being compared. Based on classification criteria for FFIT body shape, all groups are simulated on virtual avatars. Groups 1 (**Figure 3**) and Group 3 (**Figure 4**) have oval shaped bodies. Compared with Group 3, Group 1 had wider shoulders, bust, and waist circumference. In Group 3, the waist was not clearly distinguished from the buttock circumference. Group 2 (**Figure 5**) has an hourglass shape with a slight difference in hip and bust measurements of about 6.65 cm. The waist measurement (64.27 cm) is clearly distinguished from that of the hip (86.88 cm) and the bust (80.23). Group 4 (**Figure 6**) has a rectangular shape. The measurements of the hip (79.5 cm) and the bust (77.5 cm) are not significantly different. The waist (63 cm) is not clearly distinguished compared with the buttocks and the bust.

These different variables are the characteristic dimensions of the upper body: bust, waist, shoulder width, cross-chest, and bust height. The dimension components that need attention when designing samples, which have a great impact on the body analysis process for Vietnamese women aged 25–35, are shoulder width, across front/back, bust, waist, and hip. Based on the chest shape profile, it shows that the busts of four groups have different average bust sizes, but there is not much difference in bust shape. In Group 1, the average bust measurement was 88.6 cm, Group 3 was 84 cm, and the difference in bust between the two groups was 4.6 cm. Group 2 has an average bust measurement of 80 cm, while Group 4 is 77 cm. The difference in bust between the two groups is 3 cm. Group 2 (purple color) and Group 4 (blue color)

FIGURE 3 | The Shape of Group 1.

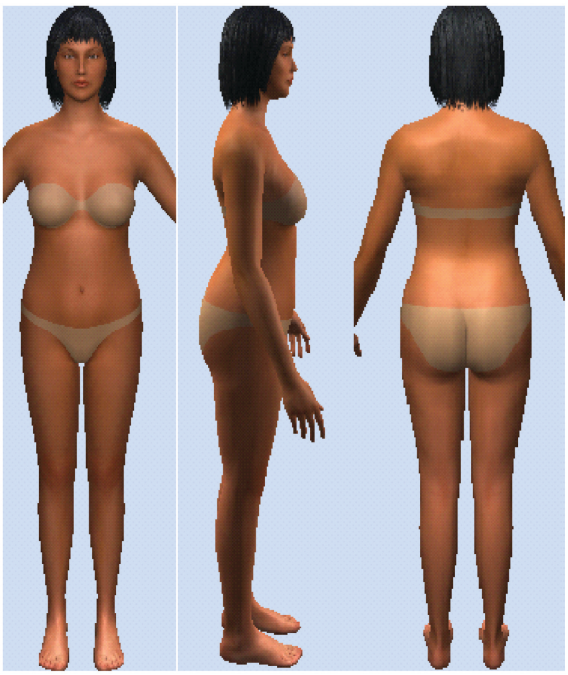


FIGURE 5 | The Shape of Group 2.

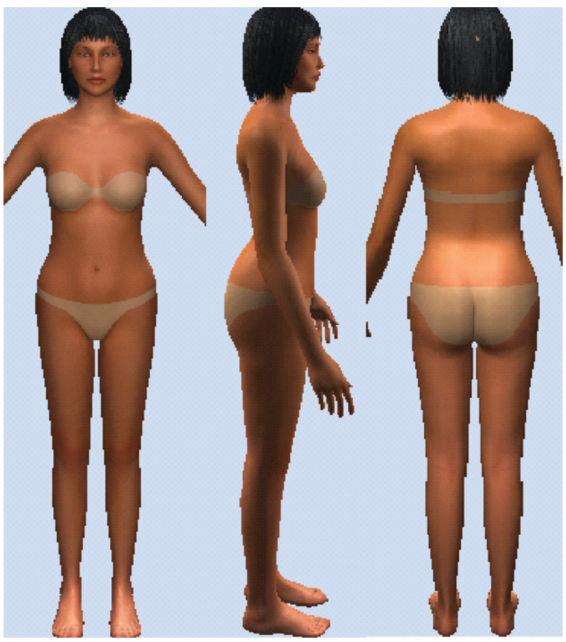


FIGURE 4 | The Shape of Group 3.

FIGURE 6 | The Shape of Group 4.

have relatively similar bust sizes, being smaller than Group 1 (black color) and Group 3 (red color) (**Figure 7**).

The designing of the 2D basic block

Based on **Table 1**, Group 3 is the group with the average measurement among the four groups and also the group with the largest number of people (39%), so Group 3 will be selected as the base group for flat pattern design (**Table 2**).

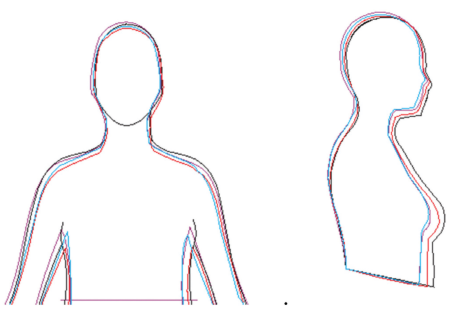
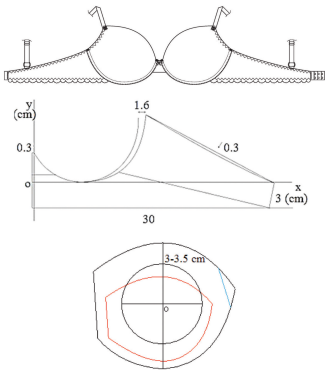
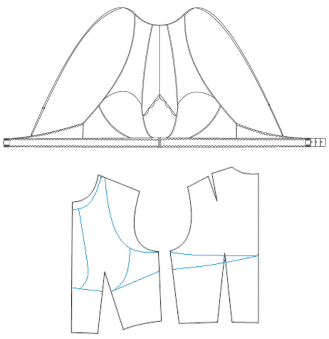
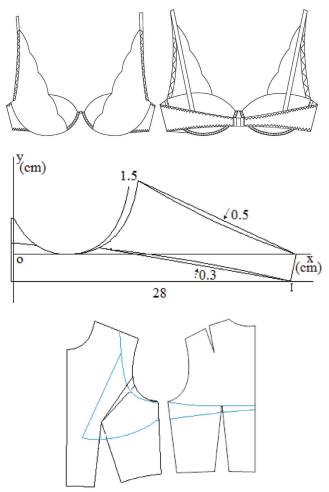


FIGURE 7 | Body difference across four groups (Groups 1, 2, 3, and 4: black, purple, red, and blue).

TABLE 2 | The sketch and the technical design for bras.

Sample	The Sketch and the Technical Design
1	
2	
3	

Analysis of the fit of the samples

Fit clothes are all about the feeling of satisfaction when wearing them. **Figure 8** shows three designs worn on models with base group body measurements. The survey of satisfaction about wearing feelings was conducted on 10 people with bust measurements belonging to the base group, with six criteria: comfort, beautiful design, like to use, and easy to wear, round fit chest, and easy movement. They all agree with these six criteria. Then, calculate Cronbach's alpha with SPSS to evaluate the reliability of the resulting scale. The results of five samples show all greater than 0.7 (**Table 3**). This

FIGURE 8 | Bras wear on models.

TABLE 3 | The Cronbach's alpha for bra samples.

Samples	Cronbach's alpha	No of Items
Sample 1	0.887	6
Sample 2	0.893	6
Sample 3	0.829	6

FIGURE 9 | Bras simulation on avatars that fit perfectly.

shows that the aforementioned survey results are completely reliable; there is a correlation and consistency in the answers of the respondents.

In addition, the authors use 3D V-Stitcher software to test the fit of the bras on the virtual avatar (**Figure 9**). The grid areas are green and yellow, showing that the designs fit perfectly and bring comfort and ease to daily use.

Conclusion

From the measurement data of 130 women aged 25–35 in the study, four groups of female body shapes with different chest profiles were classified in each group. In addition, the study uses SPSS software to process data by principal component analysis, factor analysis, and offers many subgroups to choose from. The subgroup with four different female body shapes was selected after conducting an ANOVA test. The analyzed body shapes are as follows: Group 1 and 3 have an oval body shape; Group 2 has an hourglass figure, and Group 4 has a rectangular body shape. Base sample Group 3 has measurement parameters close to the average of four groups, so it is selected as the base group for 2D flat pattern design and simulation design for three bras on V-Stitcher. As a result, this has scientific and practical significance in the

field of costume design and opens up deeper and broader research directions for other types of clothing. As a result, designers can use the data in the table to design patterns for female subjects whose bust measurements are similar to the basic block. In addition, the study also provides adjustment directions for the design positions of the body shapes to achieve the right fit, establishing a new size chart for Vietnamese women.

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