DEVELOPMENT OF BRASSIERE SIZING SYSTEM FOR SOUTH INDIAN GIRLS

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ABSTRACT

Correct size and fit are the two prime issues faced by Indian women wearing brassiere. The size is different for each country. Accordingly, developing a new sizing system for brassieres for Indian girls is crucial. The present research focuses on developing a size chart specifically for unmarried girls of south India. A total of 1000 South Indian girls aged between 18-25 years were measured. Key dimensions were determined using principal component analysis. Seven best sizes were recommended and developed size chart was validated through fit analysis.

KEYWORDS: Anthropometric Survey, Size System, Size Chart, Factor Analysis, Principle Component Analysis, Fit Analysis, Brassieres

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1. INTRODUCTION

Indians can broadly be alienated to comprise at least three cluster namely people of north India, eastern India and south India. The anthropometry and body shape of the women varies as people in diverse parts of the nation follow different diet, climatic and customs. The anthropometric data is to be restructured frequently as there is a change in people's lifestyle, food habits, and cultural composition (Singh et al 2015). Mathematical models shaped to predict a variable in one population group failed to be accurate in other populations (Kautilya et al 2013). The bust dimension of women of diverse geological origin has been a topic of conjecture during the current times past (Anderson et al 2013). There are 39 ethnic groups in India with wide variety of height, body structure, stance, etc., thus the main challenge of branded apparel retail industry is correct fit of garments across Indian population.

A good quality brassiere worn by women should provide satisfying shape, fit, comfort and required support for the breast. Greenbaum et al (2003) investigated the appropriateness of brassiere fit in 102 women adverted for breast reduction surgery and found that most of the women wore a wrong size brassiere. The majority of women put on the brassiere with below sized band and outsized cup and reported that while evaluating with manufacturer's fitting rule, the measurement of back has been underestimated and the cup size has been overestimated by a mean of three sizes. Poor fit and design of brassiere causes physical and physiological problems in the body. Tight shoulder straps will exert pressure on the shoulders and rigid under wires causing pain and rashes etc. (Cherie et al 2015). Chin et al (2010) studied the physical characteristics related to brassiere fit and stated that poorly fit brassiere causes distress and effects the sales of sellers. An important feature affecting brassiere fit is the body contour. Brassiere manufacturers are not using consistent size charts and possess size chart and their own methods of grading sizes (McGhee & Steele 2006). Manufacturing correct fitting brassieres is always been a challenging matter with producers and sellers (Wood et al., 2008). The fit issues mostly seen in brassieres are due to incorrect cup size (Oh and Chun 2014) and wearing the wrong size brassiere. Bras vary across brands from

cup sizes to band lengths (Patel 2019).

An appropriate anthropometric data is required to build an excellent sizing system (Winks 1997). Zheng et al (2006) state that a good sizing system can be built by cautiously selecting the measuring methods to attain precise measurements, manage the subject's stance and body landmark. ISO 7250 (1996) states the procedure for measuring a live model wearing a minimum clothing and no footwear. While taking the body measurements, the model stands upright with shoulders relaxed, arms left on the sides and placing the feet together. ISO 15535 (2003) describes the common requirements to create anthropometric databases pertaining to collection of data, data base format, contents and statistical procedure.

McCulloch et al (1998) used statistical model to construct an apparel sizing system. Three features are important to create a sizing system that is having large population, decreasing the number of sizes in the system and improve the fit in the accommodated population. Hsu et al (2005) constructed a sizing system using decision tree based data mining. Decision tree based data mining technique was constructive as it allows to cover a wider range of body shapes with a few number of sizes, produce standard sizing patterns and gives a reference guide to manufacturers to carry out production easily.

According to Hsiao et al (2005), principal component analysis (PCA) is a constructive tool for providing functional representative body models. Parkinson and Reed (2009) also used PCA and linear regression statistical technique to draft details from the databases to determine values for an extensive range of body measurements. Gupta (2008) used univariate and multivariate analysis to develop the sizing system for young Indian men and women in the age group of 18-24 years. Subjective fit trials were conducted with the developed size chart and obtained good fit.

The aim of the research is to develop a new size chart for brassieres. In India, the size charts of other nations are used for construction of brassieres and the size charts referred are superseded. The current sizing system used by manufacturers are out-dated ones and there is a necessity to create a size chart targeting specific population; south India women. This will definitely lessen the fit issues in brassiere and would help them to use the right size bra. Therefore, it is imperative for clothing manufactures to have a new size chart for Indian female figure types. Study on body anatomy has recognized that as the age increases, intense changes are noticed in the female breast (Rosen 2001). Posture and bilateral symmetry of women changes as they age that affects the fit of clothing (Ashdown et al 2008). Hormonal changes in teen girls and early adult women leads to variations in body dimension and changes in breast shape. The breast profile of an unmarried woman is pointed and becomes ptotic and breast shape changes after breast feeding (Dilek et al 2010). The anthropometric survey was conducted for unmarried girls of South India. The body measurements were obtained for thousand girls in the age group of 18 -25 years. To develop a sizing system, factor analysis and cluster analysis were used using SPSS statistical software. Wear trial expressions (Physiological and Psychological fit) were carried out for validating the developed size chart.

2. MATERIALS AND METHODS

2.1 Anthropometric Survey

The new size chart was developed for brassiere using large number of breast measurements. Anthropometric survey was conducted on unmarried girls of South India in the age group 18-25. A total of 1000 girls were selected, who were pursuing their undergraduate and post graduate studies in engineering institutions and arts and science colleges in Chennai,

Bangalore and Coimbatore. The samples consist of girls from five different states namely Tamil Nadu (39.7%), Kerala (30.5%), Karnataka (18.5%), Andhra Pradesh (6.1%) and Telangana (5.2%).

2.1.1 Measuring Dimensions and Measuring Points

The body dimensions were measured on each subject as per the ISO 8559/1989 anthropometric standards. Weighing scale with the capacity up to 130 kg was used to measure weight and height was taken using height chart. Seven anthropometric measurements are required for brassiere and are shown in Table 1.

Table 1 Anthropometric measuring points for Brassiere

S.NO	Human Anatomy	Measurements
1		<p>To measure the Over bust girth, measuring tape was taken around the circumference of the chest above the breasts, in which tape goes under the arms and high on the back.</p> <p>To measure the Bust girth, tape was kept around the fullest part of the breasts, typically at the nipples.</p> <p>To measure the Under bust girth, tape was taken around the midriff below the breast.</p>
2		<p>To measure the Strap length, tape was kept 4.5" below the shoulder in front and was taken over the shoulder to the back, till 2.5" below the back width.</p>
3		<p>To measure the Cup height, tape was kept from the bottom centre of the underwire (under bust) to the cup's edge. And to measure the Cup width, tape was kept from the side seam to centre front, in the full width of the bust.</p>
4		<p>To measure the Bust points, tape was kept between the two bust points</p>

2.1.2 Measurement Conditions

The objectives of the research and the importance of sizing system for Indian women were explained to all the subjects. They were advised to wear any one of the branded brassiere like Lovable, Jockey and Enamor which are non-padded and are made of materials like 100% Cotton, Cotton/Lycra and Nylon/ Polyester. Subjects were requested to wear a close fitting brassiere. The measurements were taken over the brassiere for 90% of the subjects. The subjects who were hesitant in allowing us to take the measurements over the brassiere, light weight sleeveless cotton top was provided that could be worn over the brassiere. While taking the body measurements, the brassieres that were left loose for few subjects were adjusted and kept upright. To avoid the experimental error, the type of brassiere and its fitting was ensured on all subjects before taking the measurements. The following procedures were adopted to avoid the experimental error while taking the body measurements.

- Look straight, stand erect and do not bend down
- Keep your shoulders relaxed
- Place your arms at the sides
- Keep your legs straight and knees together
- Keep the foot plane and heels placed together
- Keep length of the measuring tape parallel to the floor.
- Never flex or tense your body while you're taking measurements

2.1.3 Trained Personnel's for Taking Body Measurements

The positions of Brassiere measurement and methods used for measuring a Brassiere were explained to the personnel's (Luk & Yu 2016). Five trained females were appointed to take the body measurements on the subjects. They were final year students of Textile Technology and Apparel & Fashion Design Departments. They were well trained in a systematic manner to take accurate and consistent body measurements on the subjects. The reliability test was conducted within the five trained females using a pilot test. Twenty subjects participated in the pilot test. The trained personnel's measured the required brassiere measurements on twenty subjects. The measurements recorded by the trained personnel were compared. It was observed that the reliability between the trained people was higher and measurements error was insignificant in comparison to the differences between the trained females.

2.2 Anthropometric Analysis of Data

Data Collected from the anthropometric study were analysed statistically and the body measurements were correlated, classified and clustered to explain the body figure types and size of the subjects. Therefore, to build a size chart, factor analysis and cluster analysis methods were employed using SPSS statistical software.

2.2.1 Factor Analysis

To obtain the important factors among noticed variables, factor analysis is used. Factor analysis is used to reduce the number of variables from the data that contains many variables. Factor analysis categorizes the variables that have related characteristics. Using factor analysis, small number of factors can be derived from a higher amount of variables. Factor

analysis consist of study on correlation coefficients of the variables with each other, factors are extracted from the correlation matrix and are rotated for the purpose of increasing the relationship between the variables.

2.2.2 Bivariate Pearson Correlation

The bivariate Pearson Correlation is used to measure the force and path of linear correlation between two variables. Pearson Correlation estimates if there is statistical confirmation for a linear relationship between the similar pairs of variables in the population, represented by a population correlation coefficient, ρ ("rho").

2.2.3 Clustering

Cluster study is an examining method of data interpretation with the point of grouping objects based on their body characteristics. It is performed to understand the body dimensions of the sample. K-Means clustering using SPSS software is performed towards grouping the subjects according to similarities of measurements (Zakaria 2011). Varied figure types were recognized depending upon the clustering methods where people with related figure types were clustered together.

2.3 Development of Size Categories

The size categorization for Brassiere was developed based on size intervals. The sample population is classified into sections, through related subjects in each cluster other than considerably dissimilar subjects in different cluster groups. To establish the range of the different body dimensions, minimum; maximum; mean value and standard deviation for each definite set of body dimensions were calculated. Size intervals are chosen depending on the range of body dimensions and the total number of sizes obtained. Size interval was fixed depending on the best coverage of the population and not having much number of sizes.

2.4 Sizing System Confirmation

To confirm the sizing method developed for the sample population, the proportion of samples accommodated below every figure type and allocated size is determined. The percentage of every size was added to provide the sum percentage covered by the sizing system as a total.

3 RESULTS AND DISCUSSIONS

3.1 Mathematical study of Body Dimensions

The results of the mathematical analysis, mean and standard deviation (SD) of the anthropometric measurements of the 1000 subjects are shown in Table 2. The mean values states the figure dimensions of the "average" 18-25 years old South Indian girls. From Table 2, it is observed that among the girls aged between 18-25 years, the height of the petite girl is about 141cm and the tallest girl is about 180cm. The average height of the girls is 157.5 cm. The slimmest girl in the cluster weighs 35kg and the stoutest girl weighs 88kg. The minimum and maximum bust girth of 1000 subjects is in the range of 63 cm to 106 cm and the mean bust girth is 84.5 cm. The significant differences in the measurement between the subjects were noticed in the height, weight, under bust, bust girth and over bust areas.

Table 2: Mean and standard deviation of anthropometric measurements

Body dimension	Minimum	Maximum	Mean	SD
Height (cm)	141.0	180.0	157.5	6.2
Weight (kg)	35.0	88.0	55.9	9.6

Under bust (cm)	55.8	101.6	69.9	7.8
Bust (cm)	63.5	106.0	84.5	8.1
Over bust (cm)	60.9	100.8	80.8	7.0
Strap length (cm)	25.4	36.8	29.4	1.8
Cup height (cm)	12.7	30.5	19.3	2.6
Cup width (cm)	14.6	26.4	20.7	2.3
Distance Between Points (cm)	14.0	24.1	19.0	1.6

3.2 Analysis of Variance (ANOVA) on Key Body Measurements

One way Analysis of variance (ANOVA) on key body measurements between the age groups and within the age group of 18-25 years was studied using SPSS software. Table 3 shows the ANOVA test on key body measurements of brassiere at each age group. It was noticed that there is no considerable disparity in the body dimensions between age group of 18-25 years for brassiere. Statistically considerable differences were noted in the bust girth measurement between the age group with the sig. value of bust girth less than 0.05.

Table 3: One way analysis of variance (ANOVA) for brassiere

Body measurements		Sum of Squares	Df	Mean Square	F	Sig.
Height	Between Groups	479.772	7	68.539	1.809	.082
	Within Groups	37594.672	992	37.898		
	Total	38074.444	999			
Bust girth	Between Groups	1041.710	7	148.816	2.342	.022
	Within Groups	63020.381	992	63.529		
	Total	64062.091	999			
Cup height	Between Groups	93.598	7	13.371	1.996	.053
	Within Groups	6645.483	992	6.699		
	Total	6739.082	999			
Cup width	Between Groups	57.416	7	8.202	1.506	.161
	Within Groups	5401.605	992	5.445		
	Total	5459.021	999			

3.3 Body Height Distribution in Population

To understand the height distribution of the 1000 subjects, five different height ranges like 141-148 cm, 149-156 cm, 157-164 cm, 165-172 cm and 173-180 cm were fixed from the minimum and maximum measurements of the body height. An interval of 7 cm was fixed between the size ranges. Figure 1 show, height distribution based on bust girth. It is noticed that the maximum number of subjects fall inside the stature of 160 cm with the bust girth of 75 to 87 cm (30-35 inches). It is observed that the maximum number of subjects fall in the range of 157-164cm with 402 subjects, which is followed by 392 subjects in a range of 149-156cm. Eleven subjects were only found to be in the range of 173-180 cm. These subjects were referred as most tall in the group.

Figure 1: Height distribution (cm) based on bust girth (inch)

3.4 Body Weight Distribution Based on Mean Bust Girth

The distribution of body weight based on mean bust girth is shown in Figure 2. The weight range of 79-89 kg was highest with the mean bust girth size of 101.6 cm. As the body weight increases, the bust girth also increased showing a linear trend. The lowest body weight range was 35-45 kg which has the smallest bust girth size of 72 cm. It is noticed that the maximum no of subjects fall within the weight of 60 kg with the bust girth of 75 to 87 cm (30-35 inches).

Figure 2: Distribution of body weight (kg) and bust girth (inch)

3.5 Correlations between the Body Measurements

In order to analyse linear relationship between the two variables statistically, the correlation between the body measurements was studied. Bivariate Pearson Correlation is used to test the linear relationship between the body

measurements. The correlation was studied between two variables (body measurements) like body height & body weight; body height & bust girth; body weight & bust girth; body weight & cup width; bust girth & under bust girth; bust girth & cup width.

Correlation coefficient between the body dimensions are shown in the Table 4. The result shows that the linear relationship between the two variables were statistically significant ($p < .001$). All the variables in the cells of top right and bottom left are significantly correlated with 0.01 significance level ($p < .001$ for a two-tailed test, depending on a sample of 1000 cases). The direction of the relationship is positive and this tends to increasing for example larger height is related with larger weight. Pearson's r value in body weight and bust girth is 0.849 which is close to 1 between the two variables. Pearson's r value between under bust circumference and bust girth; bust circumference and cup width is 0.896 and 0.851 respectively, which is very close to 1. This indicates that there is a powerful association among the two variables. This shows that changes in one variable are powerfully interrelated with changes in the second variable. The degree, or strength, of the relationship is moderate ($.3 < |r| < .5$). The findings of correlation analysis between body measurements identified the girth dimensions as the key body measurements for the brassiere. The correlation analysis showed that the body height has strong correlation with girth variables.

Table 4: Correlation co-efficient between body measurements

Variables	Body weight		Bust girth	
Body height	Pearson Correlation	0.411**	Pearson Correlation	0.215**
	Sig. (2-tailed)	0.000	Sig. (2-tailed)	0.000
	N	1000	N	1000
Body weight	Bust girth		Cup width	
	Pearson Correlation	0.849**	Pearson Correlation	0.649**
	Sig. (2-tailed)	0.000	Sig. (2-tailed)	0.000
	N	1000	N	1000
Bust girth	Under bust girth		Cup width	
	Pearson Correlation	0.896**	Pearson Correlation	0.851**
	Sig. (2-tailed)	0.000	Sig. (2-tailed)	0.000
	N	1000	N	1000

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

3.6 Factor Analysis

Factor analysis was carried out on the anthropometric body measurements to establish the key body dimension that is required for brassiere. In line with Kaiser– Meyer–Olkin (KMO) criterion of adequacy (KMO) and Bartlett's test of sphericity, every examined group were appropriate for the use of Principal Component Analysis (PCA), with varimax rotation to analyse the key body dimensions. The KMO and PCA results for brassiere are shown in the Table 5.

Table 5: KMO and PCA calculation for Brassiere

Garments	Sampling adequacy (KMO)	Bartlett's tests	Component extracted (PCA)	Factor	Eigenvalue	Scree plot	Cumulative %
Brassiere	0.833	<0.01	2	Factor 1	55.79	2 Components	70.139
				Factor 2	14.349		

To analyse the force of the relationship between the variables, Kaiser-Meyer-Olkin (KMO) and Bartlett's test methods were used. To ensue with acceptable factor analysis, KMO should be larger than 0.5. Pair of variables that has a value less than 0.5 is discarded from the analysis. From Table 6, it is noticed that the KMO condition of adequacy is larger than 0.6 and Bartlett's test results shows less than 0.05 (Hrzenjak et al 2014). This confirms that principal component analysis can be performed on the collected data.

3.6.1 Principal Component Analysis of Collected Anthropometric Data

Table 6 shows the varimax rotation of component loadings in PCA of body dimensions. The result shows that, all variables in the communalities were well represented except brassiere strap measurement. The primary key component (Factor 1) corresponds to the vertical measurements. The second component (Factor 2) signifies the girth variables for brassiere. The component loadings higher than 0.7 was selected as the key dimensions under varimax rotation of factor loadings. Factor 1 and 2 was selected as the main dimensions to fragment the cluster groups for garment sizes. Eigenvalue measures the total variance related to a specific factor. The total of the Eigenvalues of PCA is equal to the summation of the variances of the data. The anthropometric measurements collected for girls shows that the Eigenvalue of Factor 2 (girth measurements) is having a value of 3.9 for brassiere. The body height shows high factor loadings in vertical body measurements. Body height is loaded at 0.976 on Factor 1. The Factor 1 only controls 14% of the variance. It is also observed from correlation analysis that body height has a correlation of 0.215 (R^2 of 0.046) with bust girth. Therefore, body height does not play a role in the sizing system. This shows that anthropometric measurements were largely dependent on girth related variables than the vertical body measurements. The key dimensions showing higher factor loadings in girth related variables are bust girth and over bust girth.

Table 6: Varimax rotation of factor loadings of body measurements

Variables (cm)	Factor 1	Factor 2	Communalities
Body height	0.976		0.956
Under bust girth		0.892	0.816
Bust girth		0.941	0.902
Over bust girth		0.906	0.837
Strap length	0.181		0.062
Cup height	0.791		0.628
Cup width		0.842	0.708
Eigen value	1.004	3.905	
% of variance	14.349	55.79	
The cumulative % of variance	14.349	70.139	

3.7 Clustering

To group the subjects in clusters, the two dimensions namely the girth variables; over bust girth and bust girth was chosen from the principal component analysis. Four groups seemed to be the best and are selected for its distinguishing personality and are sensible for clustering of female sizes (S, M, L and XL). Clusters obtained for the unmarried girls of 18-25 years and their analysis are shown in Table 7. Cluster 1 included subjects with small bust. Cluster 2 includes medium bust; cluster 3 represents large bust; Cluster 4 included extra large bust.

Table 7: Clusters of 18-25 years old females

Parameter	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Mean Over bust girth, cm	65	75	85	95
Range, cm	60.1-70	70.1-80	80.1-90	90.1-100
Mean bust girth, cm	68	78.5	85.5	99.5
Range, cm	65.1-71	72.1- 85	79.1-92	93-106
Number of Subjects	84	319	371	98
Body type	Small	Medium	Large	Extra Large

3.8 Development of Sizing System

Two measurements were selected as key or sizing dimensions: bust girth and over bust girth for sizing brassiere. Bust girth and over bust girth were the determining dimensions for size in unmarried girls of 18-25 years.

3.8.1 Determination of Size Range

The determination of range of sizes requires differentiating the lowest and highest values (Table 1). Four body types were chosen between the ranges of values namely small, medium, large and extra large that could accommodate 100% of the sample population.

3.8.2 Determination of Size Interval

According to British standards BSEN 13402-3 (2004), so as to cater for dissimilarity in a nation and manufacturer's system, size interval of 4cm or 8 cm for women is consistent for bust and waist , size interval of 4cm or 6cm is proposed. Kunick (1984) reports that the size interval of 8cm and as low as 3cm is inconsistent and suggests that the size interval of 6 cm is utmost consistent and mainly used by the countries.

Table 8 represents the whole distribution size of Indian unmarried girls of age 18-25 years with 10 size rolls. The range for over bust girth in the sample size is 40cm from (60-100 cm), which is divided into four subgroups namely 60-70 cm, 70.1-80 cm, 80.1-90 cm and 90.1-100cm. 10 cm interval is fixed between the size ranges. The size interval is selected to accommodate all body types. The total range for bust is 50 cm from (65 -106 cm); the bust size range is separated into 6 sections namely 65-71.9 cm, 72-78.9 cm, 79-85.9 cm, 86-92.9 cm, 93-99.9 cm, 100-106 cm. A size interval of 6 cm was used to divide the bust size range. The sizing system for brassiere is grouped based on small, medium, large and extra large that comprises of 4 sizes in all categories. For all the body type categories, six size grades of XS, S, M, L, XL and XXL are provided based on bust girth. The over bust girth ranges between 60-70 cm, 70.1-80 cm, 80.1-90 cm 90.1-100 cm with the bust girth range of 65 -106 cm . From Table 8, it is observed that the maximum accommodation is at medium and large body type.

In the small size category, one size is given (XS) with the over bust girth in the range of 60-70cm and bust girth in the range of 65 to 71cm. Three sizes (S, M & L) are provided in the medium and large body type (M, L & XL) with the difference in over bust girth from 70.1-80cm and 80.1-90cm respectively. The bust girth for medium and large body type was in the range of 72-99cm. The extra large body type category has three sizes (L, XL & XXL), over bust girth ranges from 90.1-100cm with bust girth between 86 cm and 106cm. A maximum of 319 subjects are in medium size and 371 subjects are in large size. Small body type has the least subjects and sizing system accommodates the population of 89.4 %.

Table 8: Size Distribution for Brassiere with Over bust girth & Bust Ranges

BRASSIERE ANALYSIS						
Size pack	Body type	Key dimensions cm			Accommodation rate	
		Over bust girth	Size grade	Bust girth (cm)	N	%
1	Small	60-70	XS	65-71.9	84	8.4
2	Medium	70.1-80	S	72-78.9	266	26.6
3			M	79-85.9	53	5.3
4			L	86-92.9	7	0.7
5	Large	80.1-90	M	79-85.9	171	17.1
6			L	86-92.9	200	20.1
7			XL	93-99.9	15	1.5
8	Extra Large	90.1-100	L	86-92.9	6	0.6
9			XL	93-99.9	65	6.5
10			XXL	100-106	27	2.7
				Total	894	89.4

3.9 Determination of Sizes for Constructing Brassiere

According to Kwon et al (2009), the choice of the foremost sizes to construct garments is according to the accommodation rate. The sizes that have the accommodation rate of more than 2% are considered for developing size chart. The sizes that accommodate majority of subjects in each body type category are chosen. From Table 8, the total number of best sizes recommended for constructing brassiere for unmarried girls of 18-25 years is seven, one size (XS) in small body type category with bust girth in the range of 65-71cm. Two sizes (S and M) in medium body type category with bust girth measuring 72-85cm. Two sizes (M and L) in large body type category with bust girth ranging from 79-92cm. Two sizes (XL & XXL) in extra large body type category with bust girth in the range of 93-106cm.

3.10 Development of Size Chart for constructing Brassiere

A standard sizing is developed for Brassiere using the over bust girth and bust girth of the target population as the most influential factors for sizing Brassiere. The sizing system produced for Brassiere for unmarried girls of 18-25 years is summarized in Table 9. In view of the fact that good fit and comfort is the primary requirement of Brassiere, a new size chart is suggested for designing Brassiere for unmarried girls of 18-25 years.

Table 9: Sizes for Brassiere

Size Designation	XXS	XS	S	M	L	XL	XXL
Over bust girth range , cm	60-70	70.1-80	70.1-80	80.1-90	80.1-90	90.1-100	90.1-100
Bust girth range , cm	65-71	72-78	79-85	79-85	86-92	93-99	100-106
Bust girth, cm	68	75	82	82	89	96	103
Over bust girth	65	74	76	85	85	94	96
Under bust girth	58	65	70	70	75	80	85
Cup height	12	14	16	18	19	21	24
Cup width	14	16	18	20	22	24	26
Accommodation, %	8.0	26.6	5.3	17.1	20.1	6.5	2.7

There are seven new sizes for brassiere to accommodate those with over bust girth between 60 -100 cm and with bust girth from 65 -106 cm. Two very small; one small, medium, large and two extra large are recommended for brassiere.

It shows the designated size - size XS, that refer to women by a body type of very small bust with the over bust girth range of 70- 80 cm in a size grade of small size and bust girth of 72-78 cm.

3.11 Substantiation of Size Chart for Brassiere

3.11.1 Pattern Design and Construction of Brassieres

Patterns were drafted for Brassieres for all seven sizes using the developed size chart and garments were constructed using cotton elastane stretch knitted fabric (92% cotton and 8% lycra). The components consist of bra cups, centre panel (bridge), bra elastic band, bra sides (bra wings), bra elastic straps and hooks. Seven Brassieres were constructed for the fit trial session. The fit session was carried out with live models. Three subjects from each size category participated in the fit session. The key dimensions over bust girth and bust girth were measured to find out the correct size of the subjects for the fit trial for Brassiere. Twenty one subjects who met the right size were selected for the fit trials, three subjects in each size. As the subjects were diffident in participating for brassiere fit assessment. The subjects wore the garment (kurti- light colored, translucent cotton) over the constructed new size brassier for the subjective fit trial assessment to avoid discomfit.

3.11.2 Fit assessment of Brassieres

Wearers perceived fit evaluation was carried out to judge the fit of the garment. Responses towards the perceived comfort and fit of brassiere were obtained from the subjects for nine aspects. Table 10 shows the questions for subjective fit assessment on brassieres. Ahead of the subjective trial fit session, the subjects were explained regarding the objective of the research and fit evaluation scales. The brassiere straps were adjusted for each subject as they wore the brassiere to achieve the best and comfortable fit. The subjects who participated in wear trial testing wore bra sizes of 28A, 30A, 30B, 30C, 32B, 32C, 32D, 34B, 34C, 34D, 36B, 36C, 36D, 40B, 40C and 40D. It was noticed that 50% of subjects wore wrong size brassiere. It was wrongly selected and underestimated by women. Most of the women were not able to precisely select the right size bra. Women wore bra that are too small in the cup. Few women reported that they struggle to get good fitted bras as they have lack of knowledge on bra cup size and have not even once got professionally measured for bra size.

A total of 10 fit trial sessions were performed over a month. Two to three subjects participated in each session. The total time given for the fit trial session was 45 minutes. The subjects were requested to carry out a range of dynamic movements while wearing the garment. The subjects' perceptions of clothing fit were determined after 25 minutes and the completion of the survey by each subject was obtained after 45 minutes (Shin 2013). Ten subjects (one subject from each size category) wore the brassiere for 8 hours and their perceived fit evaluation was obtained.

Table 10: Questions on Wearer's Perceived Fit Evaluation for Brassieres

Sl.No.	Parameters
1	The bra cup is not too tight
2	The under band is not too tight
3	The breast are fully contained within the cups
4	The back band fits well at the back
5	Straps are not too tight
6	The garment gives freedom to breathe comfortably
7	The garment is easy to put on
8	The garment is easy to remove
9	The garment gives comfortable and perfect fit

3.11.3 Wearers perceived fit evaluation analysis

Three subjects under each size category (3 subject's $\times$ 7 sizes) participated in the subjective wear trial assessment. The subject's feedback received on nine questions for each size of brassiere was analysed to study the wearer's fit responses. Mean fit ratings and total scores were calculated for three subjects in each size. Rating on the scale ranges from 9 to 45, higher rating indicated good fit in garment. The mean ratings obtained towards each parameter on wearer's fit assessment for Brassieres are shown in Table 11. Table 12 shows the mean total score and standard deviation calculated from the brassiere fit assessment.

Table 11: Mean Scores for Each Parameter Set on Wearer's Perceived Fit Evaluation (N=30)

Parameters	Sizes						
	XXS	XS	S	M	L	XL	XXL
The bra cup is not too tight	4.6	4.6	4.6	4.6	4.6	4.3	4
The under band is not too tight	4	4.3	4.3	4.6	4.6	4.6	4.6
The breast are fully contained within the cups	5	4.6	4.6	4.6	4.6	5	5
The back band fits well at the back	5	4.6	4.6	4.6	5	5	4.6
Straps are not too tight	4.3	4.6	4.6	4.6	5	4.3	4.3
The garment gives freedom to breathe comfortably	4.6	5	5	5	5	5	5
The garment is easy to put on	5	4.6	5	4.6	5	4.6	4.3
The garment is easy to take out	5	5	5	5	5	4.6	4.6
The garment gives comfortable and perfect fit	4.6	5	5	4.6	5	4.6	4.6

Table12: Mean Score and Standard Deviation of Wear Trial Fit Rating

Sizes	Mean score	Standard deviation
XXS	42	0.81
XS	42.3	0.47
S	43	0.81
M	43	1.63
L	44	1.41
XL	42	0.81
XXL	41.3	0.47

It is observed that all sizes obtained high fit score towards each parameter set and highest mean total score in e fit trial assessment. Comparatively lower ratings were noticed for the parameter, under band is not too tight. Subjects reported that the straps were comfortable and the underband was firm on the body and was tight. Subjects stated that by wearing the size brassieres, comfortable fit is attained and there was no constrain in the movement of the arms and the breast was totally encased within the cup and there was no bulging at the underarms. No significant differences were noted in the fit trial assessment obtained from the subjects who wore the brassiere for 8 hours.

4. CONCLUSIONS

Inhabitants' living in diverse countries has unlike body sizes. It is essential for every country to have their own standard size chart owing to dissimilarity in race and lifestyle. The size chart that is used in India for the construction of brassieres belongs to other countries. Thus, a new size chart was developed for brassiere. Anthropometric survey was conducted on unmarried girls of South India in the age group 18-25. Body measurements were correlated, classified and clustered to describe the body shape and size of the subjects. Factor analysis and cluster analysis methods were employed using SPSS statistical software.

The size ranges in the developed size chart accommodated 89.4% of the girls measured. The total number of best sizes recommended for constructing brassiere for unmarried girls of 18-25 years is seven, one size (XS) in small body type category with bust girth in the range of 65-71cm. Two sizes (S and M) in medium body type category with bust girth measuring 72-85cm. Two sizes (L and XL) in large body type category with bust girth ranging from 79-92cm. Two sizes (XL and XXL) in extra large body type category with bust girth in the range of 93-106cm. Most of the girls were within sizes XS (small), M (Medium) and L (Large) body category. To approve the fit of brassieres developed based on size chart, wearers perceived fit evaluation was carried out. The subjects were satisfied with the brassiere fit. Seven new sizes were established for brassieres for unmarried girls of South India in the age group 18-25 years. The resulted size chart of brassieres accommodates all body types and may possibly be used as a resource guide for clothing industries in India and also the brands that manufacture brassieres for south Indian girls. The developed size chart will enable the manufactures to construct improved fitting clothes according to the body type. This study suggests that additional anthropometric studies must be performed covering all age groups and regions for women in India.

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