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A statistical model for developing body size charts for garments

D. Gupta and B.R. Gangadhar
Department of Textile Technology, Indian Institute of Technology Delhi, New Delhi, India

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Abstract *A simple easy to follow statistical approach has been proposed for developing body size charts from anthropometric data. It has been possible to cover 95 percent of the population using 11 size charts. Multivariate analysis was carried out to detect relationships between variables. Principal component analysis was carried out to identify the key body measurements which can form the basis for classifying the population. Bust for the upper body and hip for the lower body were identified as the critical dimensions affecting garment fit. Body shapes and their distribution within the population have been identified. Validation of size charts was done by calculating the aggregate loss of fit.*

Introduction

The process of developing body size charts involves taking anthropometric body measurements of the target population and its division into homogeneous groups for the purpose of garment manufacture. Indian men and women have always worn traditional Indian dresses which are mostly draped, such as the dhoti, sari, angavastram, dupatta, or lungi. These garments are not stitched hence there was not any need for sizes. The few structured garments (such as salwar-kameez) which have evolved and are being sold as RTW are based on the concept of "One size fits all". No attempt has been made to measure up the population at the national level and so till date no body size charts are available for the Indian population.

Currently, India is poised on the brink of a major retail revolution. The younger generation is fast changing its dressing habits and western clothes are becoming more and more popular in the cities as well as suburbs. It is at this stage that an acute need is felt for an efficient garment sizing system. RTW for men is based mostly on the sizes prevalent in the international market. As the fit is less critical in that category, the market could exist and mature without any size charts. But as the women adopt formal western wear and demand more fashionable and better fit – the survival of the manufacturer or retailer will depend on the "goodness of fit" provided by his garments.

A detail review was undertaken to study the various sizing systems reported in literature. It was found that statistical methods ranging from simple percentiles to complex combinations of multivariate and regression analyses have been employed for distribution of population into subgroups. More recently, it has been possible to

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employ powerful mathematical techniques with much better results. Some of the important approaches listed in the literature are briefly discussed below.

In a study by Salusso (1982), the principal component sizing system (PCSS) has been used for classifying adult female body form with respect to the US Standard for apparel sizing. This approach is useful in identifying the critical body or the fit affecting dimensions which can form the basis of size chart development. Researchers found that 15 principal components can be used to summarize trends in body form variation. Principal components 1 and 2, i.e. laterality (fullness) and linearity (length), respectively, were selected to describe body size and type.

In another study, Tryfos (1986) suggested an integer programming approach to optimize the number of sizes so as to maximize expected sales or minimize an index of aggregate discomfort. He divides the space of body dimensions artificially into a set of discrete possible sizes. The problem is formulated as a "p median" or "Facility Location problem". Another novel approach for the construction of apparel sizing systems has been proposed by McCulloch *et al.* (1998) based on the goodness of fit that an individual experiences when wearing a garment of a particular size. Using this measure known as aggregate loss, various existing US sizing systems were compared (Ashdown, 1998). Non-linear optimization techniques were used to derive a set of possible sizing systems from anthropometric data. Results showed that size assignment as well as the ability to identify non-accommodated individuals results in substantial improvements in fit over existing sizing systems.

Most techniques used so far are rather complicated and based on complex mathematical calculations. The current study was undertaken with the aim of developing an easy to follow statistical model for developing body size charts for garment manufacture. The model has been demonstrated using a recent anthropometric data set available for young Indian females.

Material and methods

Anthropometric data for 2,095 Indian women from six metro cities in India were used. A total of 21 measurements were recorded for each subject. These included 9 linear and 12 girth measurements as shown below:

Linear measurements:

(1) height,
(2) waist length from center front,
(3) cervical to natural waist,
(4) cervical back to natural waist,
(5) cervical height,
(6) outside leg length,
(7) inside leg length,
(8) arm length, and
(9) shoulder width

Girth measurements:

(1) neck girth at midway level,
(2) neck girth at neck base,

(3) round bust,
(4) natural waist,
(5) intended/artificial waist,
(6) hip 4 (hip measured at 4 inch below the natural waist),
(7) hip 6 (hip measured at 6 inch below the natural waist),
(8) thigh,
(9) ankle,
(10) knee,
(11) upper arm, and
(12) wrist

Methodology

Statistical analysis of anthropometric data

All analyses were conducted using statistica Ver 6.0 and Microsoft® Excel 2000. Mean, median, range, skew and SD for the important measurements were calculated. Multivariate analysis of the dataset were carried out with a view to reduce the number of variables (which would form key dimensions) and to detect structure in the relationships between variables.

Principal component analysis (StatSoft, Inc., 2002)

The aim of principal component analysis is the construction of a set of variables "X_i"s ($i = 1, 2, \ldots k$), of a new set of variables (P_i) called principal components, which are linear combinations of the "X"s. These combinations are chosen so that the principal components satisfy two conditions:

(1) the principal components are orthogonal to each other, and
(2) the first principal component accounts for the highest proportion of total variation in the set of all "X"s, the second principal component accounts for the second highest proportion and so on.

Figure 1 shows a two dimensional data set (plotted in the X_1-X_2 plane) which is divided into two clusters. The variations of the data along the axes are also shown. In the current problem, this technique needs to be applied to a 20 one dimensional data set. This technique was used to identify the key dimensions which can form the basis of a sizing system for garments.

Results and discussion

Univariate analysis

At the outset, the range, mean and median for all the body dimensions were calculated. Results for three measurements are reported in Table I. As expected, data for all measurements showed a near normal distribution. Care was taken to identify the outliers under each parameter so that they could be eliminated during the final analysis. This would help to improve the accuracy of the size charts.

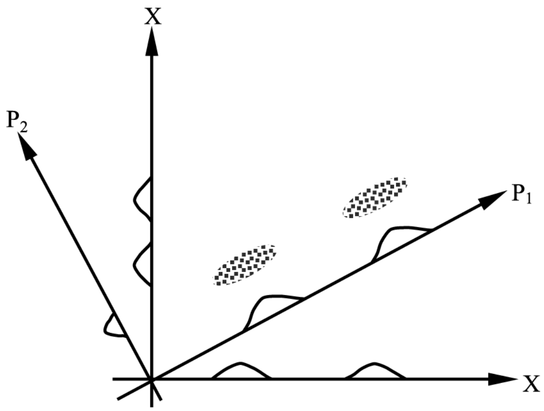

Figure 1.
Principal components

Dimension	Maximum	Minimum	Range	SD	Skew	Mean	Median
Height	78.74	53.15	25.59	2.46	0.308	61.72	61.61
Bust	53.5	20.75	32.75	3.18	0.31	32.37	32.37
Waist	45.31	18.69	26.62	3.29	0.83	27.01	26.57

Table I.
Univariate analysis of the height, bust and waist dimensions (in inches)

Height as a critical dimension. The first classification of population data was carried out on the basis of height of subjects. The population was divided into three height categories, namely:

(1) Short=$<$Mean $-$ SD,

(2) Medium = Mean $\pm$ SD, and

(3) Tall = $>$Mean+SD.

Results are reported in Table II.

The height distribution for Indian women was compared with some data available for western women (Cooklin, 1999) (Table III). An overwhelming percentage of women (73 percent) in the Indian data set is concentrated in the medium height category. Indian women are found to be shorter in all categories. Women in the US are the tallest followed by the European women.

Analysis of girth parameters. Population data for bust and waist were also analyzed. Results are compiled in Table I. Majority of the population has a bust measurement between 31 and 33 inch. This is a very narrow range of bust distribution for such

Category	Height (inch)	Count (percent)	Max.	Min.	Avg.
Short	$<$59	352 (10.55)	58.98	53.15	57.64
Medium	59-64	1522 (72.65)	63.98	59.06	61.45
Tall	$>$64	352 (16.80)	78.74	64.02	65.46

Table II.
Height categories and their distribution in the sample data

a large data set. It indicates that there is possibly a bias in the data toward the younger women.

The frequency distribution for the waist shows a concentration around waist of 25-27 inch and few data entries in the range of 15-20 inch and 40-45 inch. These latter entries may constitute the outliers, which a conventional sizing system cannot cater to. Special size categories would have to be developed to cater these outliers.

Multiple correlation analysis

Multiple coefficient analysis was carried out to determine the interrelationships between the various body parameters. BS 7231 (BSI, 1990) standard was taken as a guideline for identifying the key parameters from the correlation matrix shown in Table IV. According to this standard:

Table III. The height (in cm) distribution of populations of major nations

Country	Short	Medium	Tall
USA	155 (46)	165 (45)	175 (9)
England	150 (24)	160 (55)	170 (19)
West Germany	156 (31)	164 (47)	172 (22)
France	152 (28)	160 (51)	168 (16)
India	146 (10)	156 (73)	166 (17)

Notes: Values in parentheses indicate the percent of total population in each group

Table IV. Correlation co-efficients of key dimensions

Dimension	Height	Nat waist	Hip 6	Bust
Height	1	0.104	0.204	0.132
Cervical height	*0.866*	0.139	0.224	0.159
Natural waist	0.104	1	*0.752*	*0.781*
Waist length_center front	0.172	0.224	0.138	0.242
Cervical _natural waist	0.246	0.33	0.277	0.39
Center back_natural waist	0.235	0.124	0.091	0.167
Artificial waist	0.139	*0.801*	*0.74*	*0.716*
Outer leg	*0.713*	0.08	0.185	0.11
Inner leg	*0.52*	0.101	0.173	0.07
Hip 4	0.185	*0.78*	*0.919*	*0.74*
Hip 6	0.204	*0.752*	1	*0.714*
Thigh	0.127	*0.541*	*0.611*	*0.562*
Knee	0.205	0.478	*0.55*	*0.507*
Ankle	0.179	0.201	0.243	0.218
Bust	0.132	*0.781*	*0.714*	1
Upper arm girth	0.073	0.49	0.472	0.467
Wrist	0.146	0.279	0.275	0.252
Neck_mid	0.18	*0.638*	*0.581*	*0.62*
Neck_neck	0.138	0.484	0.435	0.488
Arm length	0.48	0.109	0.136	0.125
Shoulder_shoulder	0.275	0.348	0.326	0.347
Outer leg-inner leg	0.116	−0.035	−0.013	0.031

- if correlation co-efficient is <0.5 then no relationship;
- if correlation co-efficient is between 0.5 and 0.75 then there is a mild relationship; and
- if correlation co-efficient is >0.76 it indicates a strong relationship.

All length measurements appear to have good correlation among themselves and all girth measurements have good correlation with each other. However, there is poor correlation among the length and girth parameters. This is a significant finding as most empirical size charts are based on a linear increment across all measurement in all sizes. In other words, it is assumed that as the body grows in girth it also grows correspondingly in length or height. It is because of this assumption that the existing sizing systems yield a good fit for only 20 percent of the population they are intended for. Four body dimensions having good correlation with maximum of other dimensions were identified as key dimensions (Table IV). They are as follows.

(1) *Bust:* has mild to strong correlation with seven other body dimensions;
(2) *Hip:* has mild to strong correlation with seven other body dimensions;
(3) *Natural waist:* has mild to strong correlation with six other body dimensions; and
(4) *Height:* has mild to strong correlation with three major linear body dimensions.

From these findings it may be concluded that bust measurement for the upper body and hip measurement for the lower body garments are the most critical measurements. Waist is common to both top and lower body garments, but may not be so critical as it is adjustable in most garments. In general, it can be inferred that these four dimensions are the important landmarks on the body and hence should be related closely to the garment measurements.

Principal component analysis

In the next step, prinicipal component analysis was carried out in order to reduce the number of variables and to detect the structure in the relationships between variables. The first five principal components (factors), accounting for 66.97 percent of the total variability in the data set were identified (StatSoft, Inc., 2002). Results are reported in Table V. They further endorse the results obtained from the multiple correlation analysis. Based on the interrelationships existing in the data set, the body measurements have been classified as follows:

(1) Principal component 1 has high loadings (large co-efficients) on all girth related dimensions, i.e. natural waist, artificial waist, hip 4, hip 6 and bust.
(2) Principal component 2 has high loadings on all height related dimensions, i.e. height, cervical height, outer leg and inner leg.
(3) Principal component 3 has high loadings on upper body dimensions, i.e. waist length from center front, cervical to natural waist and cervical back to natural waist.
(4) Principal component 4 has high loadings on lower body dimensions, i.e. inner leg length and crotch length.
(5) Principal component 5 has high loadings on girth related dimensions of neck, arm and leg.

Dimension	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Height	0.02	0.20	0.01	0.01	0
Cervical height	0.03	*0.19*	0.01	0.008	0.00
Natural waist	*0.09*	0.03	0.00	7×10^{-6}	0.018
Waist length_center front	0.02	0.01	*0.29*	0.01	0.01
Cervical _natural waist	0.03	0.01	*0.26*	0.00	0.02
Center back_natural waist	0.01	0.02	*0.23*	0.02	0.03
Artificial waist	*0.09*	0.02	0.00	0.00	0.03
Outer leg	0.02	*0.19*	0.03	0.05	0.00
Inner leg	0.01	*0.12*	0.05	*0.23*	0.01
Hip 4	*0.10*	0.02	0.01	0.00	0.05
Hip 6	*0.10*	0.01	0.02	0.00	0.04
Thigh	0.06	0.01	0.01	0.00	0.01
Knee	0.06	0.00	0.01	0.00	0.00
Ankle	0.02	0.00	0.00	0.01	*0.14*
Bust	*0.09*	0.02	0.00	0.00	0.01
Upper arm girth	0.05	0.01	0.00	0.01	0.04
Wrist	0.02	1×10^{-5}	9×10^{-5}	0.02	*0.31*
Neck_mid	0.08	0.01	0.01	0	0.06
Neck_neck	0.05	0.01	0.01	5×10^{-5}	*0.18*
Arm length	0.01	0.10	0.01	0.00	0.01
Shoulder_shoulder	0.03	0.005	0.0443	0.0062	0.02
Outer leg –inner leg	4×10^{-5}	0.00	0.01	*0.61*	0.01

Table V.
Principal component analysis (revised)

These findings provide the framework for size chart development in this study. Based on these results the first classification of population was done on the basis of height (Principal component 2). This represents all height related parameters. The height categories were subdivided on the basis of ratio of critical girth measurements namely bust and hip (Principal component 2) to arrive at the body shapes. Results are discussed below.

Classification of population into body types

Classification on the basis of height

The population was divided into three height categories as indicated earlier. They are tall: ≥64 inch; short: ≤59 inch and medium: 59-64 inch.

Drop value

Within the height categories, the population was further categorised on the basis of key girth dimensions. Bust for the upper body and hip 6 for the lower body were identified as the most critical dimensions as they show mild to good correlation with maximum number of body dimensions. For identifying the overall body shape, a derived parameter drop value was used, which is the difference between the hip and bust measure (hip 6-bust). Drop values help to identify distinct relationships between key dimensions that determine body shape.

Based on drop values, the population under each height group was classified into six categories as shown in Table VI (Cooklin, 1999). Each category corresponds to one of the generally perceived body shapes namely:

- triangle or pear shaped (bust much smaller than hip), as in category 1;
- inverted triangle (bust much bigger than the hip), as in category 6;

- rectangle (bust is equal to hip) as in category 4; and
- the other categories lie in between these.

Within each bust category identified on the basis of drop value, hip 6 and bust have a linear relationship. This means that either one of these can be used as the basis for generation of body measurement tables or more suitably, bust measurement can be used as the basis of classification for the upper body garments and hip 6 can be used for classifying the lower body garments.

A closer look at the various body dimensions after classification of each individual case revealed the outliers having improbable drop values in the range of 8-27 inch. A general size chart cannot cater to these extremes thus a total of 32 individuals (1.53 percent of the sample data) with improbable measurements were eliminated. They mostly belonged to the category of very small bust or extralarge bust.

Results obtained for Indian women in various categories are compared in Table VII with figures reported for western women (Cooklin, 1999). It is observed that for the

S. no.	Category	Hip 6-bust (inch)	Short	Medium	Tall	Total(percent)
1	Very small bust	>6	21 (1)	274 (13.08)	87 (4.15)	18.23
2	Small bust	4-5	77 (3.68)	522 (24.92)	133 (6.35)	34.95
3	Medium bust	2-3	86 (4.11)	508 (24.25)	95 (4.53)	32.89
4	Full bust	0 to -1	26 (1.24)	179 (8.54)	32 (1.53)	11.31
5	Large bust	-1 to -4	9 (0.43)	31 (1.48)	5 (0.24)	2.15
6	Extra large bust	>-4	2 (0.09)	8 (0.38)	–	0.47
	Total		221 (10.5)	1522 (72.6)	352 (16.8)	100

Notes: Values in parentheses indicate the percent of total population

Table VI. Body types obtained on the basis of drop $-$ value (hip 6-bust)

Bust type	Height group	USA	England	West Germany	France	India
V small	Short	–	1	–	–	*1*
	Medium	–	3	–	–	–
	Tall	–	2	–	–	*4*
Small	Short	10	5	11	11	*4*
	Medium	10	12	16	19	*25*
	Tall	1	5	7	6	*6*
Medium	Short	21	9	15	12	*4*
	Medium	21	20	23	23	*24*
	Tall	5	7	10	7	*5*
Full	Short	14	7	5	5	*1*
	Medium	15	14	8	9	*8*
	Tall	3	4	5	3	*2*
Large	Short	–	2	–	–	*0.4*
	Medium	–	5	–	–	*2*
	Tall	–	1	–	–	*0.2*
Extra large	Short	–		–	–	*0.1*
	Medium	–	1	–	–	*0.4*
	Tall	–		–	–	–

Table VII. Distribution of bust types among population of major nations

Indian sample the data are skewed toward the small and medium bust categories with the least number of subjects in the large bust category.

Development of size charts

Having classified the population into three height categories and six body shapes, size charts for each category were developed adopting the empirical approach. The range for each body dimension under each category was identified. In order to cater all individuals, the range was spread with constant gradient over the population. A gradient of 2 inch between two consecutive sizes for key dimensions namely bust, waist and hip was maintained. The bust girth size interval of each size chart is used as the basis for all comparative calculations. For other dimensions, suitable grades were empirically determined and spread over the sizes. Some body dimensions like cervical height, center back to natural waist, center front to natural waist, etc., do not change much from one size to another. This can be attributed to the fact that the sizes are being developed from pre classified dimensions. In all, 11 size charts have been proposed covering 96.38 percent of population. The population covered by each category is given in parentheses.

- Short height – small bust (3.68 percent), medium bust (4.11 percent) and full bust (1.24 percent).
- Medium height – very small bust (13.08 percent), small bust (24.92 percent), medium bust (24.25 percent) and full bust (8.54 percent).
- Tall height – very small bust (4.15 percent), small bust (6.35 percent), medium bust (4.53 percent) and full bust (1.53 percent).

A representative chart for the short height-small bust category is given in Table VIII.

Table VIII.
Size chart for the short height, small bust category

Bust	26	28	30	32	34	36	38	40	Grade
Hip 6	30	32	34	36	38	40	42	44	2
Natural waist	22	24	26	28	30	32	34	36	2
Waist length-Center front	9	9.5	10	10.5	10.5	10.5	10.5	10.5	0.5
Cervical-waist	11	12	13	13.5	13.5	13.5	13.5	13.5	–
Center back-waist	11	11.5	12	12.5	13	13	13	13	–
Thigh	14	16.25	18.5	20.75	23	25.25	27.5	29.7	2.25
Knee	11	12.5	14	15.5	17	18.5	20	21.5	1.5
Ankle	8	9.5	11	12.5	14	15.5	17	18.5	1.5
Upper arm	8	9	10	11	12	13	14	15	1
Wrist	5	5.25	5.5	5.75	6	6.25	6.5	6.75	0.25
Neck mid	11	11.5	12	12.5	13	13.5	14	14	0.5
Neck-neck	11.5	12	12.5	13	13.5	14	14.5	14.5	0.5
Shoulder	13	14	15	15.5	16	16.25	16.5	16.5	–
Height	53	54	55	56	57	58	59	60	1.0
Outer leg length	36	36.5	37	37.5	38	38.5	39	39.5	0.5
Inside leg length	26	26.5	27	27.5	28	28.5	29	29.5	0.5
Agg. loss	1.84	1.19	1.89	2.32	1.57	1.23	3.79	2.02	

Notes: All measurements are in inches

Validation of the proposed size charts

Having proposed the size charts, the final step lies in validating the same. For this purpose, a measure known as the aggregate loss of fit (McCulloch *et al.*, 1998) was employed. An optimal sizing system with a given number of sizes would have the lowest value of aggregate loss where the average distance of individuals from their size is as low as possible. It was calculated as the average of the Euclidean distance in three dimensional space of the individuals from their allocated size using the following formula:

$$\text{Aggregate loss} = \left(\sum \sqrt{(\text{assigned bust} - \text{actual bust})^2 + (\text{assigned hip} - \text{actual hip})^2 + (\text{assigned waist} - \text{actual waist})^2}\right) \Big/ (\text{Number of individuals in the category})$$

Validation of the proposed size charts was done based on different criteria because different set of body measurements are relevant while buying different garments. For example, bust may determine the size for an upper body garment such as a shirt, while this measurement is not needed while buying a skirt or a pair of trousers. Hence for each body dimension, various values for the aggregate loss were calculated as follows.

(1) Bust, natural waist and hip with bust as the key dimension.

(2) Bust, natural waist and hip with natural waist as the key dimension.

(3) Bust, cervical to natural waist, center back to natural waist, center front to natural waist, shoulder width, neck girth at midway and neck girth at neck base to validate for the upper body dimensions needed for a shirt.

(4) Natural waist, hip, outer and inner leg seam dimensions needed for lower body measurements such as those required for trousers and skirt.

Selection of the body dimensions used for validation was based on the principal components obtained earlier. Body dimensions such as arm length, arm scye, wrist, thigh, knee, angle, were not considered during the calculation of the aggregate loss as they are not key areas for fit. However, optimization of these dimensions will be integral to a good size chart.

The ideal value for aggregate loss of fit will be a number given by the square root of the number of body dimensions considered – allowing for ± 1 inch deviation of the body dimension from the assigned size. Thus, for the calculation of the aggregate loss considering three body dimensions, the allowable aggregate loss of the goodness of fit would be $\sqrt{3}$, i.e. 1.73 inch Based on this understanding, multiple analyses were carried out using 3, 4, 5 and 7 measurements.

- Two analyses were carried out using three body dimensions each. One for the top body using cervical to natural waist, center back to natural waist, center front to natural waist and the second for the lower body using, waist, outer and inner leg. The ideal value for aggregate loss of goodness of fit in each case would be 1.73.
- Considering four body dimensions, namely bust, cervical to natural waist, center back to natural waist and center front to natural waist. The ideal value for aggregate loss of goodness of fit would be 2.00.

- Considering five body dimensions required for a dress – namely, bust, shoulder width, cervical to natural waist, center back to natural waist and center front to natural waist. The ideal value for aggregate loss of goodness of fit would be 2.23.
- Considering seven body dimensions required for a formal shirt namely bust, shoulder width, mid neck girth, base neck girth, cervical to natural waist, center back to natural waist and center front to natural waist. The ideal value for aggregate loss of goodness of fit would be 2.65.

The summary of aggregate loss of goodness of fit obtained for short height-small bust category is given in Table IX. The total aggregate loss for this category is 1.84 inch against the benchmark value of 1.73. Results for medium and tall height categories using different sets of measurements are reported in Tables X and XI. The values obtained for proposed tables are quite close to the ideal value for aggregate loss of fit.

Thus, it is obvious that the proposed size charts are quite accurate. Since the data has been sorted on the basis of drop value, the contribution of bust and hip measurements to aggregate loss can be expected to be minimum. The difference of actual size of waist from that of assigned sizes will be more. Thus, aggregate loss can be taken as a measure to assess the conformance of the actual waist measurements observed in the population to that of the assigned sizes with respect to bust and hip.

	Body type		Upper body				
Bust type	Based on bust	Based on waist	Three dimensions[a]	Four dimensions[b]	Five dimensions[c]	Seven dimensions[d]	Lower body
Very small	–	–	–	–	–	–	–
Small	1.84	4.47	1.83	1.94	2.25	2.49	2.3
Medium	1.69	2.18	2.01	2.12	2.42	2.69	2.86
Full	2.39	3.26	2.05	2.16	2.41	2.71	3.08

Notes: [a]Cervical to natural waist, center back to natural waist, center front to natural waist; [b]bust, cervical to natural waist, center back to natural waist and center front to natural waist; [c]bust, shoulder width, cervical to natural waist, center back to natural waist and center front to natural waist; and [d]bust, shoulder width, mid neck girth, base neck girth, cervical to natural waist, center back to natural waist and center front to natural waist

Table IX.
Aggregate loss for different dimensions in short height category

	Body type		Upper body				
Bust type	Based on bust	Based on waist	Three dimensions[a]	Four dimensions[b]	Five dimensions[c]	Seven dimensions[d]	Lower body
Very small	6.54	9.29	2.2	2.31	2.7	3.01	3.03
Small	2.05	4.12	2.72	2.8	3.12	3.35	2.67
Medium	3.63	2.93	2.67	2.74	2.98	3.23	2.98
Full	1.93	2.32	2.54	2.77	3.05	3.36	2.59

Notes: [a]Cervical to natural waist, center back to natural waist, center front to natural waist; [b]bust, cervical to natural waist, center back to natural waist and center front to natural waist; [c]bust, shoulder width, cervical to natural waist, center back to natural waist and center front to natural waist; and [d]bust, shoulder width, mid neck girth, base neck girth, cervical to natural waist, center back to natural waist and center front to natural waist

Table X.
Aggregate loss for different dimensions in medium height category

Bust type	Body type Based on bust	Based on waist	Upper body Three dimensions[a]	Four dimensions[b]	Five dimensions[c]	Seven dimensions[d]	Lower body
Very small	4.91	6.77	2.57	2.64	2.88	3.36	3.05
Small	2.24	2.95	2.26	2.34	2.71	3.08	2.35
Medium	1.99	2.45	2.04	2.15	2.47	2.84	1.76
Full	3.58	4.87	2.72	2.99	3.23	3.61	2.64

Notes: [a]Cervical to natural waist, center back to natural waist, center front to natural waist; [b]bust, cervical to natural waist, center back to natural waist and center front to natural waist; [c]bust, shoulder width, cervical to natural waist, center back to natural waist and center front to natural waist; and [d]bust, shoulder width, mid neck girth, base neck girth, cervical to natural waist, center back to natural waist and center front to natural waist

Table XI. Aggregate loss for different dimensions in tall height category

Conclusions

A simple statistical approach has been proposed for developing body size charts for women. Using a linear grading technique, 11 size charts for Indian women have been developed. It could be shown experimentally that bust girth rather than waist girth should be the basis for apparel sizing as this gives lower aggregate losses in most categories. For the lower body hip girth was identified as the most critical dimension The sizing system has been optimized with respect to three key dimensions simultaneously so as to obtain a minimum aggregate loss value. The proposed size charts indicate only body measurements. The actual garment measurements can be derived by incorporating the ease and design allowances.

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Further reading

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