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Comprehensive Analysis of Body Shapes in the Indian Male Population: A National and Regional Study

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ABSTRACT

The product creation process in India relies on imported anthropometric data from other nations, posing a major challenge for Indian consumers who desire tailored things that cater to their distinct physical attributes. Indian shoppers sometimes face difficulties in finding well-fitting garments due to the limited availability of comprehensive information on Indian body types and sizes. This issue is especially prevalent in the textile industry. The gravity of this situation is underscored by recent calculations indicating that apparel returns constitute a substantial 20% to 40% of sales, a trend that is exacerbated by the growing e-commerce sector. In response to the pressing need, a comprehensive statewide anthropometric survey was conducted using state-of-the-art 3D whole-body scanning technology. Conducted on a significant scale, this study encompassed a cohort of more than 13,000 male volunteers (total scanned subjects 13279 and valid subjects 12546), aged 15 to 70. The selection process was meticulous, ensuring representation from all six geographical regions of India. The collected data was methodically grouped into clusters, resulting in the categorization of body shapes on both a regional and national level. This classification technique was established based on accurate measurements of height and significant girth dimensions, specifically focusing on the waist, hip, upper hip, and chest girths. The three most frequent body types among Indian men, according to this indigenous survey, are the rectangle, the inverted trapezoid, and the trapezoid. Furthermore, a comprehensive analysis of body shapes at the regional level was conducted and compared to the shape clusters seen at the national level. The fundamental body structure groupings among Indian males were discovered to be in line with the national groupings, notwithstanding regional differences. The three primary male body forms were present in all the regions, however there were disparities in how common these shapes were. This ground-breaking study underscores how crucial it is to take regional variances in product sizing and design into account in order to appropriately serve the diversified Indian population.

Keywords: Anthropometry, 3d body scanning, Sizing survey, Body shape and size, National and regional shape clustering

INTRODUCTION

India is the world's most populous country, home to almost 1.4 billion people (Worldometer, 2023). Its consumer market is predicted to grow to become the third largest in the world by 2027 (after the US and China) and it is currently the fifth largest economy (Forbes, 2023), (Jacob, 2023).

Menswear, despite such an important area of the apparel consumption, there have been not much research undertaken on Indian male customers in the context of garment fit. In fact, the entire population of India is dealing from garment fit related concerns due the non-availability of size charts based on the Indian body proportions. There have been some studies undertaken in this field but these are limited in breadth and in scientific methodology as well.

Based on a comprehensive study of the Indian male population, this research article focuses at the body types of Indian men both nationally and regionally. The study gives a complete approach for determining body form. The indigenous research revealed the trapezoid, inverted trapezoid, and rectangle as the three most common body forms among Indian men. Not only does this new study shed light on the particular body types of Indian males, but it also provides crucial insights for corporations who wish to design items that fit better, enhancing consumer happiness and minimizing return costs. It also illustrates how crucial it is to address regional variances in product sizing and design in order to appropriately serve the diverse Indian population.

Apparel Fit Issues

DesMarteau (2000) discussed the importance of fit, the reasons behind garment misfitting, and how it affects both customers and service providers. A KSA poll indicates that 62% of men and 50% of women find it difficult to obtain clothing that fits properly, and additional research indicates that fit concerns account for 50% of catalogue returns (DesMarteau, 2000). Unstandardized Indian size charts remain a major issue for fitting clothes. Anand (2011) highlights the dearth of comprehensive anthropometric data on Indian men that can serve as a national representative and whose dimensions are useful for apparel and other reasons. These data are lacking for the country as a whole (Chakrabarty, 1997), (Anand, 2011).

Research has been done in India on the use of anthropometrics in clothing fitting, but it hasn't gotten much attention. Additionally, the research's findings were not commercialized or used in large quantities (Tiwari, 2017). Sewn clothing that fits the body is preferred over traditional draped garments at the moment. An Indian body size chart has to be created since apparel must now be mass-produced to fit Indian bodies as a result of this shift in demand. In the absence of such guidelines, the American, European, and British body size measurements have been used by the Indian apparel sector, which frequently leads to garments that are ill-fitting (Ministry of Textiles, 2018). Manufacturers currently use their "instinct" and "experience" to "adapt" or "tweak" size charts from different countries in order to create a size chart specific to their brand (Anand, 2011). A startling and common reason for the estimated 25 to 40 percent of returns for clothing is poor fit (Forum, 2020). These returns are expected to increase as e-commerce grows (Vidya, 2022).

Shape Analysis

A sizing system shows the entire range of sizes according to a male type's dimension grading (Glock & Kunz, 2005) and fitting combinations available in the garments (Cooklin, 1992). The size charts are created based on the target market's body type and the type of clothing (i.e., upper body, lower body, innerwear, etc.) (Aldrich, 1980). Boswell (1993) addresses the need for a distinct subset of technical descriptors that provide details about the person for whom the clothing would be appropriate. Another technical term for this relationship between two body measurements is "drop," which is used to describe the difference in circumference of the waist and chest in fitted male bodies. The droplets vary according to body types (Boswell, 1993).

Shin, Istook, and Lee (2011) drew attention to the paucity of comprehensive research on male body type and sizing schemes. The standards are not created with various drops or body kinds in mind (Shin et al., 2011). Lee (2004) classified the shapes of human heads using statistical methods such as factor analysis and cluster analysis (Lee, 2004). Connell et al. (2004) created the Body Shape Analysis Scale (BSAS©) specifically for the body types of women (Connell et al., 2002). Similarly, Simmons et al. (2004) created the Female Figure Identification Technique (FFIT©) which was based on the mathematical data analysis of the female subjects' 3D scans (Simmons et al., 2004).

Wilson & Istook (2019) classified the body shapes of men between the ages of 26 and 35 by using Size USA's 3D body scan data. Two distinct methods 1. Cluster analysis; 2. Shape cluster identification with an MSIT (Male Shape Identification Technique) based on Microsoft Excel. Using the MSIT (Male Shape Identification Technique), five drop combinations—chest-waist, hip-waist, chest-high hip, waist-high hip, and hip-high hip measurements were utilized to identify the body shape (Wilson & Istook, 2019), (Wilson, 2016). From the literature as indicated above, it can be inferred that there is a relatively lesser research work done in the area of male body shape classification.

Factor Analysis

Using Principal Component Analysis (PCA), one can reduce variables. Principal component analysis is applied to apply factor analysis, which reduces and compresses data into a small number of components that indicate important aspects.

Many anthropometric data analysis researchers, such as Salusso (1985), have extensively used component analysis employing Principal Component Analysis (PCA) to choose dimensions for bivariate categorization (Salusso et al., 1985), In order to size clothing for women 55 years of age and older, Salusso et al. (2006) adopted the principal component sizing system (PCSS), an alternate method (Salusso et al., 2006).

Clustering

One of the most important data mining methods for classifying and reducing data is cluster analysis. The subject population may be divided into homogeneous groups using cluster analysis in the context of anthropometric research (Zakaria & Gupta, 2014).

METHODS AND TECHNIQUES

Subject Profile

In total, approximately 13,000 men (total subjects scanned 13279 and valid subjects 12546), aged 15 to 70, were included in this study. They were split equally across eleven age categories (refer Table 1), five income groups, two rural and urban populations, and the six geographic areas of India.

Table 1. Age-wise subjects distribution.

Age Group	Number of Subjects	Number of Valid Subjects	% Share of Valid Subjects
> 15 <= 20	1884	1787	14.24%
> 20 <= 25	1767	1738	13.85%
> 25 <= 30	1646	1601	12.76%
> 30 <= 35	1390	1322	10.54%
> 35 <= 40	1362	1284	10.23%
> 40 <= 45	1137	1063	8.47%
> 45 <= 50	1047	959	7.64%
> 50 <= 55	818	757	6.03%
> 55 <= 60	792	725	5.78%
> 60 <= 65	679	640	5.10%
> 65 <= 70	757	670	5.34%
Grand Total	13279	12546	100.00%

Using the 2011 census data, the stratified sampling approach was used to statistically calculate the sample size for the data collection. The North, West, South, Central, East, and North-east regions were among the six geographic regions. The study's subjects ranged in age according to the 2014 National Youth Policy criteria (Ministry of Youth Affairs and sports, 2014) and National Council for Older People 2014 (Ministry of Social Justice & Empowerment, 2014). As recommended in the ISO 15535:2012, the subjects were divided into age groups of 5 years multiples (ISO 15535, 2012). According to the BCG research on Indian consumers, the subjects' income categories were determined by taking their yearly household income into account. The five income categories were as follows: Aspirers: annual household income between Rs. 5.0 and 10 lacs; Next Billion: annual household income between Rs. 1.5 and 5.0 lacs; Strugglers: annual household income below Rs. 1.5 lacs; Elite: annual household income above Rs. 20 lacs; Affluent: annual household income between Rs. 10.0 and 20.0 lacs (Sanghi et al., 2017).

Data Collection

The information was gathered through 3D body scanning. To assess the performance of the 3D body scanner, the individuals were manually measured at random on a few important dimensions. The necessary ISO suggested processes (including ISO 20685:2005, ISO 20685:2018, and ISO 8559:1989) were adhered to in order to guarantee the 3D body scanners' accuracy and validity (Tiwari & Anand, 2020), (Tiwari & Anand, 2022). Anthropometric information was gathered on a range of body parameters, such as heights from the floor, girth measurements, depth/length measurements, segment lengths, and arc measurements in accordance with ISO 20685: 2010–11 suggested postures. In order to identify landmarks, the ISO 8559-1:2017 and ISO 7250-1:2017 standards defined the body dimensions. The measurements were chosen in accordance with industry standards to create various clothing items.

Data Preparation

A composite file including the anthropometric measures obtained through 3D body scanning was one of the steps in the data processing process. The extreme values and outliers that were anomalous and fell outside of the range of $\pm$ three σ (standard deviation) limits were treated in the subsequent phase of cleaning the data (Hsu, 2009), (Moon & Nam, 2003). After that, the data was exported to IBM SPSS V. 28 for factor analysis, clustering, and descriptive statistics, among other fundamental statistical analyses. After cleaning, the obtained body dimension data was examined for normality and it was found that the data for each body dimension was virtually normally distributed.

Data Classification

IBM SPSS Modeler V. 18.2 was the main tool used to classify the data. Based on the standard deviation, the data was divided into five categories for height, and the next subsections will detail how the k-means clustering technique was used to identify the body form groups based on the six drop combinations.

Data Validation

Data validation was done by conducting three tests as: 1. sufficiency of the sample; 2. sphericity; and 3. internal consistency. These tests guarantee that the data set is appropriate for additional analysis and are a necessary precondition for factor analysis (Zakaria, 2014).

1. **Test of sample adequacy:** The Kaiser-Meyer-Olkin (KMO) value was computed to assess the appropriateness of the data sampling. Compared to the recommended value of 0.60, the observed KMO value of 0.946 can be deemed excellent (Hrženjak et al., 2015).
2. **Test of sphericity:** By examining the redundancy between the variables, the Bartlett's test is performed to determine whether the data is spherical. The observed Bartlett's test result value was getting close to 0. A test result of less than 0.05 is deemed acceptable since it validates the sphericity of the data (Hsu et al., 2007).

3. **Test of consistency and unidimensionality of the data:** The data's internal consistency (reliability) was assessed using Cronbach's alpha. A higher Cronbach's alpha score denotes greater reliability. The values range from 0 to 1. For data consistency, a Cronbach's alpha value of > 0.6 is considered sufficient (Cronbach, 1951). The Cronbach's alpha value observed for the dataset was above 0.95, hence the unidimensionality of the data was confirmed.

Factor Analysis

The factor analysis was applied using principal component analysis, which condensed the volume of data into a few essential factors. The critical elements were discovered by applying the Kaiser criterion (also known as the latent root criterion), variance criterion, scree plot, and eigenvalues. The primary factors with eigenvalues greater than one were the height and girth parameters. A principal component analysis was used to identify the length factor and the girth factor as the two primary components.

The highest potential variance coverage and eigenvalues larger than 1 are found in the first two components. 45.17 percent of the variation was covered by the first component, and 25.84 percent by the second. These two components together were responsible for 71.02 percent of the variation. In order to show the utility of PCA, it is generally recommended that these selected components should account for at least 60% of the overall variance. In this investigation, the first two components explained more variance (71.02%) than the minimum needed level of 60 percent (Malhotra, 2010).

The rotated component matrix indicating dimensions with factor loading >= 0.90. Stature (height) with 0.902 loading factor was observed among the top ten dimensions with the highest factor loadings with the length component. Since the key dimensions must be easy to measure and the body dimensions should be familiar for everybody, height was considered as one of the parameter for the data classification (Moon & Nam, 2003). Among the girths, Upper Hip Girth, Waist girth, Chest girth, and Hip girth were observed as the dimensions with highest factor loading.

Height Categories

The mean height was observed as 165.54 cm with a standard deviation of 6.9 cm. As the data witnessed a near normal distribution with the skewness observed as 0.014, while median and mode values 165.55 cm and 163.55 cm respectively. For convenience in height categorization, the center value was considered as 166.0 cm, and the central height category was determined with +/− 4.0 cm from this value. The total dataset was divided into five height categories as indicated in Table 2. It can be noticed that the Average height category covered almost 44% of the subjects, followed by Short normal (26.06%), and Tall normal category with 22.22%. The categories Short and Tall height categories covered relatively lesser number of subjects with just 4.53% and 3.56% subjects respectively. The central three height categories covered a whopping 91.91% of the subjects.

Table 2. Height categories.

Sr. No.	Height Category Name	Height Range (cm)	Percentage Share
1	Short	Height <154.00 cm	4.53%
2	Short Normal	>=154.00 cm to <162.00 cm	26.06%
3	Average	>=162.00 cm to <170.00 cm	43.63%
4	Tall Normal	>=170.00 cm <178.00 cm	22.22%
5	Tall	Height >=170.00 cm	3.56%
Total			100.00%

Drop Combinations for Body Shape Clustering

Data clustering was done based on the different drop combinations by selecting the girth dimensions. The selection of the girth dimensions was based on the factor loading as observed in the PCA. Six different drop combinations were found for the clustering analysis as Chest – Waist, Hip – Waist, Chest – Hip, Chest – Upper Hip, Hip – Upper Hip, and Waist – Upper Hip. The k-means clustering was employed for the body shape analysis, and overall 3 distinct clusters (body shapes) were discovered for the male population. The identified body forms are listed in the Table 3.

Table 3. Body shape clusters.

Body Shapes Clusters Male			
Drop Combination	Body Shape		
	Rectangle	Inverted Trapezoid	Trapezoid
D1(Chest girth – Waist girth)	0.765	7.8	13.44
D2(Hip girth – Waist girth)	0.083	4.696	13.487
D3(Chest girth – Hip girth)	0.633	3.343	0.222
D4(Chest girth – Upper Hip girth)	−1.123	6.491	11.312
D5(Hip girth – Upper Hip girth)	−1.756	3.148	11.09
D6(Waist girth – Upper Hip girth)	−1.888	−1.309	−2.128
Percentage of subjects	24.02%	34.92%	41.06%

As noted in the Table 3, total 6 drop combinations (D1 to D6) were applied for clustering of the data. clustering The values linked with the drop combinations represent the average difference between the dimensions of that drop combination for a certain body form. For instance, in case of the rectangular body form, the average difference between chest girth and waist girth is 0.765 cm, while the same difference is 7.8 cm and 13.44 cm for the inverted trapezoid and Trapezoid shapes.

The clustering of the anthropometric data based on the 6 drop combinations demonstrated relationship among the essential body dimensions i.e. Chest girth, waist girth, and hip girth. These correlations, or laws, are valuable may be used in identifying the body forms for the India male population is stated in Table 4.

Table 4. Body shapes and relationship among body dimensions.

Body Shape	Relationship Among Body Dimensions	Remark
Rectangle	Difference between Chest girth and Waist girth is 0.00 cm to +3.0 cm. Difference between Chest girth and Hip girth is between -3.0 cm to +3.0 cm. Difference between Hip girth and Waist girth is between -3.0 cm to +4.0 cm	This shape can be classified as **Rectangle** because the measurements indicate a relatively similar distribution of girth throughout the body.
Inverted Trapezoid	Difference between Chest girth and Waist girth is +7.0 cm to +9.0 cm. Difference between Chest girth and Hip girth is between -1.0 cm to +7.0 cm. Difference between Hip girth and Waist girth is between +1.0 cm to +8.0 cm	This shape can be classified as **Inverted Trapezoid** because it showcases a broader chest in contrast to the waist, with hips that are not as wide as the chest. The presence of a slight waist definition creates the distinctive appearance of an inverted trapezoid.
Trapezoid	Difference between Chest girth and Waist girth is +13 cm to +14.0 cm. Difference between Chest girth and Hip girth is between -3.0 cm to +3.0 cm. Difference between Hip girth and Waist girth is between +11.0 cm to +16.0 cm.	This shape is categorized as a **Trapezoid** due to its distinct features. It exhibits a wider chest compared to the waist while maintaining proportional hips. The noticeable differentiation between the hips and waist creates the characteristic trapezoidal appearance.

From the Table 4, it is clear that the shapes identified are quite distinguished from each other and can be noticed based on the conditions indicated.

National Shape Clustering

The clustering of the entire data was done by combining all the geographic regions for identified body shapes with height categories. This distribution can be seen in the Table 5.

Table 5. Body shape clustering - national.

Geographic Region	Height Category	Inverted Trapezoid	Rectangle	Trapezoid	Total
		% Subjects			
All Regions	Short	1.87%	1.24%	1.41%	4.53%
	Short Normal	9.62%	7.25%	9.18%	26.06%
	Average	15.42%	10.55%	17.66%	43.63%
	Tall Normal	7.08%	4.33%	10.82%	22.22%
	Tall	0.92%	0.65%	1.98%	3.56%
	Total	34.92%	24.02%	41.06%	100.00%

The analysis demonstrates (see Table 5) that the Trapezoid body shape group, characterized by higher chest and hip girths compared to the waist girth by an average of 13 cm, is the most widespread, including 41.06% of the individuals. Following closely, the Inverted Trapezoid group, where the chest girth is considerably greater than the hip girth and the hip girth is also relatively larger than the waist girth, albeit with minor variances compared to the Trapezoid form, includes 34.92% of the respondents. Meanwhile, the Rectangle body form, in which the chest, waist, and hip girths are virtually comparable, accounts for 24.02% of the subjects. Within the "Average height" category, 17.66% of the respondents are represented, and the Trapezoid body shape remains the popular choice. It is followed by the Inverted Trapezoid shape at 15.42% and the Rectangle shape at 10.55% for persons of the same height. It is worth noting that body forms in the "Short" and "Tall" height categories have a much smaller presence, each totalling less than 2.0% of the total participants. Consequently, it is suggested to ignore these shape categories when generating a size chart (Petrova, 2007), (Kwon et al., 2009), (Zakaria, 2011).

Regional Shape Clustering

The body shape clustering pattern with respect to height categories was also checked for the geographic regions. The objective was to investigate and understand the body shape deviations in the given geographic regions from the national shape pattern. Further, in case there are significant deviations in the shape in some specific geographic regions, it may justify the requirement for creative an exclusive size charts for such geographic region(s).

RESULTS AND DISCUSSIONS

Except for the North-east India region, the body shape patterns observed in various geographic regions closely mirror the national body shape trends. In the five major geographical regions - North India, West India, South India, Central India, and East India - the Trapezoid shape with Average height prevailed as the dominant category. However, it's noteworthy that in the South India region, both the Trapezoid shape (16.74%) and the Inverted Trapezoid shape (17.18%) were significantly represented within the same height category.

In North India, the body shape pattern resembled the national pattern, with the majority falling under the Trapezoid category (40.04%), followed by Inverted Trapezoid (34.89%), and Rectangle (25.07%).

In the West India, South India, and Central India regions, the Trapezoid shape in the Tall height category had a substantial presence, exceeding 2%. Conversely, in the West India and North-east India regions, the Inverted Trapezoid body shape was prominent among subjects in the Short height category, possibly linked to the relatively shorter stature of individuals from these eastern and north-eastern regions of India.

The North-east region exhibited a distinct body shape pattern compared to the national trend. The Trapezoid body shape emerged as the most prevalent category, encompassing 26.90% of the subjects, followed by 19.84% in the same body shape but in the Average height category. The next most common body shape category was Inverted Trapezoid among subjects with Short height, constituting 15.26%. These three body shape categories collectively accounted for approximately 62% of the subjects from this geographical region. Additionally, this region saw the emergence of two more body shape categories, Inverted Trapezoid (5.47%) and Trapezoid (7.32%) in the Short height group, both comprising more than 2% of the subjects. The variation in body shape patterns in North-east India may be attributed to the relatively shorter height of the subjects in this region.

CONCLUSION

As described in earlier sections, it is obvious that most geographic regions roughly coincide with the national body form trends, with one major exception being the North-east region. Here are the key observations:

- For the Average height group, North, West, Central, and East India demonstrated body shape patterns consistent with the national norm, featuring the Trapezoid body shape as the dominant category, followed by Inverted Trapezoid and Rectangle body forms. In South India, both Trapezoid and Inverted Trapezoid body types were roughly equally represented.
- In the Tall Normal height category, the body form patterns in all regions, except for the North-east, closely mirrored the national body shape patterns. In this situation, the Trapezoid body shape took priority, followed by Inverted Trapezoid and Rectangle body types.

The North-east area, on the other hand, revealed a different body shape pattern compared to the national trend. This discrepancy is likely owing to the significantly lower stature of persons in this region, causing the identical body form patterns observed in the Average and Tall height categories nationwide to be reflected in the Short Normal and Average height categories in the North-east region, respectively.

From a size chart development perspective, given the broad range of height categories (with the central three height categories covering 91.91% of the subjects across all three body shape categories), it is anticipated that subjects from the North-east region can be accommodated within the same national size charts.

This ground-breaking research study focuses on the varied spectrum of Indian male body shapes, methodically dividing them into three distinct body types based on essential body dimensions, including Chest girth, Waist girth, and Hip girth. This research provides as a firm foundation for the construction of a comprehensive sizing system based on body type, specially adapted for Indian male population.

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