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Anthropometric dimensions among Indian males — A principal component analysis

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Abstract

Anthropometry is a potential tool in estimating body composition indicators and assist in understanding human physical variations in terms of their long-range utility in understanding the body growth. The present study focused on factorial analysis of anthropometric data collected on a population to explore the possibility of clustering of body dimension data as body composition indicators. This study was carried on rural male population of Orissa, India. 26 anthropometric parameters comprising of lengths, breadths, circumferences and skinfold thicknesses were measured. The variables were treated for PCA, which generated three principal components – volume indicator, body length indicator and body fat indicator, explaining 79.5% cumulative variance of the total parameters. Split analysis of subsets of the sample showed same pattern of result as of for the analysis using the full sample. Internal data reliability test (Cronbach's Alpha) of the sample as well as individual variables was above 0.9. Applying PCA, the study sub-grouped the anthropometric parameters under three clusters as volume indicator (breadths and circumferences on the transverse plane), body length indicator (lengths on the coronal plane) and body fat indicator (skinfold thicknesses). The data provided in this study indicate that the parameters are generalizable to the population represented by this data set for male population.

Keywords: *Anthropometry, ergonomics, factor analysis, Indian men, body composition*

Introduction

Human body dimensions have been substantially used in physical anthropology, forensics, apparel sizing and ergonomic design of tools and workplace. In all of these areas, body composition indicators play a vital role. Evidences also reveal that anthropometry is a potential tool in estimating body composition indicators (Fosbøl and Zerahn, 2014) and specifically distribution from models that utilize body circumferences and skinfolds (Wang et al., 2004). Importance of data on human body

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dimensions was realized way back for partial fitting in equipment design among Germans, Frenchmen, Italians, Japanese, Thais and Vietnamese (Abeysekera and Shahnavaz, 1989). It was recognized that the difference in body dimensions existed between populations, geographical zones etc. (Saha, 1985; Gite and Singh, 1997; Dewangan et al., 2005; Zhizhong et al., 2007). Representation of anthropometric data from community/zones address this variability. These data would assist in understanding human physical variations and aid in anthropological classification in terms of their long-range utility in understanding the body growth.

For decades, efforts are being made to collect anthropometric data on various populations. The usability of these data for the purposes of body composition, design performance etc. needs specific set of parameters. Studies have considered specific anthropometric parameters as per their objectives (Dewangan et al., 2005; Gite et al., 2009; Massidda et al., 2013; Macias et al., 2014), limiting their utilization in variable departments. Studies have reported non-availability of the requisite anthropometric data about worker populations hinders efficient product and process design and accurate analyses (Victor et al., 2002; Nadadur and Parkinson, 2008). This implies that dimensions for a population would not attribute for the population with dissimilar demography or set of parameters taken would not be versatile for use in variable purposes. As a measure, it would be elemental to statistically cluster anthropometric parameters into sets of independent factors that retained the information. It would limit the effort of collection of data, management of data, analysis and utilization.

Hsiao et al. (2005) reported principal component analysis (PCA) as a useful tool for providing functional representative body models which reduced 13 body dimensions for tractor design to 3 new variables expressed as linear functions of the original dimensions. Parkinson and Reed (2009) also used PCA on data from detailed anthropometric databases to synthesize anthropometry that are more representative of the target user population. Factor analysis thus can be used to extrapolate anthropometric variables on a varied population (Dwivedi et al., 2005). A PCA study to determine the anthropometric characteristics reported body shapes for the Turkish female population under five factors—corpulence, length of body parts, upper body length, length of arm and hip-thigh region (Cengiz, 2014). The present study focused on factorial analysis of anthropometric data collected on a population to explore the possibility of clustering of body dimension data as body composition indicators.

Materials and methods

The study was carried on a rural population of similar socio-economic status from Orissa, India. The research team visited each data collection site, where a camp for the data collection was set up. The participants were randomly selected from among the healthy men attending the camp, in the age group of 18-65 years. All the participants were free from physical abnormalities and were in good health. On arrival, the participants were informed about the purpose of the study and the measurement procedures. Each participant was given a written informed consent form for signing on agreeing to participate in the study. Anthropometric measurements were then recorded with bare body and shorts/lungi (garment wrapped around waist resembling long skirt). Stature was taken on a flat base with stadiometer (Bioplus, India) attached to the wall. Weight was measured on an electronic balance (Rossmax, Swiss Gmbh) accurate to 0.1 kg. The anthropometric lengths (eye height, acromial height, iliocristale height, trochanteric height, metacarpal-III height, knee height and elbow height) and breadths (waist, interscye and chest depth) were measured with hand-held Harpenden anthropometer (Holtain Ltd., Crosswell, Crymych, UK). A steel measurement tape was used to measure the circumferences (chest, waist, hip, calf, wrist and scapula to waist-breadth length). The skinfold measurement were taken with skinfold caliper (Holtain Ltd., Crosswell, Crymych, UK) at biceps, triceps, subscapular, suprailiac, abdominal, chest, midaxillary, thigh, calf sites as per the methodology described in Gite et al. (2009). The protocol of the study was approved by the Ethics Committee of the Institute.

Data analysis

Data analysis was performed in SPSS 16.0. A test of consistency of the population distributions was performed using Shapiro-Wilk test.

The data was further tested for principal component analysis, to reduce the number of variables (having some redundancy in between themselves) explicating the variance in a population to a smaller, manageable number of variables. This hierarchical cluster analysis may then be used as criterion variables in subsequent development of multivariate accommodation models. After the principal components have been extracted out, the data was treated for assessment of their reliability by computing Cronbach alpha: an index of internal consistency reliability. Reliable anthropometric data for a target population were necessary when designing for that population otherwise the product may not be suitable for the user (Ashby, 1975). It has also been observed that instrument imprecision as well as human inconsistencies reflect in the measurements of anthropometric data (Sebo et al., 2008). Inaccurate measurement can also influence the diagnosis as well as use of data for other purpose, especially in setting up of design criteria. Therefore, it is important to address the validity and reliability of the data collected statistically.

Results

Summary statistics for the measured body dimensions are presented in Table 1. The above parameters were considered for further analysis and principal component analysis was conducted for 147 male and 26 body dimension parameters. A correlation matrix was generated to measure the correlation between the individual elements of the three types of anthropometric measurements—widths and circumferences, skinfolds and lengths (Table 2a, 2b, 2c). The correlation matrix revealed that all parameters were correlated with each other. The overall measure of sampling adequacy for the set of variables included in the analysis (KMO and Bartlett's measure) was accounted for 0.944, significant at 0.001 level.

Anti-image matrix in the PCA revealed that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (MSA) for all of the individual variables included in the analysis was greater than 0.5, supporting their retention in the analysis (Table 3a, 3b,3c). The communalities of the parameters extracted by PCA were above 0.5, suggesting that all the 26 parameters taken for PCA can be analyzed further for the Split analysis. Analysis of the total variance showed that three PCs emerged (volume indicator, body fat indicator and body length indicator) with eigenvalues > 1.0, explaining 79.5% cumulative variance of the total parameters. Further, the component 1 (volume indicator) accounted for the largest proportion of variance in the data explaining 52.9% alone, followed by 21.6% by component 2 (body fat indicator), and 5.0% by component 3 (body length indicator) (Table 4). The latent root criterion for number of factors to derive would indicate that there were three components to be extracted for these variables. Rotated component matrix reveals that parameters were distributed among three components.

Table 1: Descriptive statistics for measured anthropometric dimensions in the study

Parameters	N	Mean	SD	Range	Percentile		Shapiro-Wilk	
					5	95	Statistic	Sig.
Weight (kg)	195	60.0	10.5	38-94	44.0	78.3	.988	.271
Stature	187	1647	62	1460-1861	1551	1754	.979	.034
Eye height	168	1539	60	1404-1714	1452	1643	.987	.206
Acromial height	168	1372	50	1267-1538	1293	1463	.983	.091
Iliocristale height	167	963	48	680-1104	896	1048	.920	.000
Trochanteric height	167	844	41	704-945	779	919	.983	.091
Metacarpal-III height	167	704	39	632-987	647	763	.834	.000
Knee height	167	468	30	248-544	431	510	.831	.000
Elbow height	168	1046	39	959-1149	978	1118	.990	.432
Scapula to waist back length	166	542	37	450-660	482	600	.991	.516
Waist breadth	165	275	31	187-366	233	329	.994	.788
Inter scye breadth	165	336	28	251-402	289	379	.993	.725
Chest circumference	196	886	70	715-1090	770	1006	.990	.454
Waist circumference	196	800	103	575-1100	654	1000	.986	.185
Hip circumference	181	881	71	710-1120	756	995	.989	.385
Calf circumference	196	320	32	165-440	269	375	.988	.259
Wrist circumference	188	156	9	135-185	140	173	.963	.001
Chest depth	164	223	21	164-283	192	258	.991	.476
Biceps skinfold thickness	186	4.5	2.2	2-22.2	2.4	8.5	.832	.000
Triceps skinfold thickness	186	9.1	4.2	3-20.6	3.8	18.0	.938	.000
Subscapular skinfold thickness	186	12.1	4.9	4.8-27.2	5.9	22.8	.949	.000
Supra iliac skinfold thickness	186	8.6	4.7	2.8-28.8	3.4	18.6	.876	.000
Abdominal skinfold thickness	194	12.6	6.5	3.2-28.4	4.2	24.9	.952	.000
Chest skinfold thickness	193	9.4	4.5	3-26.5	3.8	17.4	.955	.000
Midaxillary skinfold thickness	193	9.2	4.8	2-30	4.0	19.1	.882	.000
Thigh skinfold thickness	193	12.6	5.3	3.6-26.4	5.1	22.3	.971	.005
Calf skinfold thickness	192	12.0	5.8	2.6-29	4.3	23.1	.967	.002

Note: All values in mm, unless otherwise mentioned.
* Lower bound value of true significance.

Table 2a: Correlation coefficient matrix for width and circumference measurements

		1	2	3	4	5	6	7	8	9
1	Weight	1.000								
2	Waist breadth	.795	1.000							
3	Waist circumference	.838	.847	1.000						
4	Hip circumference	.918	.800	.850	1.000					
5	Scapula to waist back length	.758	.719	.681	.774	1.000				
6	Inter scye breadth	.745	.724	.708	.747	.686	1.000			
7	Chest circumference	.886	.838	.874	.883	.782	.798	1.000		
8	Wrist circumference	.746	.666	.645	.709	.655	.551	.681	1.000	
9	Calf circumference	.795	.606	.670	.775	.670	.600	.688	.687	1.000
10	Chest depth	.752	.729	.761	.744	.644	.686	.839	.609	.585

Table 2b: Correlation coefficient matrix for skinfold measurements

		1	2	3	4	5	6	7	8
1	Biceps skinfold thickness	1.000							
2	Triceps skinfold thickness	.780	1.000						
3	Subscapular skinfold thickness	.718	.698	1.000					
4	Supra iliac skinfold thickness	.799	.731	.785	1.000				
5	Abdominal skinfold thickness	.671	.711	.773	.825	1.000			
6	Chest skinfold thickness	.767	.800	.759	.805	.818	1.000		
7	Midaxillary skinfold thickness	.778	.789	.811	.861	.790	.806	1.000	
8	Thigh skinfold thickness	.698	.745	.612	.687	.632	.698	.646	1.000
9	Calf skinfold thickness	.621	.686	.482	.561	.451	.545	.568	.688

Table 2c: Correlation coefficient matrix for length measurements

		1	2	3	4	5	6	7
1	Stature	1.000						
2	Eye height	.963	1.000					
3	Acromial height	.915	.941	1.000				
4	Metacarpal-III height	.789	.811	.809	1.000			
5	Iliocristale height	.815	.830	.795	.699	1.000		
6	Trochanteric height	.810	.852	.831	.750	.872	1.000	
7	Knee height	.674	.697	.682	.628	.637	.664	1.000

Table 3a: Anti-image coefficient matrix for width and circumference measurements

		1	2	3	4	5	6	7	8	9	10
1	Weight	.965[a]									
2	Waist breadth	.072	.939[a]								
3	Waist circumference	-.111	-.293	.970[a]							
4	Hip circumference	-.211	-.058	-.096	.965[a]						
5	Scapula to waist back length	.127	-.143	.071	-.086	.971[a]					
6	Inter scye breadth	-.049	-.171	-.034	-.087	-.038	.967[a]				
7	Chest circumference	-.247	-.137	-.147	-.263	-.225	-.207	.941[a]			
8	Wrist circumference	-.086	-.213	-.115	.024	.007	.179	.018	.962[a]		
9	Calf circumference	-.300	.180	-.038	-.211	-.197	-.115	.134	-.303	.931[a]	
10	Chest depth	-.097	-.031	-.014	.027	-.006	-.064	-.407	-.117	.040	.958[a]

[a] Measures of sampling adequacy (MSA)

Table 3b: Anti-image coefficient matrix for skinfold measurements

		1	2	3	4	5	6	7	8	9
1	Biceps skin fold thickness	.914[a]								
2	Triceps skin fold thickness	-.255	.934[a]							
3	Subscapular skin fold thickness	-.163	-.024	.969[a]						
4	Supra iliac skin fold thickness	-.376	.173	.032	.926[a]					
5	Abdominal skin fold thickness	.221	-.158	-.212	-.346	.946[a]				
6	Chest skin fold thickness	-.120	-.295	.017	.006	-.280	.961[a]			
7	Midaxillary skin fold thickness	-.028	-.284	-.148	-.354	-.037	-.030	.962[a]		
8	Thigh skin fold thickness	-.010	-.174	-.041	-.099	-.124	-.128	.091	.953[a]	
9	Calf skin fold thickness	-.163	-.220	.094	-.057	.129	.014	-.038	-.299	.912[a]

[a] Measures of sampling adequacy (MSA)

Table 3c: Anti-image coefficient matrix for length measurements

		2	3	4	5	6	7	8
1	Stature	.919[a]						
2	Eye height	-.614	.905[a]					
3	Acromial height	-.116	-.405	.935[a]				
4	Metacarpal-III height	-.059	-.112	-.155	.940[a]			
5	Trochanteric height	.121	-.229	-.219	-.146	.901[a]		
6	Iliocristale height	-.204	-.003	.062	.116	-.530	.900[a]	
7	Knee height	.083	-.100	-.011	-.213	.040	-.250	.929[a]

[a] Measures of sampling adequacy (MSA)

Further, PCA on each half of the sample was done to validate the analysis. The results of these two split sample again analyzed with the analysis of the full data set. The communalities at Split 0 and Split 1 revealed that all the 26 parameters taken, had the extraction value above 0.5 score. The pattern of factor loading for both split samples shows that three principal components were extracted by varimax with Kaiser Normalization rotation method, converging the rotations in 6 iterations. Analysis suggests that 80% of the communalities in both validation samples met the criteria. However, factor loading for both validation analysis showed the same pattern of variables as of for the analysis using the full sample, though the components have switched places. In effect, the same analysis was done on two separate sub-samples of cases and obtained the same results.

The internal data reliability test of the sample was carried out by factorial treatment wherein numbers of cases excluding the outlier above absolute 3.0 were only considered. Cronbach's Alpha was computed as 0.942. To improve the internal consistency of the scale variables, Cronbach's Alpha was also considered among the individual parameters, which ranged between 0.935 to 0.943, which is above the minimum considerable score of 0.8 (Hung et al., 2004).

Table 4: Loadings on the principal components

		Component		
		1	**2**	**3**
Dimension type	**Eigen values**	**13.762**	**5.616**	**1.302**
	% of variance	**52.932**	**21.602**	**5.008**
	Cumulative % of variance	**52.932**	**74.534**	**79.542**
Volume indicator	Weight	.692		
	Waist breadth	.763		
	Waist circumference	.772		
	Hip circumference	.669		
	Scapula to waist back length	.627		
	Inter scye breadth	.766		
	Chest circumference	.844		
	Wrist circumference	.574		
	Calf circumference	.571		
	Chest depth	.827		
Body fat indicator	Biceps skin fold thickness		.820	
	Triceps skin fold thickness		.878	
	Subscapular skin fold thickness		.642	
	Supra iliac skin fold thickness		.747	
	Abdominal skin fold thickness		.669	
	Chest skin fold thickness		.766	
	Midaxillary skin fold thickness		.747	
	Thigh skin fold thickness		.862	
	Calf skin fold thickness		.817	
Body length indicator	Stature			.902
	Eye height			.925
	Acromial height			.901
	Metacarpal-III height			.860
	Trochanteric height			.907
	Iliocristale height			.897
	Knee height			.743

Discussion

The present study concentrated on clustering of body dimension data as body composition indicators. The tests of consistency of the variables reveal that skinfold thickness parameters (Table 1) for explaining the fat mass did not meet the normality assumption; however they are taken into consideration for further analysis. This is because these parameters individually do not predict the indicators of body fat mass, rather in combined form; they are equated to predict the body fat percentage and lean body mass. Non-normal distribution of the skinfold parameters were also because of the fact that the age range of the population was large and with varied distribution of weight and so the body fat distribution. The reported data are in line with the previous study on rural population of Orissa (Gite et al., 2009).

Of various methods of obtaining body composition indicators viz. Dual energy X-ray absorptiometry scans, magnetic resonance imaging, bio-electrical impedance analysis etc. anthropometric technique is less expensive and practical, particularly for the field data collection. It measures the body dimensions and mathematically calculates the body composition indicators as reported in earlier studies (Duthie et al., 2006; Gite et al., 2009). Further PCA, a mathematical transformation technique enables a number of correlated variables to be reduced to number of uncorrelated variables called principal components internally deriving from the data. The PCA also assume linear relationships in the underlying data supported by anthropometric standards (Parkinson and Reed, 2009).

The three components derived were named as volume indicator, body fat indicator and body length indicator based on the distribution of parameters in each compartment. The pattern of factor loading for both split samples supported the nomenclature. As seen in Table 2a, 2b and 2c, the correlation matrix between the parameters derived under each nomenclature are correlated with each other. MSA values in the anti-image matrix for the parameters derived under each nomenclature (Table 3a, 3b and 3c) also support the nomenclature. As some of the anthropometric variables are not symmetrically distributed, 5th and 95th percentile values are provided (Table 5). This analysis supports that the results of this principal component analysis are generalizable to the population represented by this data set for male population.

Table 5. Variables contributing towards augmenting the variance in current population

Dimension type	Parameters	5th percentile	95th percentile
Volume indicator	Weight	41.3	77.9
	Waist breadth	22.6	32.8
	Waist circumference	63.0	100.0
	Hip circumference	75.0	99.3
	Scapula to waist back length	47.0	60.0
	Inter scye breadth	26.8	37.8
	Chest circumference	74.4	100.3
	Wrist circumference	13.5	17.0
	Calf circumference	26.5	37.3
	Chest depth	17.9	25.8
Body fat indicator	Biceps skin fold thickness	2.4	8.6
	Triceps skin fold thickness	3.8	18.0
	Subscapular skin fold thickness	5.2	22.5
	Supra iliac skin fold thickness	3.4	18.6
	Abdominal skin fold thickness	3.8	24.7
	Chest skin fold thickness	3.6	17.4
	Midaxillary skin fold thickness	3.8	18.9
	Thigh skin fold thickness	5.2	23.0
	Calf skin fold thickness	4.4	22.9
Body length indicator	Stature	153.0	175.4
	Eye height	140.8	164.3
	Acromial height	127.8	146.0
	Metacarpal-III height	63.4	76.2
	Trochanteric height	76.7	91.7
	Iliocristale height	87.3	104.7
	Knee height	40.6	50.8

Note: All values in mm, unless otherwise mentioned.

The limiting factor in this study was the number of subjects measured. For the purpose of human modeling however, it is necessary to include every major segment of the body so as to get a complete representation of the whole body. Additional research is needed to determine the age variability as well as occupational groups that may differ in the relationships among anthropometric measures. The study sub-grouped the anthropometric parameters under three clusters as volume indicator, indicating transverse breadths and circumferences body, length indicator, indicating lengths on the coronal plane and body fat indicator indicating the skinfold thicknesses. This attempt indicated that the parameters are generalizable to the population represented by this data set for male population.

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