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Anthropometrically Determined Subcutaneous Fat Distribution among Urban South African Children: A Principal Components Analysis

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Abstract: Body fat distribution is deleterious to health. This study evaluates subcutaneous fat distribution among South African children, by utilising Principal Components Analysis (PCA). This cross-sectional study involved 1136 participants (548 boys and 588 girls) and 581 black and 555 white children from 12 public schools in Central Pretoria, South Africa. Stature, body mass and eight skinfolds: triceps, subscapular, biceps, supraspinale, abdomen, front thigh, iliac crest and medial calf were measured. PCA technique was applied to examine the components loadings. An eigen value of >1.0 was retained for analysis. Boys and girls showed positive loadings in all the skinfolds thickness, implying a fatness or size factor component with a total variance of 48.3 and 54.4% for boys and girls, respectively. Similarly, black and white children's skinfolds thickness loaded positively on the first component indicating a fatness or size factor component and explaining 52.8 and 48.9% in black and white children, respectively. The trunk-extremity and upper-lower body extremity fat patterning components are discernible among the children. There were variations in indices of fat patterning studied across gender and race. Girls possessed higher adiposity in their subscapular and triceps areas whereas boys showed propensity to centralized fat pattern. Also, this study demonstrates dissimilar pattern in the trunk-extremity and upper-lower trunk components in both the black and white South African children. There is need to control central fat patterning in the children.

Key words: Subcutaneous fat distribution, ethnic variation, principal components analysis, children, South African, centralized

INTRODUCTION

Obesity has become a global public health issue, affecting both developed and developing countries. However, the focus should not be only on overall obesity but also on the distribution of body fat (Zhang and Wang, 2015) because subcutaneous fat (under the skin) or visceral fat (around the organs) is strongly associated with cardiovascular risk factors than total body fat (Savva *et al*., 2000; Daniels *et al*., 1999). The literature has indicated greater central fat deposition increases the risk of metabolic complications such as atherogenic lipoprotein profile (high Low-Density Lipoprotein (LDL) cholesterol and triglycerides and low High-Density Lipoprotein (HDL) cholesterol) insulin resistance and corresponding high basal insulin concentrations and glucose intolerance in children (Daniels *et al*., 2000; Gower *et al*., 2001; Posikitt, 2002; Teixeira *et al*., 2001; Gutin *et al*., 2007) and adults (Han *et al*., 2006; Niederauer *et al*., 2006).

Anthropometric assessment is easy and practical and early predictor for excess body fat in children (Atef *et al*., 2015). Fat deposition in children varies in different racial groups at varying rates and at different sites (He *et al*., 2004a; Liu *et al*., 2011). A lack of understanding ethnic differences in body fat distribution may result in the misuse or misinterpretation of results obtained from anthropometric indices (Liu *et al*., 2011). As such in a multi-racial like South Africa, it is important to have appropriate information about fat patterning for each group and sex. Moreover, it has been postulated that race and ethnicity are an index of many factors including environmental influences (such as nutrition) and cultural practices that can affect growth outcomes (Toselli *et al*., 2005).

PCA is a statistical technique which transforms many possibly correlated variables into fewer variables, called principal components. Although, this method have been utilised to analyse fat patterns in children (Ramirez and Mueller, 1980; Hattori *et al*., 1987; Cameron *et al*., 1992;

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Malina *et al*., 1995) and adults (Mueller and Reid, 1979; Norgan and Ferro-Luzzi, 1985; Indech *et al*., 1991) in other countries, scare data exist on South African children. The only study Cameron *et al*. (1992) in which PCA was applied in determining fat patterning involved rural South African black children and the study failed to investigate racial profiling of fat patterning. Besides, unlike data on total obesity, scanty information exists on the body fat distribution in South African children. The present study utilised the PCA to assess gender and racial fat patterning among South African children aged 9-13 years.

MATERIALS AND METHODS

Design: This study was a cross-sectional survey among primary school children aged 9-13 years attending public schools in Pretoria Municipality City, Gauteng Province, South Africa. This age group were selected to target the onset of puberty age which varies in sex and regions.

Sampling: The sampling frame was defined using the enrolment number for each school. This study employed a stratified, two stage cluster sampling strategy. This procedure ensures adequate representativeness of the study population in the sample. The procedure involved arrangement of study population into schools and class-level clusters. The first stage involved selecting randomly, schools with a probability proportional to the size and enrolment of each school. The second stage involved selecting classes within the participating schools systematically and with equal probability of participation. This afforded all learners in the selected classes the eligibility to participate in the study. Race was determined based on the children's parental background using questionnaire and was categorised as black and white. Participants whose backgrounds did not meet these criteria were excluded from the study. A total of 1286 children were randomly selected to participate in the study. However, due to absenteeism and incomplete data of 150 participants, 1136 participants (548 boys and 588 girls) eventually completed the tests and their data were used in the statistical analysis. The study was conducted from August-December 2008 and in March-June 2009.

Ethics: The nature and scope of the study were explained to the children and their parents who gave informed consent. In addition, children who were minors were briefed on the nature and procedures of the study and gave their accent to participate in the study. Approval for the study was given by the Gauteng Department of Education (DoE), Johannesburg, South Africa. The Ethics Committee of Tshwane University of Technology, Pretoria, South Africa approved the research protocol before data collection.

Anthropometric measurements: Stature, body mass and skinfolds (triceps, subscapular, biceps, supraspinale, abdomen, front thigh, iliac crest and medial calf) were taken according to the standard procedure of International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones *et al*., 2006). Participant's body mass was measured without shoes and with light clothing to the nearest 0.1 kg, using a digital scale (Tanita-HD 309, Creative Health Products, MI, USA). Their stature was measured to the nearest 0.1 cm using a mounted stadiometer. Skinfolds were measured to the nearest 0.1 mm using Harpenden Calliper.

Reliability: The intra-observer reliability of anthropometric measurements was determined by examining intraclass correlation coefficient (r) (Pearson's method) (Malina *et al*., 1995) based on data obtained from repeated measurements of a small sample of participants (n = 20). The intraclass correlation coefficients on anthropometric measures between observers were: stature (0.98), body mass (0.97), triceps (0.95), subscapular (0.94), biceps (0.96), supraspinale (0.93), abdomen (0.95), front thigh (0.89), iliac crest (0.92) and medial calf (0.95). The reliability coefficients fell within acceptable limits (Lohman *et al*., 1988).

Statistical procedure: Principal components analysis of eight skinfolds was used to evaluate fat distribution using the procedures described by Healy and Tanner (1981) modified by Mueller (1982). In the first step, each skinfold was transformed into its natural log and then each log-transformed skinfold was regressed on the mean log-transformed skinfolds. Residuals of regression were used in PCA. The percentage of variance criterion was used to explain the specific amount of variance in the anthropometric measurements. Using the rotation sums of the squared loadings, the percentage variance was employed to explain for the total sample. The eigenvalue equal to 1.0 or larger than 1.0 was considered as significant and retained while factors with eigenvalues <1.0 were viewed as insignificant and were not used for further analysis.

RESULTS AND DISCUSSION

Table 1 and 2 show the anthropometric measurements of the participants stratified by gender and race. The highest and lowest skinfold values among boys

Table1: Mean and Standard Deviation (SD) for anthropometric measurements of South African boys and girls

Variables	Boys (n = 548) Mean±SD	Girls (n = 588) Mean±SD	Combined (n =1136) Mean ± SD	95% CI	p-values
Age (years)	11.3±1.4	11.0±1.4	11.1±1.4	11.0-11.0	0.512
Body mass (kg)	41.9±12.0	42.3±12.1	42.1±12.0	41.4-42.8	0.001*
Stature (cm)	146.8±11.1	144.0±10.6	145.4±11	144.7-146.0	0.001*
Triceps (mm)	11.2±5.9	15.1±5.7	13.2±6.1	12.8-13.5	0.001*
Subscapular (mm)	8.2±5.0	13.2±7.4	10.8±6.8	10.4-11.2	0.001*
Biceps (mm)	7.5±4.3	10.6±5.1	9.1±5.0	8.8-9.4	0.001*
Iliac crest (mm)	10.4±7.1	14.9±9.0	12.7±8.5	12.2-13.2	0.001*
Supraspinale (mm)	8.3±5.6	13.4±7.8	11.0±7.3	10.7-11.4	0.001*
Abdominal (mm)	12.0±8.6	16.3±7.8	14.2±8.5	13.7-14.7	0.001*
Front thigh (mm)	17.0±7.6	21.7±6.8	19.4±7.6	19.0-19.9	0.001*
Medial calf (mm)	12.8±7.1	15.9±5.1	14.4±6.3	14.0-14.8	0.001*

Table 2: Anthropometric characteristics of the participants according to race

Variables	Black (n = 581) Mean±SD	White (n = 555) Mean±SD	Combined (n = 1136) Mean±SD	95% CI	p-values
Age (years)	10.8±1.5	11.5±1.3	11.1±1.4	11.0-11.2	0.000*
Body mass (kg)	40.1±11.1	44.2±12.4	42.1±12.0	41.4-42.8	0.001*
Stature (cm)	142.2±10.2	148.7±10.6	145.4±11	144.7-146.0	0.001*
Triceps (mm)	13.9 ±6.6	12.4±5.4	13.2±6.1	12.8-13.5	0.001*
Subscapular (mm)	11.2±7.4	10.3±6.1	10.8±6.8	10.4-11.2	0.028*
Biceps (mm)	9.7±5.3	8.5±4.4	9.1±5.0	8.8-9.4	0.001*
Iliac crest (mm)	13.3±8.1	12.1±8.8	12.7±8.5	12.2-13.2	0.018*
Supraspinale (mm)	11.3±7.6	10.6±6.9	11.0±7.3	10.7-11.4	0.077
Abdominal (mm)	14.7±8.6	13.7±8.2	14.2±8.5	13.7-14.7	0.034*
Front thigh (mm)	20.0±8.6	18.8±6.3	19.4±7.6	19.0-19.9	0.004*
Medial calf (mm)	14.8±7.0	13.9±5.4	14.4±6.3	14.0-14.8	0.019*

*Statistically significant at p = 0.05; CI = Confidence Interval; SD = Standard Deviation

Table 3: Principal components analysis of the skinfolds data of South African children stratified by gender

	Boys			Girls		
Skinfolds	PC1	PC2	PC3	PC1	PC2	PC3
Triceps	0.887	0.725	-0.402	0.739	-0.627	0.385
Subscapular	0.584	-0.520	0.742	0.882	-0.803	-0.456
Biceps	0.751	0.681	0.278	0.778	0.653	0.312
Iliac crest	0.846	0.701	0.172	0.595	0.437	0.213
Supraspinale	0.864	0.821	0.173	0.822	0.711	0.174
Abdomen	0.707	-0.672	-0.419	0.875	0.763	0.140
Medial calf	0.710	-0.689	0.164	0.578	-0.497	0.176
Front thigh	0.778	-0.653	0.207	0.473	-0.421	0.377
Eigen value	2.604	1.972	1.604	2.812	2.120	1.962
Percent variance explained	0.483	0.126	0.125	0.544	0.132	0.103

PC = Principal Components

were front thigh (17.0 mm) and bicep (7.5 mm) skinfolds, respectively. Corresponding data for girls were also in respect of front thigh (21.7 mm) and bicep (10.6 mm) skinfolds. The supraspinale skinfold was not significantly different between black and white children. However, black children had significantly ($p = 0.001$; $p<0.05$) higher mean values of skinfold thickness, particularly at the triceps, sub-scapular, biceps, iliac crest, abdominal, front thigh and medial sites, compared to white children (Table 2).

The results of the gender-specific PCA of the eight skinfolds are summarised in Table 3. Boys and girls had positive loadings in all the skinfolds thickness, suggesting a fatness or size factor component. This fatness component accounts for 48.3 and 54.4% of the total variance in skinfold thickness for boys and girls, respectively. For PC2, boys had a positive loading for the triceps skinfold (0.725) and negative loading for the abdominal skinfold (-0.672) suggesting a lower trunk-upper extremity fat distribution. This proportion of variance explained by this component is 12.6%. The third component has a positive loading for the subscapular (0.742) and a negative loading for the abdominal (-0.419) skinfolds and suggests an upper-trunk-lower trunk contrast in relative subcutaneous fat distribution in boys. This component explains 12.5% of the total variance. Collectively, PC1-PC3 components account for (73.4%) of the variance in the sum of the eight skinfolds in boys.

Among the girls, PC2 loads positively on the abdominal (0.763), biceps (0.653), iliac crest (0.437) and supraspinale (0.711) skinfolds and a negative loading on the triceps (-0.627) skinfold. This component has 13.2% total variance and could be interpreted as a lower trunk-upper extremity contrast in relative subcutaneous fat distribution. Conversely, the PC3 with a variance of 10.3% has a negative loading for the subscapular skinfold (-0.456) and a positive loading for the triceps skinfold (0.385) and indicates a trunk-extremity contrast in fat distribution. The three components explain about 77.9% of the total variance in the sum of eight skinfolds in girls.

Table 4: Principal components analysis of the skinfolds data of black and white South African children

	Blacks			Whites		
Skinfolds	PC1	PC2	PC3	PC1	PC2	PC3
Triceps	0.473	-0.523	0.657	0.348	-0.359	0.662
Subscapular	0.891	0.726	0.189	0.865	0.801	0.127
Biceps	0.820	-0.781	0.110	0.730	-0.671	-0.373
Iliac crest	0.877	0.734	-0.208	0.589	0.472	-0.197
Supraspinale	0.869	0.751	-0.109	0.879	0.762	-0.196
Abdomen	0.805	0.769	-0.252	0.880	0.793	-0.213
Medial calf	0.627	-0.583	-0.520	0.713	-0.654	-0.274
Front thigh	0.695	-0.637	-0.585	0.594	-0.502	-0.327
Eigen value	2.581	2.242	1.872	2.656	1.982	1.545
Percent variance explained	0.528	0.138	0.123	0.489	0.177	0.144

PC = Principal Components

Results of the principal components analysis of the skinfolds data according to race is displayed in Table 4. Black and white children's skinfolds thickness was loaded positively on PC1. This component was labelled the fatness or size factor component, explaining 52.8% and 48.9% in black and white children, respectively. Among the black children, the PC2 contrasts the subscapular (0.726), iliac crest (0.734), supraspinale (0.751) and abdomen (0.769) (positive loadings) with the triceps (-0.523), biceps (-0.726), medial calf (-0.583) and front thigh (-0.637) (negative loadings) and is therefore termed the trunk-extremity component. It accounts for 13.8% of the variance. The PC3 seems to contrast upper and lower body skinfolds, especially the extremity skinfolds with a high positive loading on the triceps (0.657) and a moderate negative loading on the medial calf skinfold. The loadings for the other skinfolds are in the same direction but low, that is, subscapular and biceps skinfolds are positive and other skinfolds (iliac crest, supraspinale, abdominal, medial calf and front thigh) are negative. This component could thus be classified as an upper-lower trunk component, explaining 12.3% of the variance. Overall, the three components explained 78.9% of the total variance for black children.

The pattern of components appears to be similar among the two ethnic groups. Like the black children, among white children too, the PC2 was positively loaded on the subscapular (0.801), iliac crest (0.472), supraspinale (0.762) and abdominal (0.793) contrasting the triceps (-0.359), biceps (-0.671), medial calf (-0.654) and front thigh (-0.502) (negative loadings). It could also be interpreted as a trunk-extremity component with a total variance of 17.7%. The PC3 appears to contrast upper and lower body skinfolds and had a high positive loading on the triceps (0.662) and a moderate negative loading on the medial calf (-0.274) and front thigh (-0.327) skinfolds. This third component may be labelled an upper-lower trunk component, accounting for 14.4% variation in the component. Together, the three components (PC1-PC3) explained 81.2% of the variance.

Applying PCA, this present study identified three fat pattern components stratified by gender and race for urban South African children in Central Pretoria. These components are overall fatness (component 1), extremity-trunk fat patterning (component 2) and upper-lower body fat patterning (component 3). Given the paucity of data on fat distribution in South African children, the results of this present study could only be compared to studies conducted elsewhere. Consistent with Becque *et al.* (1986) study, the findings of the present study demonstrated that for the boys, trunk fat is located in the abdominal and iliac sites but for the girl's trunk fat are located at all three sites on the torso: subscapular, iliac and abdominal. It is observable that increased lower-body fat for the boys occurs particularly at the thigh whereas for girls lower-body fat occurs at both the thigh and iliac regions. Similarly increased upper-body for the boys occurs at the triceps site and for girls at the triceps and subcapular sites. Collectively, girls appear to have fat distribution over a greater number of skinfold sites for each component than the boys. This concurs with a long, earlier observation of Vague (1956) that female body fat is more evenly distributed over the body surface.

This study demonstrates that the patterns of subcutaneous fat deposition of the children are similar to those earlier described in populations elsewhere (Ramirez and Mueller, 1980; Hattori *et al.*, 1987; Malina *et al.*, 1995; Mueller and Reid, 1979). The PCA demonstrated dissimilar pattern in the trunk-extremity and upper-lower trunk components in both the black and white South African children. Several factors could be responsible for the different fat pattern observed between the black and white South African children. According to He *et al.* (2004b), ethnic differences in fat distribution is less well understood, especially in children and adolescents because of the effect of sexual maturation on body composition. As such, the group of children studied in this present study could not be an exception. The effect of local environments, both physical and cultural, too may not be ruled out as factors influencing fat patterning. However, this should be seen as only speculative, since, such conclusions are beyond the data available here.

The findings of this study suggest that the deposition of subcutaneous fat in the trunk extremity among the children. The study documents a pattern of upper-body fatness for South African children living in

Pretoria that is concerning and this observation highlight important clinical and public health implications. Body fat whether in terms of total amount or relative distribution leads to a variety of metabolic disorders including hypertension, diabetes and dsylipidemia as well as increased in cardiovascular disease risk (Canoy *et al*., 2007; Kelly *et al*., 2004; Reinehr *et al*., 2006). Prevention strategies are thus needed to control the pattern of fat distribution among South African children, particularly among those residing in urban settings susceptible to risk factors likely to promote excess weight and fat accumulation.

CONCLUSION

The trunk-extremity and upper-lower body extremity fat patterning components are discernible among the sample of South African children in this setting. Girls possessed higher adiposity in their subscapular and triceps areas whereas boys showed propensity to centralized fat pattern. Also, this study demonstrates dissimilar pattern in the trunk-extremity and upper-lower trunk components in both the black and white South African children.

LIMITATIONS

Several limitations should be considered when interpreting the findings in the present study. Given the cost and technical sophistication of the magnetic resonance imaging or computed tomography and dual-energy X-ray absorptiometry which are direct methods of fat assessment, proxy, relatively simple and inexpensive anthropometric technique of skinfold measurement was applied. Despite the considerable variability in subcutaneous skinfold thickness measurement, this method of estimating subcutaneous fat with skinfold calipers has been shown to correlate with computed tomography or magnetic resonance imaging (Orphanidou *et al*., 1994; Hayes *et al*., 1988). Also, it should be noted that nutritional, maturation, socioeconomic status, parent education and cultural beliefs may play a significant role in levels of adiposity. However, these variables were not measured in this study. Additionally, only schoolchildren (black and white) were studied, so that the results of the present study do not necessarily apply to all South African children or other racial groups. Despite these limitations, the study has provided important baseline information on skinfolds fat patterning on South African children, utilising the PCA.

SUGGESTIONS

Uncontrolled trend of central fat patterning in these children might suggest the development of cardiometabolic risk factors in future. Therefore, developing health promotion strategies aimed at preventing fat accumulation in children should be a priority. The results of this study pertain; of course, to the South African black and white children sample and it would be helpful to have these results confirmed in other racial groups (Indian and Coloured) as well. Evaluating the fat patterning in relation to socio-economic status would provide useful information in explaining the possible environmental and social paradigms affecting fat patterning in a transitional South Africa nation. Also, it will be interesting to examine fat distribution of the children in relation to cardiovascular risk factors such as total cholesterol, triglycerides, fasting blood glucose and blood pressures.

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