

## Fatness and Fat Patterning as Independent Anatomical Characteristics of Body Composition: A Study of Urban South African Children

Daniel Ter Goon, D.Tech

Centre for Biokinetics, Recreation and Sport Science, University of Venda, Thohoyandou, South Africa

Received: *Agu 24, 2012*; Accepted: *May 12, 2013*; First Online Available: *Jul 08, 2013*

### Abstract

**Objective:** The purpose of this study was to examine the relationship between fat patterning, age and body composition, among urban South African children in Pretoria, Central.

**Methods:** Samples for the study comprised 1136 participants (548 boys and 588 girls) and 581 black and 555 white drawn from 12 primary schools in Pretoria Central. Anthropometrical measurements include stature, body mass and eight skinfolds: triceps, subscapular, biceps, suprascapular, abdomen, front thigh, iliac crest and medial calf. Principal components analysis technique was applied to examine the components loadings. An eigenvalue of >1.0 was retained for analysis. Pearson's correlation coefficient was used to determine the relationship of fat patterning scores, age and body composition measures.

**Findings:** Three principal components emerged. The first principal component was a size component (fatness), accounting for 62.3% variance. The second component (central-peripheral patterning) accounted for the total variance of 14.1%. The third component (lower trunk-upper extremity) of relative subcutaneous fat distribution, explained about 10.2% of the total residual variance. Overall, the three components account approximately for 87.0% of the total variance. The correlation coefficients indicating probabilities demonstrated that the overall body fatness (PC1), but not PC2 or PC3 was significantly correlated with body mass index ( $r=0.745$ ,  $P<0.01$ ), FM ( $r=0.672$ ,  $P<0.01$ ), fat-free mass ( $r=0.583$ ,  $P<0.01$ ), Percentage body fat ( $r=0.701$ ,  $P<0.01$ ) and children's age ( $r=0.062$ ,  $P<0.05$ ).

**Conclusion:** The central-peripheral and upper-lower body extremity fat patterning components are discernible among the sample of South African children in Pretoria. The results indicated that principal component 1, but not 2 and 3 was significantly correlated with body composition variables and age, suggesting that component 1 is truly an indicator of total body fatness and not fat patterning.

*Iranian Journal of Pediatrics, Volume 23 (Number 4), August 2013, Pages: 423-429*

**Key Words:** Fat Patterning; Principal Components Analysis; Body Composition; South African Children

### Introduction

Anatomical fat patterning refers to the distribution or patterning of fat over the body. The importance of total body fat and distribution has been stressed as major risk factors such as hypertriglyceridemia, hypercholesterolemia, C-reactive protein, type 2 diabetes mellitus,

elevated blood pressure, and endothelial dysfunction for both adults and children<sup>[1,2]</sup> and as such a major concern among medical and health practitioners and researchers. Earlier studies have shown that total body fat (fatness) and relative fat (patterning) are independent anatomical characteristics of body composition variables<sup>[3,4]</sup>, using the multivariate technique of principal

\* Corresponding Author;

Address: Centre for Biokinetics, Recreation and Sport Science, University of Venda, Thohoyandou, South Africa

E-mail: daniel\_goon2004@yahoo.com

© 2013 by Pediatrics Center of Excellence, Children's Medical Center, Tehran University of Medical Sciences, All rights reserved.

components analysis (PCA). Principal components analysis is an unsupervised data projection method that can be helpful in classification. The central idea of PCA is to reduce the dimensionality (number of variables) of a data set but retain most of the original variability in the data<sup>[5,6]</sup>. It computes a few linear combinations of the original variables, which can be used to summarize the data with minimal loss of information<sup>[7]</sup>.

Principal components analysis has been applied in many fat patterning studies involving children<sup>[4,8-11]</sup> and adults<sup>[12,13]</sup>. This technique of PCA has rarely been used to explore the anatomical fat patterning of South African children. The few studies<sup>[10,14-16]</sup> utilized other parametric methods of assessing fat patterning. None of such previous research employs a multivariate PCA in their fat patterning analysis. A good understanding of fat patterning has important clinical and public health implications. It can be helpful in the designing of clinical intervention strategies to lower cardiovascular risk for children<sup>[2]</sup>. It is worthwhile studying fat patterning among the South African children, given the seemingly rapid nutritional transition and a changing lifestyle pattern been witnessed in recent times in South Africa. Changing nutrition and lifestyle patterns are thought to be the leading causes of the current increases in the prevalence of obesity worldwide. Granted that obesity, total or abdominal tracked to adulthood, it is expected that the gradual fat disposition and distribution of children or adolescents when they attained adulthood becomes crucial regarding their trunk fat accumulation and susceptibility to cardiovascular risk. Given the paucity of information on fat patterning among South African children in Central Pretoria, this study was undertaken to examine the relationship between fat patterning, age and body composition, among urban South African children in Central Pretoria.

## Subjects and Methods

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. Details regarding

the methodology are described elsewhere<sup>[16,17]</sup>. Briefly, the sampling frame was defined using the enrolment number for each school. This study employed a stratified, two stage cluster sampling strategy. 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 enrollment 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.

A total initial sample of 1286 children was 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.

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 assent 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 (Ref: 2008/07/001). Data were collected from August 2008 to October 2009.

Anthropometric measurements of stature, body mass and skinfolds (triceps, subscapular) were taken according to the standard procedure of International Society for the Advancement of Kinanthropometry (ISAK)<sup>[18]</sup>. Participants' 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 caliper.

The intra-observer reliability of anthropometric measurements was determined by examining technical error of measurement (TEM) and intraclass correlation coefficient ( $r$ ) (Pearson's method)<sup>[19]</sup> based on data obtained from repeated measurements of a small sample of participants ( $n=20$ ). The TEM values were stature 0.35, body mass 0.29, triceps 0.18 and subscapular 0.20 while

the intraclass correlation coefficients on anthropometric measures between observers were: stature 0.98, body mass 0.97, triceps 0.95 and subscapular 0.94. The reliability coefficients fell within acceptable limits<sup>[20]</sup>.

Body mass index (BMI) was calculated:

$$\text{BMI} = \text{Body weight (kg)} / [\text{stature(m)}]^2$$

Percentage body fat (%BF) was calculated using the skinfold equation of Slaughter et al<sup>[21]</sup> for predicting body fat in children aged eight to 18 years. The present study utilized the following equations to predict body fat by using triceps (TSKF) and subscapular (SSKF) skinfolds:

Triceps + Subscapular >35 mm

Boys: % Body fat = 0.783 (TSKF + SSKF) + 1.6

Girls: % Body fat = 0.546 (TSKF + SSKF) + 9.7

Triceps + Subscapular <35 mm

Boys: % Body fat = 1.21 (TSKF + SSKF) - 0.008 (TSKF + SSKF)<sup>2</sup> - 1.7

Girls: % Body fat = 1.33 (TSKF + SSKF) - 0.065 (TSKF + SSKF)<sup>2</sup> + 2.5

Fat mass (FM) and fat-free mass (FFM) were calculated using percentage fat and body weight:

$$\text{FM} = [\text{Body weight (kg)} \times \text{Percentage fat}] / 100$$

$$\text{FFM (kg)} = \text{Body weight (kg)} - \text{Fat Mass}$$

Principal components analysis of eight skinfolds was used to evaluate fat distribution using the procedures described by Healy and Tanner<sup>[22]</sup> modified by Mueller et al<sup>[23]</sup>. 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. This method has advantages in that it allows for the description of fat distribution differences between individuals or groups independent of their degree of total fatness, since the measure of shape is described as everything residual to size. Additionally, the method avoids problems related to units of measurement and differences in the coefficients of variation for each variable<sup>[3]</sup>.

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 less than 1.0 were

viewed as insignificant and were not used for further analysis.

The first principal component (or factor) to be extracted will account for as much variance within the sample as possible. The second component, independent of the first, explains as much of the remaining variance as possible and so on, noting that each successive component is uncorrelated with all others<sup>[6]</sup>. The coefficients that define these linear combinations are called 'factor loadings' and are the correlations of each corresponding variable with that component (in this case, between each skinfold and the component). In order to examine the relationship between fat patterning, age and body composition, Pearson correlation analysis was performed. All statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) for Windows version 17.0.

## Findings

Anthropometric variables data were collected from 548 (48.2%) boys and 588 (51.8%) girls. The mean age of the participants was 11.0±1.0 years. No significant difference was found for age between boys and girls (P=0.512). The mean values for body mass and skinfolds were significantly (P=0.001; P≤0.05) higher in girls compared to boys. Boys were however, significantly (P=0.001; P≤0.05) taller compared to girls. Regarding the derived anthropometric measurements, apart from fat-free mass index which did not yield any significant gender differences (P=0.352; P>0.05), all other body composition variables and fat patterning indices significantly differed in both sexes (Table 1). Except for FFM, girls had significantly higher mean values of BMI, %BF and fat mass (FM) (Table 1).

The unrotated PCA of the combined group of South African children is displayed in Table 2.

Three components emerged with eigenvalues greater than 1.0 and were considered statistically meaningful. The first principal component (PC1) had a positive correlation with each skinfold and hence represented a size component (fatness). The proportion of the total variance explained by the PC1 is 62.3%. The second and third principal

**Table 1:** Mean and standard deviation (SD) for anthropometric and body composition measurements of South African children

Variables	Boys (n= 548)	Girls (n=588)	Combined (n= 1136)	95% CI	P. value
	Mean (SD)	Mean (SD)	Mean (SD)		
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
BMI (kg.m <sup>-2</sup> )	19.1 (3.5)	20.2 (4.2)	19.7 (3.9)	19.4-19.9	0.001
Body fat (%)	16.1(7.7)	22.7 (5.7)	19.6 (7.5)	19.1-20.0	0.001
Fat mass (kg)	7.3 (5.6)	10.1(4.8)	8.7 (5.4)	8.4-9.0	0.001
Fat-free mass (kg)	34.6 (8.2)	32.3 (7.9)	33.4 (8.1)	33.0-33.9	0.001

CI: Confidence Interval; SD: Standard Deviation; BMI=Body Mass Index

components represent the pattern of fat distribution independent of size and fatness. PC2 is positively loaded on the subscapular (0.791), abdominal (0.758) and iliac crest (0.670) and a negative loading for the triceps (-0.747), medial calf (-0.602) and front thigh (-0.592) skinfolds sites. This component could be considered as indicating a central-peripheral fat distribution among the South African children. The proportion of the total variance explained by the PC2 is 14.1%. The third principal component (PC3) has a positive loading on the triceps (0.506), but a negative loading on the abdomen (-0.403), iliac crest (-0.197) and supraspinal (-0.855) skinfolds sites, thus suggesting a upper-lower extremity of relative subcutaneous fat distribution. PC3 explained about 10.2% of the total residual variance. Overall, the three components account for approximately 87.0% of the total variance. Components loadings, however, demonstrate stronger patterning in second and third components for the entire sample (Table 2). Table 3, shows the Pearson's correlation coefficient (*r*)

for the principal component scores, selected anthropometric body composition variables (BMI, FM, FFM and %BF) and age of South African children. As expected, overall body fatness as represented by PC1 is highly correlated ( $P<0.01$ ) with all anthropometric variables. Specifically, the results indicated that PC1, but not PC2 or PC3, was significantly correlated with BMI ( $r=0.745$ ,  $P<0.01$ ) and the children's age ( $r=0.062$ ,  $P<0.05$ ), affirming that only PC1 was an indicator of fatness. PC1 (but not PC2 or PC3) was linearly related to BMI.

## Discussion

There is a wide range of data and information on fat and fat patterning for samples from the developed world, however, studies from less developed nations and regions are scarce. This study examines the relationship between fat

**Table 2:** Principal components analysis of the skinfolds data of South African children

Skinfolds	Principal components		
	1	2	3
Triceps	0.856	-0.747	0.506
Subscapular	0.812	0.791	0.432
Biceps	0.831	0.724	0.314
Iliac crest	0.773	0.670	-0.197
Supraspinal	0.832	0.732	-0.755
Abdomen	0.858	0.758	-0.403
Medial calf	0.734	-0.602	2.275
Front thigh	0.674	-0.592	0.261
Eigen value	3.343	2.072	1.669
Percent variance explained	0.623	0.141	0.102

**Table 3:** Pearson's correlation coefficients and associated probabilities for the principal components of eight skinfolds (factor scores) with age and selected anthropometric body composition of South African children

Variable	Pearson's correlation coefficient ( <i>r</i> )				
	Age	BMI	FM	FFM	%BF
PCI 'fatness' (size)	-0.062*	0.745 <sup>†</sup>	0.672 <sup>†</sup>	0.583 <sup>†</sup>	0.701 <sup>†</sup>
PC2 'fat patterning' (shape) central-peripheral	-0.043	-0.059	-0.029	-0.037	-0.502
PC3 'fat patterning' (shape) lower trunk-upper extremity	-0.032	-0.041	-0.022	-0.041	-0.039

\*Correlations statistically significant at the 0.05 level (two-tailed). † Correlation is significant at 0.01 level (two-tailed).

BMI: Body Mass Index; FM: Fat Mss; FFM: Fat-Free Mass; BF:

patterning, age and body composition, among urban South African children attending public primary schools in Pretoria Central. This is a rare study utilizing PCA to determine fat patterning in South African children aged 9–13 years.

Principal components analysis of eight skinfolds has identified three fat pattern components for urban South Africans living in Pretoria. The components identified are overall fatness (component 1), central-peripheral fat patterning (component 2), and upper-lower body fat patterning (component 3). There is hardly data available on fat patterning utilizing principal components in South African populations to compare the present results, except<sup>[10]</sup>, which was conducted on rural black children. In this regard, the results of this study could only be compared to studies from other countries. Components 2 and 3 are comparable to those identified by Mueller and Reid<sup>[4]</sup> for Colombian adults and children and the Becque et al<sup>[24]</sup> study involving obese adolescents. However, Cameron et al<sup>[10]</sup> study conducted nineteen years ago involving rural black South African children aged 6–19 years, showed contradictory findings with the present study. It should be noted that eight skinfolds thickness were used to evaluate fat patterning in the present study, whereas Cameron et al<sup>[10]</sup> study used four skinfolds. Therefore, it is possible that the difference in the number of skinfold site in Cameron et al's study compared to this study might cause the difference. Again, the first component in the present study indicated a *size* component (*fatness*), contrasting Cameron et al<sup>[10]</sup> differential distribution of fat on the trunk and extremity (as first component).

The present study demonstrated that the selected anthropometric body composition variables (BMI, FM, FFM and %BF) and age of the sample are correlated with principal component

scores, as analyzed using Pearson's correlation. Expectedly, total body fatness as represented by PC1 was highly correlated with all the selected body composition variables. However, PC2 or PC3 were not significantly correlated with any of the body composition variables. What this suggests is that only PC1 is an indicator of total fatness as it is linearly related to BMI. Although BMI seems to be not a perfect measure of fatness, it is widely used in epidemiological and clinical studies involving children and adults. The findings of this present study affirming PC1 as an indicator of total fatness, in contrast to PC2 and PC3 supports earlier studies<sup>[3,4]</sup> in literature.

**Limitations of the study:** The limitations of the study are worth mentioning. There are several methods of examining fat patterning in children. Ideally, to estimate visceral adipose tissue independent of total body fat, criterion measures such as CT and DEXA would be employed. However, the use of such "gold standard" methods, has limited applicability when screening larger sample sizes such as this, especially in developing countries like South Africa, largely because it is expensive, unavailable and time-consuming. In its place, measurements of anthropometry (stature, body mass, skinfold thickness and circumferences) were taken to determine fat patterning among the children in this present study. The use of this method has been validated<sup>[15]</sup>. Although these anthropometric measures can introduce measurement error, such error is likely to be random and thus would not bias the observed results.

The lack of pubertal staging further limits the interpretation of any sex-related differences in fat patterning in the study. At the beginning of the study, pubertal status was the planned variable for assessment. It was thought that as maturational status is a key factor affecting the changes in fat

patterning in children and adolescence, correction for levels of maturation between children might improve the understanding of fat patterning. However, due to non-cooperation of the schools, perhaps because of cultural or religious beliefs regarding their inclusion in the study, it was removed. Also, evaluating the fat patterning in relation to socio-economic status, physical activity and dietary intake would have provided useful information in explaining the possible environmental and social paradigms affecting fat patterning in a transitional South Africa nation. Therefore, further studies should endeavor to incorporate these factors in exploring fat patterning among the children.

Another limitation of the study was that 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. Although the findings may not be representative of all South African children, the random sampling method in this survey of children from primary schools in Pretoria optimized the representative nature of the samples. Despite these limitations, the study has provided important new information on fat patterning in South African children, on which scanty information exists.

## Conclusion

The present study confirms, as in previous studies that fatness and fat patterning are independent anatomical characteristics of body composition. The present study did not seek to determine age, sex and racial differences in fat patterning among the sample, nor the etiology of accumulation of excess fat patterning in children, but to determine whether fatness and fat patterning are independent anatomical characteristics of body composition in a sample of 1136 urban South African children, aged 9-13 years by utilizing the PCA approach.

Future studies examining fat patterning in these children should endeavor to include cardiovascular risk variables such as total cholesterol, triglycerides, fasting blood glucose, and systolic and diastolic blood pressures. This

will aid understanding of the relationship of fat patterning with physiological variables often associated with increased metabolic risk among South African children.

## Acknowledgements

The author is grateful to the research assistants, participants, their parents and principals of the schools which participated in the study. Tshwane University of Technology funded the study.

**Conflict of Interest:** None

## References

1. Canoy D, Boekholdt SM, Wareham N, et al. Body fat distribution and risk of coronary heart disease in men and women in the European prospective investigation into cancer and nutrition in Norfolk cohort: a population-based prospective study. *Circulation* 2007;116(25):2933-43.
2. Mirhosseini NZ, Shahar S, Ghayour-Mobarhan M, et al. Body fat distribution and its association with cardiovascular risk factors in adolescent Iranian girls. *Iran J Pediatr* 2012;22(2):197-204.
3. Bogin B, Sullivan T. Socioeconomic status, sex, age, and ethnicity as determinants of body fat distribution for Guatemalan children. *Am J Phys Anthropol* 1986;69(4):527-35.
4. Mueller WH, Reid RM. A multivariate analysis of fatness and relative fat patterning. *Am J Phys Anthropol* 1979;50(2):199-208.
5. Jolliffe IT. Principal component analysis (2<sup>nd</sup> ed). New York: Springer, 2002.
6. Daffertsofer A, Lamoth CJC, Meijer OG, et al. Principal component analysis in studying coordination and variability: a tutorial. *Clin Biomech (Bristol, Avon)* 2004; 19(4):415-28.
7. Deluzio KJ, Astephen JL. Biomechanical features of gait waveform data associated with knee osteoarthritis: an application of principal component analysis. *Gait Posture* 2007; 25(1):86-93.
8. Ramirez ME, Mueller WH. The development of obesity and fat patterning in Tokelau children. *Hum Biol* 1980;52(4):675-87.
9. Hattori K, Becque MD, Katch VL, et al. Fat patterning of adolescents. *Ann Hum Biol* 1987;14(1):23-8.
10. Cameron N, Johnston FE, Kgamphe JS, et al. Body fat patterning in rural South African black children. *Am J Hum Biol* 1992;4(3):353-64.
11. Malina RM, Huang YC, Brown KH. Subcutaneous adipose tissue distribution in adolescent girls of four ethnic groups. *Int J Obes Relat Metab Disord* 1995; 19(11):793-7.

12. Norgan NG, Ferro-Luzzi A. Principal components as indicators of body fatness and subcutaneous fat patterning. *Hum Nutr Clin Nutr* 1985;39(1):45-53.
13. Indech GD, Sanjeev I, Jit I, et al. Age, sex and socioeconomic correlates of fat patterning among adults from the Chandigarh zone of northwest India. *Ann Hum Biol* 1991;18(5):463-70.
14. Toriola AL, Monyeki KD, Monyeki MA, et al. Body mass index and circumferences: are they suitable measures of fat distribution in rural South African children? *J Hum Stud* 2001;41:13-24.
15. Monyeki MA, Koppers LLJ, Kemper HCG, et al. Body composition and physical fitness of undernourished South African rural primary school children. *Eur J Clin Nutr* 2005;59(7):877-83.
16. Goon DT, Toriola AL, Shaw BS, et al. Body fat ratios in urban South African children. *Afr J Phys Health Edu Recre Dance* 2011;(Suppl 2:1):246-57.
17. Goon DT, Toriola AL, Shaw BS, et al. Centripetal fat patterning in South African children. *Pak J Med Sci* 2011;27(4):832-6.
18. Marfell-Jones M, Olds T, Stew A, et al. International standards for anthropometric assessment. Australia: The International Society for the Advancement of Kinanthropometry, 2006.
19. Malina RM, Hamill PVV, Lemeshow S. Selected measurements of children 6-11 years, United States. Vital and Health Statistics, Series 11, No. 123. Washington, DC: Department of Health and Human Services, US Government Printing Office, 1973. Available at: [http://www.cdc.gov/nchs/data/series/sr\\_11/sr11\\_123acc.pdf](http://www.cdc.gov/nchs/data/series/sr_11/sr11_123acc.pdf)
20. Lohman TG, Roche AF, Martorell R. Anthropometric standardisation reference manual. Champaign, Illinois: Human Kinetics Books, 1988.
21. Slaughter MH, Lohman TG, Boileau RA, et al. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988;60(5):709-23.
22. Healy MJR, Tanner JM. Size and shape in relation to growth and form. *Symposium of the Zoological Society of London* 1981;46:19-35.
23. Mueller WH. The changes with age of the anatomical distribution of fat. *Soc Sci Med* 1982; 16(2):191-6.
24. Becque MD, Hattori K, Katch VL, et al. Relationship of fat patterning to coronary artery disease risk in obese adolescents. *Am J Phys Anthropol* 1986;71(4): 423-9.