

# Body composition in stunted, compared to non-stunted, black South African children, from two rural communities

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## Abstract

**Background:** The objective was to compare the body composition of black stunted, and non-stunted, children, from two rural communities in South Africa, and investigate whether increased total and central adiposity is found in stunted children. The design was a cross-sectional study. The setting was two study populations of children in rural South Africa. The subjects were 351 children aged 10-15 years old [Transition and Health during Urbanisation of South Africans (THUSA BANA) study], and 1 760 children aged 6-13 years old [Ellisras Longitudinal Growth and Health Study (ELS)].

**Method:** The body mass index (BMI), BMI for age z-score, sum of triceps and subscapular skin folds (SSF), waist circumference (WC), waist:height ratio (WHR) of stunted, and non-stunted, children, were compared.

**Results:** Almost 10% (n = 203) of children were stunted, and 34% had a BMI for age z-score below -2. After adjustment for age, non-stunted children had significantly higher values for BMI and WC, in both boys and girls. SSF was similar in stunted and non-stunted boys, but tended to be greater in non-stunted, rather than stunted girls. In the ELS, stunted boys and girls had significantly higher WHtR than non-stunted children, while similar results were found in the THUSA BANA study, although the difference was not significant in the girls. All stunted groups had a WHtR greater than 0.41, proposed as a cut-off point due to its association with increased risk for high blood pressure in children.

**Conclusion:** More research needs to be carried out on anthropometric indices for the distribution of body fat, independent of age, race, gender, and sexual maturation, in children and adolescents. This study showed inconsistent results, and highlights the complexity of using various adiposity measures in stunted and non-stunted children.

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## Introduction

Stunting in children is considered to be a consequence of chronic poor nutrition.<sup>1</sup> Stunting is associated with developmental delay and impaired cognitive function, and is a predictor of child mortality in children who are younger than five years old.<sup>2</sup> Stunting remains the most common anthropometric nutritional disorder affecting children in South Africa, with an estimated national prevalence of 18% in children aged 1-9 years.<sup>3</sup> Linear growth loss in infancy may not be fully recovered with improved energy intake later on.<sup>4</sup> Thus, if energy intake exceeds expenditure, weight gain may follow preferentially to length gain.<sup>5</sup> Therefore, stunted children may become obese adults in societies that are undergoing rapid changes in patterns relating to diet and physical activity, that lead to positive energy balance. For an individual child, the relation between stunting and overweight is not a simple situation of co-existence. Epidemiological and experimental evidence is accumulating to indicate a causal relationship.<sup>6</sup> Understanding the prevalence and patterns of

undernutrition, particularly stunting, the emergence of overweight and obesity in children and adolescents, and the concomitant risk for metabolic disease, is of critical importance when formulating public health policy.<sup>7</sup>

Possible potential mechanisms that link growth retardation and increased adiposity have been suggested, including impaired fat oxidation, and the action of cortisol as part of the causal pathway.<sup>6</sup> According to Benefice et al,<sup>8</sup> body composition, especially fat mass, could be an important component and outcome of long-term stunting. Therefore, body composition assessment is becoming a standard measure in many clinical and nutrition-related studies. In African populations, preschool-aged children, in particular, are exposed to malnutrition, and this may have a major effect on growth and development.<sup>8</sup> However, studies on obesity and relative fat distribution during childhood and adolescence are scarce, especially in rural areas.<sup>7,9</sup> Of particular concern is whether or not increased adiposity is found in stunted children. Therefore, the objective of this

study was to compare the body composition of black stunted, and non-stunted, children, from two rural communities in South Africa, and investigate whether increased total and central adiposity is found in stunted children.

## Method

### Study setting and population

The sample for the current analysis comprises black children from two cross-sectional studies conducted in rural South African communities, namely the [Transition and Health during Urbanisation of South Africans (THUSA BANA) study, in which BANA means children] in the North West province, and the Ellisras Longitudinal Growth and Health Study (ELS) in the Limpopo province. At the time of the survey, almost 90% of households in the North West province had access to piped water within the home, and in general, the houses were constructed from bricks. Most households used flushing toilets, and electricity to cook.

Poverty affected 62% of the population, the second highest provincial figure in South Africa. Although the province is predominantly rural, the rate of urbanisation is increasing, largely due to lack of employment opportunities in the rural areas.<sup>10</sup> Ellisras is a rural area, situated in the Limpopo province. Housing material varies from traditional, to mud, to brick, houses. At the time of the survey, piped water was available at community level. Sanitation was relatively insufficient. The majority of households used pit latrines. Many households used open fires to cook. The people relied heavily on agriculture for household food security.<sup>11</sup> Data were collected from 1 254 children, aged between 10-15 years from May 2000-June 2001 in the THUSA BANA study, of whom 351 were rural children, included in the present study. Similar data were collected from 1 760 rural children, aged between 6-13 years in May 2000 in the ELS. Procedures used for sampling and collection of anthropometric data have been reported in detail elsewhere.<sup>12,13</sup> The THUSA BANA study was approved by the ethics committee of the North-West University, and ELS was approved by the ethics committee of the University of Limpopo. The caregivers of all the children gave their informed consent.

### Anthropometric measures

In both studies, anthropometric measurements were carried out by trained anthropometrists, using standard methods. Weight was measured to the nearest 0.1 kg, using electronic scales. The children were weighed clothed in underwear, and barefoot. Height was measured to the nearest 0.1 cm using a Martin anthropometer in the ELS study, and an IP 1465 stadiometer in the THUSA BANA study. Skinfold thicknesses were measured using a John Bull® skinfold caliper (British Indicators, London, UK) in the THUSA BANA study, while a Slim Guide skinfold caliper® (Rosscraft, Vancouver, Canada) was used in the ELS. All skinfolds were measured in duplicate in the THUSA BANA study, and in triplicate in the ELS, and the means of the measurements were used in data analysis. Waist circumference (WC) was measured at the narrowest circumference on the waist above the iliac crest, and below the lower rib, using a non-stretching flexible tape (Lufkin, Apex, NC, USA) in the THUSA BANA study, and an anthropometric non-stretching flexible tape (Rosscraft, Vancouver, Canada) for girths in the ELS.

Details of the two studies are summarised in Table I.

### Body composition

The different body composition indices were calculated, as shown in Table II. Body mass index (BMI) and sum of skinfolds (SSF) were used as proxy measures for global adiposity, while WC, waist-to-height ratio (WHtR), and subscapular-to-triceps ratio (STR) were used as proxy measures for central adiposity.

### Statistical analysis

Data were analysed using the STATISTICA statistical package (StatSoft, Inc, 2009).<sup>18</sup> Data for the two study areas (THUSA BANA and ELS) were analysed separately, because preliminary data analysis showed significant differences between the two communities for age, as well as for some of the anthropometric indicators. Descriptive statistics were calculated for all children by gender, for each study area. The data were not categorised into age groups, because some age groups had fewer than 30 children, which is too small a number for statistical analysis. For each study area, children were stratified into two groups, namely stunted and non-stunted. Stunting was

**Table I:** Summary of the methods from the two studies, showing similarities and differences

	THUSA BANA Study <sup>a</sup> , North West province (n = 351)	ELS <sup>b</sup> , Limpopo province (n=1760)
Time of data collection	May 2000-June 2001	May 2000
Sampling procedure	44 schools were randomly selected. Children were randomly selected systematically from class lists, that in order to be representative of the population of North West province.	22 schools (10 pre-school and 12 primary) were randomly selected from 68 schools in the Ellisras area. Each school was then assigned a grade, with the expectation that most children in a particular age category would be found in that grade.
Age range of children	9-15 years old	6-13 years old
Height measurement	IP 1465 stadiometer	Martin anthropometer
Weight measurement	Precision electronic scale	Electronic scale
Waist circumference measurement	Flexible Lufkin steel tape, midway between the lowest portion of the rib cage and the iliac crest.	Rosscraft steel anthropometric tape for girths, laterally, midway between the lowest portion of the rib cage and the iliac crest.

a = Transition and Health during Urbanisation of South Africans study, b = Ellisras Longitudinal Growth and Health Study

**Table II:** Formulae for calculating the various indices and cut-off points to indicate adiposity

Index	Formulae	Use of index	Cut-off point
Body mass index	Weight (kg)/height (m) <sup>2</sup>	Total body adiposity	BMI <sup>a</sup> for age z-score > +2 <sup>14</sup>
Sum of skinfolds	Triceps and subscapular skinfolds (mm)	Total adiposity	> 22 mm (boys), > 27mm (girls), indicate high percentage body fat <sup>15</sup>
Waist:height ratio	waist circumference (cm)/height (cm)	Abdominal adiposity	> 0.41 <sup>16</sup>
Subscapular:triceps ratio	subscapular skinfold (mm)/triceps skinfold (mm)	Truncal adiposity	Not specified, 0.83 proposed <sup>17</sup>

a = body mass index

defined as height for age z-score (HAZ) below -2 standard deviations of the 2007 World Health Organization (WHO) reference data.<sup>14</sup> The relation between anthropometric measures and body fat distribution is dependent on age. Differences between stunted and non-stunted children with respect to adiposity measures were determined, using analysis of covariance (ANCOVA), adjusting for age. Results were considered statistically significant at p-value < 0.05.

## Results

Table III shows the descriptive characteristics of the children from the two study areas. The prevalence of stunting in THUSA BANA was 29%, and 6% in ELS. Using a BMI z-score above +2 to indicate overweight, none of the children in the ELS, and 3.7% of children (seven girls and six boys) in the Thusa Bana study, were classified as being overweight. On the contrary, 35.9% of the children in the ELS,

**Table III:** Characteristics of children from the two study areas, mean (standard deviation)

Variable	Boys			Girls		
	ELS <sup>a</sup> (n = 909)	THUSA BANA <sup>b</sup> (n = 170)	p-value	ELS (n = 851)	THUSA BANA (n = 181)	p-value <sup>c</sup>
Age (years)	10.5 (1.9)	12.0 (1.5)	< 0.001	10.5 (1.8)	12.2 (1.6)	< 0.001
Weight (kg)	27.6 (5.6)	33.0 (9.0)	< 0.001	28.3 (6.7)	37.0 (10.7)	< 0.001
Height (cm)	137.8 (10.3)	141.4 (10.6)	< 0.001	139.1 (10.7)	144.6 (10.8)	< 0.001
Waist (cm)	55.5 (4.1)	58.6 (6.2)	< 0.001	55.4 (4.5)	60.2 (7.8)	< 0.001
Body mass index (kg/m <sup>2</sup> )	14.4 (1.3)	16.2 (2.5)	< 0.001	14.4 (1.7)	17.4 (3.4)	< 0.001
Body mass index for age z-score	-1.70 (1.0)	-0.90 (1.2)	0.001	-1.70 (1.0)	-0.49 (1.3)	0.001
Waist:height ratio	0.40 (0.03)	0.41 (0.03)	< 0.001	0.40 (0.03)	0.42 (0.04)	< 0.001
Sum of TSF <sup>d</sup> + SSF <sup>e</sup> (mm)	13.1 (3.3)	15.5 (8.4)	0.01	17.2 (5.5)	23.4 (12.9)	< 0.001
Subscapular:triceps ratio	0.82 (0.15)	0.80 (0.17)	0.04	0.83 (0.15)	0.86 (0.27)	0.02

a = Ellisras Longitudinal Growth and Health Study; b = Transition and Health during Urbanisation of South Africans study; c = difference between the two studies within the gender groups, analysis of covariance adjusted for age; d = triceps skinfold; e = sum of skinfolds

**Table IV:** Adjusted means (standard error) of body composition measures for stunted and non-stunted children by study area and gender

ELS <sup>a</sup>	Boys			Girls		
	Non-stunted (n = 858)	Stunted (n = 51)	p-value	Non-stunted (n = 801)	Stunted (n = 50)	p-value <sup>b</sup>
Body mass index (kg/m <sup>2</sup> )	14.4 (0.04)	13.7 (0.2)	0.008	14.5 (0.05)	13.7 (0.23)	0.0008
Body mass index for age z-score	-1.73 (0.03)	-2.34 (0.14)	0.001	-1.61 (0.04)	-2.15 (0.14)	0.003
Sum of TSF <sup>c</sup> and SSF <sup>d</sup> (mm)	13.0 (0.3)	12.3 (0.5)	0.45	17.1 (0.4)	15.8 (0.9)	0.19
Waist circumference (cm)	55.6 (0.1)	53.4 (0.5)	0.0002	55.5 (0.5)	52.9 (0.1)	0.0001
Waist:height ratio	0.40 (0.0008)	0.43 (0.003)	< 0.00001	0.40 (0.001)	0.42 (0.002)	0.00003
Subscapular:triceps ratio	0.82 (0.005)	0.82 (0.03)	0.86	0.82 (0.05)	0.79 (0.02)	0.15
THUSA BANA <sup>e</sup> Study	(n = 114)	(n = 56)		(n = 135)	(n = 46)	
Body mass index (kg/m <sup>2</sup> )	16.6 (0.2)	15.9 (0.3)	0.03	17.8 (0.2)	16.6 (0.4)	0.006
Body mass index for age z-score	-0.83 (0.07)	-1.27 (0.16)	0.01	-0.42 (0.07)	-0.97 (0.18)	0.006
Sum of TSF and SSF (mm)	16.1 (0.8)	14.3 (1.1)	0.19	24.5 (1.1)	19.5 (1.9)	0.02
Waist circumference (cm)	59.9 (0.3)	56.0 (0.7)	0.00001	61.4 (0.4)	55.9 (0.9)	0.00003
Waist:height ratio	0.41 (0.002)	0.42 (0.005)	0.009	0.41 (0.002)	0.42 (0.006)	0.23
Subscapular:triceps ratio	0.79 (0.03)	0.81 (0.03)	0.74	0.85 (0.03)	0.92 (0.05)	(p-value = 0.17)

a = Ellisras Longitudinal Growth and Health Study, b = difference between non-stunted and stunted children within the gender groups; analysis of covariance adjusted for age; c = triceps skinfold, d = sum of skinfolds, e = Transition and Health during Urbanisation of South Africans study

and 25.6% of the children in the THUSA BANA study, respectively, had a BMI for age z-score below -2, indicating thinness. The children in the THUSA BANA study were older, and had higher mean values for weight, height, WC, BMI, BMI for age z-score, WHtR and SSF. The boys in the ELS had higher STR than those in the THUSA BANA study.

Table IV shows the mean values for different body composition measures between stunted, and non-stunted, children, by study group and gender. Non-stunted children from both studies had significantly higher values for BMI, BMI for age z-score and WC, than stunted children. In both studies, STR did not differ between stunted and non-stunted children, but WHtR was significantly higher in stunted boys from both studies, and in girls from the ELS, than in the non-stunted ones (Table IV). There was a trend of higher WHtR and STR in stunted girls in the THUSA BANA study, than in non-stunted girls.

## Discussion

The prevalence of stunting differed between the two study areas, with 29% of stunted children in the THUSA BANA study in the North West province, vs. 6.1% in the ELS in the Limpopo province. The 2002 Youth Risk Behaviour Survey also showed higher stunting rates in high school children in the North West province, as compared to the Limpopo province, although the difference was small (14.8% vs. 11.1%).<sup>19</sup> In 1999, the North West province had a higher rate of self-reported child hunger than Limpopo (62% vs. 55%).<sup>20</sup> Globally, long-term poverty-related malnutrition is the single most common cause of chronic growth retardation.<sup>21</sup> Therefore, the higher rate of hunger in the North West province could have contributed towards the higher prevalence of stunting in children in the THUSA BANA study. The adverse socio-economic environment, and the low levels of food availability, compromise and probably delay the physical development of the affected children in all phases of growth. The lower stunting rate in the Ellisras area in the Limpopo province may be due to greater food security in the households, due to access to land for subsistence agriculture, despite high rates of unemployment and income poverty. According to M'marete,<sup>11</sup> Limpopo province is one of South Africa's richest agricultural areas. The difference in stunting prevalence may also be due to pockets of poverty within provinces, with either higher, or lower, rates of stunting, than provincial levels. The prevalence of thinness, based on BMI for age z-score was relatively high in both groups at 25.6% in the THUSA BANA study, and 35.9% in the ELS. Stunting is an indication of chronic undernutrition, while thinness indicates short-term energy deficiency.<sup>22</sup>

Reference values for growth indicators in children are based on age and sex. Cut-off values to indicate underweight or overweight are based on z-scores calculated using growth standards or references based on a healthy population.<sup>14,23</sup> The prevalence of overweight based on BMI for age z-score higher than +2 was very low in the study participants (zero in ELS, 3.7% in THUSA BANA). In boys, the low prevalence of overweight was also reflected by the low mean sum of skinfolds. However, greater skinfold thickness was observed among the girls, especially the non-stunted girls from the THUSA BANA study. There are indications that a BMI for age of around

the 71<sup>st</sup>-77<sup>th</sup> percentile among primary school children predicts cardiovascular risk and insulin resistance.<sup>24</sup> Although the children may not seem overweight according to BMI, their low BMI may indicate relatively small muscle mass and greater fat mass. This study highlights the complexity of using various adiposity measures in stunted and non-stunted children. BMI and WC were significantly higher in non-stunted children, while WHtR was higher in stunted boys, and STR did not differ between stunted and non-stunted children.

Although BMI is widely used to define childhood obesity, the validity of using BMI as an indicator of obesity, especially in stunted populations, and to assess body composition in growing children has been questioned.<sup>22</sup> Given the relatively high prevalence of obesity in countries with a high prevalence of stunting,<sup>6,8</sup> it is important to determine the impact of growth retardation on the association between BMI and body fat.<sup>20-25</sup> However, this does not imply that BMI should not be used to categorise children as either normal weight or overweight, especially in large epidemiological studies. However, when studying body composition, caution should be used when applying BMI as a measure of body fat.<sup>6</sup> Sum of skinfolds may be a better indicator of body fat. The SSF did not differ significantly between stunted and non-stunted boys, but, compared to stunted girls, SSF was significantly greater for non-stunted girls in the THUSA BANA study, and tended to be greater in non-stunted girls in the ELS.

The WC and WHtR were used as indicators of abdominal adiposity. These two indicators showed conflicting results, as stunted children had a smaller WC, but a greater WHtR, except for the girls in the THUSA BANA study, but the trend was similar. It is not clear which is the best indicator of abdominal adiposity. As rightfully stated by Panjikkaran et al,<sup>26</sup> body weight and height are not considered when using waist circumference as a measure of overweight and obesity. Cameron et al<sup>27</sup> argued that not quantifying the association between WC and height to create an independent index of WC has resulted in the erroneous belief that WC is the best indicator of risk throughout childhood and adolescence. They argue that WC should become more important as an indicator of fat deposition during puberty, when most of the centralisation of fat occurs. Although the relation of WHtR with overweight is yet to be standardised, it has been shown that individuals with WHtR above 0.5 are likely to fall in the overweight or obese category, irrespective of age.<sup>28</sup> As there is currently no consensus on the methodology and criteria for classifying abdominal obesity among adolescents,<sup>29</sup> more research in this field is needed. However, there are indications that a WHtR above 0.41 is associated with increased risk of high blood pressure among black South African children.<sup>16</sup> The mean WHtR of all groups of stunted children in the present study was higher than 0.41, and indicates increased abdominal fat distribution compared to non-stunted children, and also a higher risk of non-communicable diseases in stunted children, than in non-stunted ones.<sup>7,16,25</sup>

Potential mechanisms linking growth retardation to increased central adiposity have been suggested, including impaired fat oxidation, and the action of cortisol as part of the causal pathway.<sup>6</sup> No significant difference in STR as a measure of truncal obesity was observed between the stunted and non-stunted children in

this study. A longitudinal study in Senegalese adolescents showed a greater accumulation of subcutaneous fat in the upper part of the body (the trunk and arms) in those who were stunted, irrespective of the overall quantity of subcutaneous fat. The authors argue that although there is as yet, no precise explanation for this greater deposit of fat in the upper part of the body in stunted adolescents, it may be attributed to complex hormonal adjustments that occur with the onset of puberty, and which could be affected by malnutrition.<sup>8</sup> Although not statistically different, mean STR was higher in stunted girls from the THUSA BANA study than in non-stunted girls (0.92 vs. 0.85,  $p$ -value = 0.17).

Possible limitations of this study include the cross-sectional design. Therefore, the causality of excess fat accumulation due to stunting cannot be established. Currently, there are no clear guidelines on which indicators best describe truncal or central adiposity in children. When selecting anthropometric indicators for fat distribution in children, the indicators' ability to accurately characterise the distribution of body fat, independent of other factors, such as gender, and the ease of use in a practical research setting, need to be considered.<sup>30</sup> Therefore, more research is needed on anthropometric indices for the distribution of body fat, independent of age, race, gender, and sexual maturation in children and adolescents. This study showed inconsistent results, and highlights the complexity of using various adiposity measures in stunted and non-stunted children.

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